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Critical Thinking in Everyday Life

Edited by
Christopher P. Dwyer

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Guest Editor

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About the Editor

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Christopher P. Dwyer is a senior researcher in the Department of Technology Education at the Technological University of the Shannon who specialises in the fields of cognition and education, and has international expertise in the field of critical thinking. He is the author of two academic books, both published by Cambridge University Press: *Critical Thinking: Historical Perspectives & Practical Guidelines* and the forthcoming *Knowledge Doesn't Exist & Other Thoughts on Critical Thinking*. Chris also writes an ongoing blog for Psychology Today, titled *Thoughts on Thinking*, and contributed the 'Teaching Critical Thinking' entry to the *Sage Encyclopedia of Higher Education*.

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Editorial

An Editorial Introduction to Critical Thinking in Everyday Settings

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When I was first invited to guest edit a Special Issue of the *Journal of Intelligence* on critical thinking (CT), I was quite excited by the prospect for what I saw as two important reasons. First, it would give me the opportunity to collaborate with so many great researchers in the field (including both established CT researchers who I have admired for many years and early career researchers who are doing some really exciting work)—each of whom I want to thank so very much for their great work and contribution to this Special Issue. This collection of work would not be possible without their efforts and insights. Indeed, the field of CT owes them their gratitude! Second, the prospect of editing a Special Issue gave me a chance to sit down and really think about what actually *needs* addressing in the world of CT research, more broadly than one's own research, and the potential contribution such focus could make.

Critical thinking is a metacognitive process that, through purposeful, self-regulatory reflective judgment; skills of analysis, evaluation, and inference; and a disposition towards thinking, increases the chances of producing a logical conclusion to an argument or a solution to a problem. Notably, as a result of the dramatically rising availability of information (including both misinformation and disinformation), the need for CT is arguably more important now than ever. While application of CT in 'everyday settings' might seem as an obvious focus of CT research (especially in light of zeitgeist perceptions at present in our world around us), it may come as surprising to many not entirely familiar with the field that, arguably, it is not really where the research spotlight typically shines. Among the most widespread focuses of CT research is conceptualising and defining it. Indeed, CT research has been commonly doing this since the late 1980s/early 1990s—and that is not a criticism, per se. To a large extent, I still really enjoy reading these conceptual manuscripts on CT, regarding what it is and how we do it. However, there comes a point where you can only read so many papers that say more or less the same thing about CT. Too often, after reading such manuscripts, I am left wondering about the applicability of this in a meaningful, practical way that has not already been explored countless times before. What does this actually mean for the world, the people and the thinking around us—outside the academia bubble?

Likewise, we know CT is important; otherwise, we would not put so much of our time and effort into researching it. But just because it is important does not mean everyone else recognises that, let alone knows how to do it. As a result, another large bulk of the CT research focuses on how to create this capacity and improve it—which, of course, we typically do through teaching and learning. Indeed, making students interested in improving their decision-making and teaching them how to think critically is a noble cause, with CT representing a commonly desired educational outcome by not only educators but employers and society more generally. However, the problem with this focus is that it generally limits discussions of CT to educational settings, which is further problematic because it alienates individuals who did not have or will not have the opportunity to attend third-level education (where CT is most commonly taught in an explicit manner) or, perhaps more broadly, individuals who are simply just not part of the academic world.

Do not get me wrong; understanding what CT refers to and how we can use that conceptualisation to improve it through training are fundamental to the goals of researchers in CT. Indeed, most of my research career has focused on these very things. However, what is equally important is understanding the practicalities surrounding CT's application in the real world. Moreover, this is not to say that CT research (such as that presented in this Special Issue) should not or no longer discuss CT in conceptual or educational contexts. Rather further efforts need to be made in the research, be it with respect to further integration within methodological rationales or targets for enhancement, to address real-world issues and applications (and not just as a token point in a study's discussion section), so as to ensure clarity regarding how and why CT is so important for our world's societies. Furthermore, this is why I was—and am—so excited about this Special Issue on "Critical Thinking in Everyday Settings". It represents a collection of some really interesting pieces that encourages its authors and readers alike to step out into the real world, where CT can be discussed in terms of wide-ranging applications.

Given the role of higher-order cognitive processes at the core of CT, the relationship between intelligence and CT is important for consideration not only for readers of the *Journal of Intelligence* (within which this Special Issue on CT calls home) but anyone in cognitive science, education, or simply those that want to enhance the quality of thinking in their everyday lives. As a large body of CT research has focused on its conceptualisation and enhancement through educational strategies, this Special Issue provides a unique scope by exploring the application of CT to real-world settings and everyday life through a collection of original research, a review of the literature, and position pieces regarding topics of utmost relevance to such applications.

Specifically, in the Research section, Saiz and Rivas (2023) propose a research project focused on examining the relationship among CT, personal well-being and lifelong formation as an integrated approach to real-world problem-solving. The proposal takes a refreshingly holistic approach to CT, with the authors tackling rationale-building through not just the established cognitive, CT-focused literature but also insights from philosophy, technology development and assessment of social trends. Indeed, CT research has, arguably, always valued the concept of becoming (i.e., forming) a critical thinker, if for no other reason than personal well-being, but the manner in which this relationship is presented here—exemplified in light of real-world examples—really lands with respect to cementing the purpose of this relationship.

Guamanga et al. (2023) discuss our daily decision-making efforts through the notion of inference to the best explanation (IBE) in light of both people's vulnerability to bias and errors of judgment. Subsequently, the authors discuss IBE's role in the ARDESOS-DIAPROVE programme, which provides some useful insights on approaches to training CT. Particularly interesting was focused discussion on 'explanation' from an epistemological standpoint and how understanding the nature of explanation, through metacognitive processes such as CT, can help facilitate the development of problem-solving skills.

Hačatrjana and Namsone (2024) address the aforementioned issues of conceptualisation and training of higher-order thinking skills associated with CT in an applied manner, specifically, in the context of primary and secondary education policy. Specifically, they aim to distinguish the various thinking skills associated with CT to make them more readily accessible and approachable for students and teachers in the real-world context of everyday classroom work. As part of this, they address numerous questions, one of which I found particularly important from the perspective of engaging real-world considerations: that is, how are the concepts of thinking and reasoning as defined in policy documents reflected in curriculum descriptions across different disciplines?

Cui and Zhao's (2024) contribution highlights the importance of not only how CT is conducted as a (meta)cognitive process, but also how that thinking is communicated, such as in real-world settings. From the standpoint of operationally defining CT, the assessment of CT performance is vital. In this context, they identify dialogue as the most commonly used means of communication and propose a qualitative coding scheme for CT in dialogue.

In the Review section, Butler's (2024) contribution also focuses on the nature of operationalising CT through assessment. She conducts a deep dive on the current landscape of CT measures in light of strengths and weaknesses while interestingly framing it with respect to how such measures can be a useful predictor of negative life events. Coupled with real-world examples of CT's utility, she uses this observation as an impetus for educators and educational institutions to make efforts to prioritise the *measurable* improvement of CT and, beyond the ivory tower of third-level education, for facilitation for wider populations to access CT materials and resources for their own independent learning.

Bensley (2023) performs a deep dive on the relationship between CT and intelligence with respect to real-world judgment and belief. Specifically, he highlights that, despite some conceptual overlap, CT can, perhaps, better account for trading in real-world information that we use, on a daily basis, in the formation of beliefs and judgments. That is, those who engage in CT more regularly are less likely to form unsubstantiated beliefs. To some extent, this may be a result of our common multi-dimensional view of CT, which allows for understanding and assessment beyond that of what intelligence tests typically assess—the latter, Bensley highlights, is utilised in few extant studies on unsubstantiated beliefs.

In the final section, Dumitru and Halpern (2023) provide both a very timely and interesting discussion on the applied importance of CT in light of evolving work dynamics, with particular focus on artificial intelligence and job automation. They present CT as a 'job-proof skill' that, once developed, makes the thinker not only a valuable asset with respect to their position in the job market but also in terms of their role in citizenship (despite reinforcing this value sometimes being a challenge). Dumitru and Halpern further recommend ways in which CT can be enhanced to help support job markets.

Eigenauer (2024) then discusses the potential of enhancing CT through specific-purpose 'mindware', referring to modular knowledge to be applied in appropriate contexts, akin to a heuristic. Though not novel from a cognitive psychology standpoint, its recommendation in a CT context most certainly is, as what it proposes, on the surface, seems radically contrary to what we know CT to be and endorse. However, since reading this thought-provoking article, I have personally cited it as a promising means of fighting proverbial fire with fire with respect to using CT-mindware training to combat heuristic-based, gut-level decision-making.

Next, Sternberg and Hayes (2025) utilise the former's triangular theory of love as a basis for understanding our 'love and hate' for ideas and how these emotional implications can impact CT. From such discussion, they propose a model of how peripheral cognitive processes—in this context, broadly consumed within attitude and affect—can influence CT. Notably, Sternberg and Hayes make explicit the point that I think is core to the whole of this Special Issue: CT in the real world often bears little resemblance to that shown in tests or in school—if CT is to be taught, it should be performed so in reference to how it exists in the world, not in rarefied settings.

Finally, I also contribute a manuscript regarding what seemed to me to be receiving a glaring lack of attention in CT research (Dwyer 2023): whereas most of the aforementioned conceptual papers make a point of all the skills, dispositions, and practice one needs to conduct CT, seldom do I find that such manuscripts really enter into the discussion of barriers and impediments to CT. Thus, my manuscript focuses on the negative impact that some factors that we often take for granted or ignore in real-world scenarios can have on CT application—particularly, epistemological misunderstanding, too much intuitive judgment, and our ever-present bias and emotion. *That said*, I was delighted to see, in response to the call for papers to be included in this Special Issue, specifically geared towards everyday settings, so many manuscripts submitted that explicitly address barriers to CT (e.g., Bensley 2023; Guamanga et al. 2023; Sternberg and Hayes 2025, just to name a few).

Perhaps that is why, in addition to simply 'filling a gap in research', consideration of CT in everyday settings is so important—it highlights the use of CT in very practical settings (with all of its supports and barriers) and strips away the façade of the 'ideal' that is so often associated with how CT should be taught in educational settings. These ideas and their collection in the manuscripts that make up this Special Issue engage the messy world of decision-making, head-on, for what it is and offer useful advice for how to navigate this rocky terrain. With that, I hope you enjoy these articles as much as I enjoyed collating them and collaborating with their authors as part of this collection. I hope they reinforce your interest in CT as much as they have mine.

Conflicts of Interest: The author declares no conflict of interest.

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Article

Critical Thinking, Formation, and Change

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Abstract: In this paper, we propose an application of critical thinking (CT) to real-world problems, taking into account personal well-being (PB) and lifelong formation (FO). First, we raise a substantial problem with CT, which is that causal explanation is of little importance in solving everyday problems. If we care about everyday problems, we must treat the identification of causal relationships as a fundamental mechanism and action as a form of solution once the origin of the problem is unequivocally known. Decision-making and problem-solving skills should be the execution of the causal explanations reached. By acting this way, we change reality and achieve our goals, which are none other than those imposed by our PB. However, to achieve changes or results, we must have these fundamental competencies in CT, and these are not innate; we must acquire and develop them, that is, we must train ourselves to have CT competencies according to the demands of today's world. Finally, in this paper we propose a causal model that seeks to identify and test the causal relationships that exist between the different factors or variables that determine the CT-PB-FO relationship. We present some results on the relevance of causality and how to effectively form and address real-world problems from causality. However, there are still questions to be clarified that need to be investigated in future studies.

Keywords: critical thinking; causal explanation; decision making; problem solving; instruction and evaluation

1. Introduction

In this special issue, we "... explore the application of CT to real-world situations and everyday life...". The authors of this issue are asked to answer how CT is applied in our daily lives. This paper will answer this question by understanding that CT is a problem-solving process based principally on causal explanation. If we want CT to be applied to real-world problems, what it must do is solve them, and these today are more challenging and complex than they were a little more than two decades ago. To solve a problem is to achieve our goals; to do that, we need to explain reality to act most efficiently. Daily life consists of events, things that happen, and behaviors demanded by those events, which have consequences or effects. To understand reality, we need causality. For this reason, our proposal prioritizes causal explanations in the solution of the problems of daily life. Now, to achieve our goals, we need to think and act well to achieve something like personal well-being. However, the skills that make it possible to achieve our goals and, therefore, our well-being must be acquired or developed because we are not born with those skills. Thus, in CT, the skills that best address the problems of today's challenging world must be taken into account and developed in order to achieve our goals effectively. In short, we must treat the CT-PB-FO dependency relationship to offer a way to apply CT to daily life.

We will develop these aspects in five sections. In the first section, we will deal with the limitations of CT due to its difficulty in adapting to the new times because of its lack of response to the problems of today's world; in the second section, we will explain the changes and new demands of the present times that impose new strategies for confrontation;

in the third section, we will deal with the need to improve CT given the enormous current difficulties in its acquisition, something that can only be achieved through training; in the fourth section, we will deal with what gives meaning to all this, namely, achieving a certain personal well-being; and in the fifth and last section, we will propose a causal model integrating all these aspects to achieve the change we need to achieve that personal well-being or to be able to face the problems of the real world effectively. The order in the treatment of all these sections follows a logic that imposes the dependence of one aspect on another: limitations appear with the new times, these and require continuous training to face them, and this improvement of our skills is key to achieving our welfare, and this is only achieved by changing the reality, which is only achieved from the causality. This is the story we are going to tell.

2. Critical Thinking: Limits and Ways to Overcome Them

Is the field of CT growing sufficiently, in the sense of evolving as much as it could? Keeping the historical and important distances, the same thing is happening to CT that happened to physics before the appearance of the geniuses of the Renaissance. Physics did not evolve as much as it could have because of, let us say, the "Aristotelian dominance". The influence of this genius was such that it prevailed over that of another exceptional mind, Archimedes. If it had had the same influence as Aristotle's physics, the thought of this genius in physics, engineering, astronomy, and other fields that aspired to the understanding of the world, perhaps that wonderful period of the Renaissance where science was invented would have happened long before the intellectual darkness of the Middle Ages (Wootton 2015; to understand the analogy with Toulmin and the consequences of Aristotle's greater influence than Archimedes on physics and the subsequent development of science, see his excellent analysis of Wootton 2015 and the development of the history of science in Flores 1979). Drawing an analogy with the development of physics, we can say the CT has also experienced a similar influence, the "Toulminian dominance" (Saiz 2020). Toulmin (1958, 2003), with his excellent work on the use of argumentation, determined the development of CT, and it has been very difficult to escape from that model (see Baron 2024; we must make it clear that everyone recognizes Toulmin's fundamental contribution to stimulating the development and importance of CT). As with physics, logic and argumentation largely guided the evolution of the CT field. Again, the predominance of rationalism leaves little room for empiricism, and this is a problem because both should have equal prominence in science. Moreover, when applying CT to everyday life, we must act or intervene in reality. For this, a good reflection is not enough; this is materialized by employing decision-making and problem-solving strategies. However, these new strategies or thinking processes result from research in cognitive sciences starting in the 1990s (Holyoak and Morrison 2005; Sternberg and Funke 2019). This new knowledge involved incorporating processes different from argumentation (pre-decisional), such as those related to problem-solving and decision-making (post-decisional).

The fact of incorporating post-decisional mechanisms generates conceptual difficulties because they are processes of a different nature from argumentation. In fact, by contemplating these new competencies, the homogeneity of the prevailing theory of argumentation is broken, since skills are introduced that have more to do with what would be a theory of action (Rivas and Saiz 2023; Saiz and Rivas 2011). This causes important theoretical problems due to the resistance generated by the acceptance of these mental processes as belonging to the field of CT (Johnson and Hamby 2015). It is difficult to integrate both kinds of processes: the representational ones and those that execute them. These discrepancies are also at the origin, let us say, of a certain paralysis in the evolution of the field of CT because it has delayed the incorporation and application of these new mechanisms (Rivas and Saiz 2023).

Toulmin's model has established argumentation as the main actor of CT or as the competence that determines and conditions everything; the significant philosophical influence on CT, we believe, must remain but in another way. In our opinion, this domain must be the guide of correct reflection, but it must not determine other things simply because it cannot. Argumentation allows us to represent in the best possible way the reality of that part of the world we need to understand or comprehend; however, in most cases, it is necessary to apply, to execute those conclusions we have reached in that representation. However, at this point, the skills we manifest are very different from everything that has to do with reflection; in other words, action is the daughter of thought (Franco and Saiz 2020; Marcio 2001). Its concretion consists of interacting with the world through behavior, which has consequences that must be explained to give meaning to events, but this understanding or reflection is not enough; we need causality. We want to clarify that we are referring to *causal explanation and its demonstration*; causal identification alone is insufficient, and verification is also needed. This idea is equivalent to what Bird (2010) calls "Holmesian inference" (for a more in-depth analysis, see Azar 2019; Grimm 2010; Guamanga et al. 2023). For us, this is the unseen elephant in the CT room (Saiz 2020).

Those CT approaches based on argumentation also consider explanation or causal reasoning but from a different epistemological approach. The explanation of behavior can be approached from comprehension or explanation. In the first case, we seek to understand behavior from intentionality (teleological approach; see von Wright 1979); in the second, we seek to understand behavior from causal explanation (see Toulmin 1977; von Wright 1979). Our position is clear: CT can only progress and answer everyday problems from *causality or causal explanation*. The reason for our position is obvious: intentionality is unobservable.

This will be the central thesis of our work. From here, we will justify that, without this approach, CT cannot progress because its main problem lies in being characterized by too much representation and too little action; the predominance of the pre-decisional and the merely testimonial character of the post-decisional are important limitations. In the present paper, we will offer a solution to this problem with the help of Judea Pearl's *new science of causality* (Pearl 2009; Pearl and Mackenzie 2018).

As we said, if the mental representation resulting from reflection was enough to survive, we would not need to translate it into reality. Translating our ideas into the world forces us to act; it requires action and behavior. For different reasons, these competencies have never been well integrated within primarily argumentation-based approaches to CT. They have not been well integrated because the incorporation of causality and skills such as decision making and problem solving remain disproportionately minor compared to the basic forms of formal and informal reasoning; we need only go through the content and space occupied by formal and informal argumentation in relevant works in the field (see Bassham et al. 2023; Bowell and Kemp 2002; Epstein 2006; Fisher 2011; Freely and Steinberg 2013; Foresman et al. 2017; Govier 2014; Jackson and Newberry 2012; Johnson 2000; Johnson and Hamby 2015; Kenyon 2008; Moore and Parker 2021; Tittle 2011; van Eemeren et al. 2007; Walton 2006; Walton et al. 2008). However, other CT perspectives did understand the relevance of post-decisional mechanisms following substantial contributions from cognitive science (see Ennis 1996; Facione 1990; Halpern 1989; Paul 1995). These decisive early contributions have given way to perspectives that are more comprehensive and better define what CT is today, in our view (see Baron 2024; Dwyer 2017; Facione 2011; Facione and Gittens 2013; Halpern and Dunn 2023; Hunter 2014; Paul and Elder 2012; Pinker 2021; Saiz 2017, 2020; Sternberg 2021; Sternberg and Halpern 2020; Sternberg and Funke 2019). However, despite this important progress, there is a need to reconceptualize the CT approach from causality. As we pointed out, this would be one way to solve the problem of slower CT progress, but only in part. It is not as important to better integrate the fundamental cognitive competencies and change their function as it is to put causal explanation at the center of CT; this would be one part of the solution to the problem. The other important part of the problem would be the scarce attention given to behavior, action, and change in the different approaches to CT (Saiz 2020). If CT wants to offer effective strategies for adaptation to the real world, it is reasonable to consider the new realities. It would be an anticipated failure if CT did not consider current changes and demands because the world of the 21st century demands greater interaction, communication, group decision making, and solutions to new problems. However, all these demands can hardly be attended to if we do not opt for causality as the main actor in the proposals for improving daily life with CT. Let us see in what sense this does not seem to have enough influence.

3. Critical Thinking: The Changes and New Demands of Today's World

The changes in the world of this century are dizzying and impose the challenge of new demands. For our purposes, two key dates have marked and will mark these transformations: 2007 and 2023. In 2007, the first mature smartphone (iPhone) appeared, enabling the proliferation of social networks in the following years. In 2023, the first mature global artificial intelligence (AI) projects appeared, and in recent months, they have developed in such a way that expectations soar thanks to the *OpenAI* project (ChatGPT). In a short time, the advances in AI and its combination with neuroscience (Hawkins 2021) have been spectacular and worrying. Adaptation is, therefore, a difficult task.

To support this pessimistic statement, we present and discuss data that leave no doubt about these deficiencies (see Saiz et al. 2020). Additionally, there are very convincing data from attention experiments. Gloria Mark notes that today, we can only pay attention or concentrate for a maximum of 47 s, whereas 20 years ago, we could maintain our attention for up to two and a half minutes (Mark 2023). Also, we can see these limits by getting into technical and complex work on biases and noise by Kahneman et al. (2021).

There is a principle called the *universal law of learning* (ULL), which is that any person, institution, or society has to learn at least at the same speed with which the environment changes to survive and, if it wants to progress, it must do it faster (Marina and Rambaud 2018). The question is, in general, do we survive or do we progress? In particular, in CT, the same question is posed; our answer is that we will certainly not progress. Recall that the title of this work consists of three terms, and the second is included in the idea of ULL, *learning* to survive or progress. This process is the one that allows us to understand our interaction with the world better because what we need is to adapt, and learning is what makes that possible (Sternberg 2021); if we do not learn, we do not survive. Vygotsky's (1993, 1978) idea of intelligent adaptation, which according to him depends on the learning capacity we possess, is recovered.

Overstimulation causes concentration and attention problems. If attention deteriorates, our thinking can only be superficial, so deep or complex thinking becomes an exception. Observation of our students in recent years allows us to state that they are not able to make more than two inferences in a row in their daily academic work. A relevant and solid conclusion needs at least three inferences; therefore, deep thinking is called into question. Increased entertainment causes a greater predominance of MINIMAX—the law of MINIMUM effort and MAXIMUM gratification—(Saiz et al. 2020). This law is adaptive from the species' point of view, but not in many other ways. Well-founded and contrasted knowledge does not come easily; it requires good observation, effort, and deep thinking. Contrasting or evaluating a position, thesis, or conclusion requires the application of the appropriate criteria, which are the result of reflection or good judgment. This ensures the credibility of these ideas or knowledge.

Attention and concentration problems make the acquisition of knowledge (or learning) difficult. Knowledge is inferential; an idea or concept is the conclusion or result of a reflection, which requires relating information to categorize or establish relationships of belonging or class. Knowledge ends when we can causally explain reality and modify it, not before; only then, we can speak of the product of that process, namely, the result of the acquisition of knowledge based on a causal explanation. We agree with Perkins (2009) when he states that we can only say that we know something if we can apply it.

Cognitive problems resulting from these new times cause us deficiencies that are not found in our genes. However, they are not the only deficiencies that beset us. We all know that our cognitive system is not perfect. These deficiencies, biases, or intellectual limitations, which are the fruit of descriptive research in thought, have been known for decades. Baron (2024) rightly distinguished research in thinking as descriptive, normative, and prescriptive. The first descriptive works, i.e., those aimed at finding out how we think in everyday life, already revealed the lack of logic in our thought processes (Henle 1962). However, neither deficiencies of one type nor the other figure prominently in CT development and improvement initiatives, despite their clearly applied nature (Saiz 2017).

At least in our country, what we have observed in recent years among university students is a significant increase in family and social protection and permissiveness. Greater protection or overprotection reduces personal autonomy, and permissiveness or consent reduces personal responsibility. If the level of demand is low, MINIMAX nullifies initiative and the search for solutions since there will already be someone to do it for us. On the other hand, if behaviors have no consequences, the essential learning that our actions provide us with disappears due to the lack of responsibility, since someone else will assume the consequences in our place.

For our work, the development or improvement of CT is a difficult task to perform when personal initiative has deteriorated and the consequences of our actions are not assumed individually. Therefore, if we are looking for CT to be a good guide in our daily or everyday life, we must take into account the cognitive and behavioral problems caused by the social changes that have occurred in recent times; unfortunately, these considerations are rather scarce in most of the initiatives aimed at such improvement (Saiz 2017).

Resnick (1999) said some time ago that the ultimate goal of education is thinking, although she did not have CT in mind. Today it is the object of desire of education, in fact, the desired result of education (Dwyer 2023). When we talk about thinking, CT, or intelligence, we know that we are referring to higher-order cognitive processes and different models of mental functioning. A classical model of intelligence based on IQ is a good predictor of academic or job performance, but it does not predict as well the performance in the face of everyday problems or real-world problems (Halpern and Butler 2018; Halpern and Dunn 2021; Rivas et al. 2023b). The complexity of today's world problems is better coped with by other models such as some CT approaches, which incorporate skills such as problem-solving or decision-making strategies (Halpern and Dunn 2021). Other models of intelligence equally cope well with everyday problems. Robert Sternberg, a relevant representative of the theories on intelligence, has in recent years put forward an integrative approach based on the classic concept of adaptation and learning to solve problems. Expressions such as "learning to think critically", "adaptive intelligence", or "successful intelligence" (Bonney and Sternberg 2011; Sternberg 2018, 2021) are conceptions that are difficult to distinguish from what many understand as CT. Sternberg (2021) himself differentiates general intelligence and adaptive intelligence, and we believe this is a good distinction; we understand intelligence as the potentiality (Ackerman 2018), which we cannot know or measure, and the expression of that potentiality, which we can know, measure, and improve. Thought processes are such expression and are the cognitive components of CT (Saiz 2020). In short, thanks to these skills, we reach our goals, solve problems, or change the situation.

Sometimes we forget that our cognitive system is at the service of our biological nature, ultimately survival, for which we need adaptation to the environment. The question, for example, of why we think has a very simple answer: because we need to, or because want something we do not possess and want to get it, or we want to avoid something we do not want; in all cases, we have a problem to solve. We return to our approach at the beginning, that is, the fundamental goal of CT is to resolve to achieve change, to act to achieve our purposes; the front and reverse of our cognitive coin are thought and action.

We said that CT is the object of desire, not only of education but also of companies and different organizations of different natures (Dwyer 2023; Halpern and Dunn 2021), at least in words. The expression "we must think critically" is more of a mantra, nothing more. Teaching or learning to think well starts with the difficulty of knowing what it is to think well or critically and what it is to teach or learn. Necessity sharpens the mind, and the pandemic catastrophe and other global misfortunes have contributed to this, in the sense of becoming aware of the increasingly complex and sophisticated problems of our world. In part, this has been a stimulus to more frequently orient and define CT as a set of cognitive skills that enable us to obtain desired results or to solve problems in the most effective way. More than half a century ago, Newell and Simon (1972) were already pointing the way. We can finally say that we are emerging from the "Toulmian dominance".

CT is increasingly understood as a matter of solving problems, which requires action. For this reason, we go a step further and say that to *think critically is to reach the best explanation for a fact, phenomenon, or problem to know or to solve it effectively* (Saiz 2020, p. 27). As we have proposed above and will develop further on, we incorporate explanation, and causality, because efficacy is not possible without it. We give the mechanism of causal explanation the maximum protagonism, but it needs the collaboration of argumentation (and not the other way around) to decide and solve. The solution is already in the causal explanation, we only need to act to produce a change and achieve our goals effectively. Argue to help explain, explain to help decide or solve, and solve to bring about change effectively. For us, these are the fundamental skills of CT and the relationship that is established between them (see Saiz 2020). These are the cognitive components of CT, but there are others of a non-cognitive nature, such as dispositional, motivational, attitudinal, or metacognitive, without which CT cannot occur. Some directly integrate these two dimensions, cognitive and non-cognitive, defining CT as a metacognitive process (Dwyer 2017, 2023). We believe that this is neither a good idea theoretically nor practically. Conceptually, we increase the confusion, since there are already enough problems with metacognition and motivation (or vice versa), at least in one of its meanings, that is, regarding the planning and organization of behavior. Thus, we practically tie our hands from the point of view of instruction or improvement of CT (Rivas et al. 2022). Awareness of what happens mentally is always present in any CT improvement initiative; without the "awareness of," improvement is not possible, and there can be no learning or acquisition without that level of awareness or metacognition. The problem lies in how to modify or promote metacognition and know that we have done it; we are facing the same problem we have with motivation: its manipulation or operationalization. Our eternal wall is the mental and its quantification.

4. Critical Thinking and Formation

Teaching or learning to think critically, for us, consists of developing those fundamental skills mentioned above. At least, *what to* teach or learn we have detailed; without knowing what we are talking about, there is little we can do regarding CT development. Diane Halpern has justified this very well in different relevant works, stating that to change or improve CT, the skills that are intended to be improved must be concretely specified (Halpern 1998; Halpern and Dunn 2023; Marin and Halpern 2011; Saiz 2017). However, do *we teach, learn, or form ourselves?* What are the differences? Alternatively, are we talking about the same thing using different terms? Before the internet existed, it made sense to talk about *teaching* where the administration or organization of knowledge and the transmission of knowledge were the fundamental tasks of education. The fundamental activity was the reception and reproduction of the content, with a predominance of declarative knowledge and, consequently, little practice and application. The teacher–student relationship was unidirectional. In the post-internet era and until the end of the first decade of this century, education is now understood more as *learning*. The acquisition process is now focused on understanding, and reception or passivity is being replaced by interaction through questions, developing synthesis and relating content. Practical and applied activities are also beginning to be incorporated. Procedural knowledge begins to gain prominence, as well as learning management (*learnability*) as opposed to knowledge administration. Finally, the teacher–student relationship is bidirectional (see Saiz et al. 2020).

What is happening today? Our experience is that in university education in our country (although again, we believe it is generalizable to other places), the development of critical thinking is not happening, even though it is the time and place where it could and should happen. There are somewhat concerning studies that highlight that university students, as they progress through their degree, worsen their level of thinking (Arum and Roksa 2011). In contrast, our students, because they go through our instructional program in the first year of university, not only maintain but improve their CT level four years later (Rivas and Saiz 2016). We only want to highlight a general way of CT development; we have specific techniques for its improvement, verified in several studies.

We have been working for some time on *formation*, rather than learning or, of course, teaching. In our opinion, the consequences of the changes and new demands of the present times force us to use a new approach to manage these times of great uncertainty. Companies have long been demanding the same skills, regardless of qualification: communication skills (argumentation), teamwork, decision making, and problem solving. How curious are they asking us for professionals with good CT skills (Saiz et al. 2020)? (See Figure 1 two pages later) In reality, they are asking for much more because it is no longer enough to have a good grasp on our own domain; we also need to be able to solve new problems using our own preparation or expertise. In the workplace, horizontal or transversal competencies are required to be effective, not only efficient.

These demands from the world of work are a logical consequence of the great mobility and flexibility of the market and business. Studies have shown that, for some time now, graduates will change jobs between twelve and fourteen times during their working lives (30–35 years), and this mobility seems to be increasing. What will be increasingly in demand are what they call "knowledge nomads" (also known as *knowmads*); see Saiz et al. (2020). If this is the trend, how can companies not need professionals with horizontal competencies such as those of CT? The question is, is technical and personal formation going in that direction? The answer is clearly no. To the question of what to do, the answer, for us, is *formation*. Let's see how.

Today, society at large is absorbed in smartphones, social networks, YouTube, and such . . . and classrooms are colonized by this obsession. Moreover, AI is rapidly advancing in the performance of tasks. Educational institutions are beginning to be replaced by tech giants (*GAFAM*). A study done in the USA shows that three of these five technological companies have discovered the big business of training and are investing around 4 billion dollars; this is equivalent to three times the GDP of our country (see Marina 2017, 2022a). *STEM* is the big professional demand and will remain so for quite some time. The majority of American universities seem to have experienced a kind of abandonment of CT, progressively replacing it with identity politics (identitary thinking; see Marina 2017, 2022a). Who is going to be formed in CT? Clearly, the "immunity" that the CT vaccine can provide will not be reached; instead, a vulnerability to disinformation, the undervaluing of science, the devaluation of truth, the difficulty in selecting information, or an overall lack of direction may become pervasive. Faced with this prospect, what is the plan? It is clear to us that the current teaching and learning models are insufficient.

Given the present circumstances, *formation* seems to be the only solution. Knowledge based on causal explanation should be the standard acquisition process; when possible, work must rely on the social support of a community of inquiry. The formation process should be based on solving real problems and seeing if changes have occurred or results have been achieved. Likewise, asking questions remains a fundamental process, as is mainly procedural work, with inter- and intradomain practices and applications to promote generalization or transfer. Formation must be permanent, and the autonomy and the initiative of the one who forms must also be constant (see Saiz et al. 2020). Not without pessimism, we can rescue the old slogan of *do it yourself* because deepening and mastering fundamental CT skills and applying them effectively to everyday life requires this kind of preparation. In the current circumstances, the model of autonomous and lifelong formation is the only preparation model that can slow down the negative effects of the ULL, the one that can fully develop acquisition processes and reach the maximum availability of horizontal competencies that are in demand. This approach retains some of the features of the other two, education and learning, where relevant, e.g., the lecture, and amplifies the use of those features it shares. For instance, answering questions should be used in most of the formation process, we would say in 85–90%. However, this approach only provides the framework for CT development. How to operate in this context requires specific methods of action based on those we have already contrasted (see Rivas and Saiz 2023; Saiz and Rivas 2011, 2012, 2016; Saiz et al. 2015).

5. Critical Thinking and Personal Well-Being

As we said, the development or improvement of CT demands a what and a how—what to improve and how to achieve it—but also a why or what for. We think because we need to; specifically, we think critically to solve real-world problems that affect us directly or indirectly. From this way of looking at CT, we have taken an important step by placing action at the core of this approach. It is in the interaction with the environment that we solve problems or achieve our goals. In this way, CT begins to make some sense, were it not for the fact that we forget something essential: why solve problems? Because we need it? This is saying rather little. What needs are we talking about? Here, we enter the realm of the non-cognitive dimension of CT. Motivation to solve our problems would be a first approximation to what it is that drives CT skills to get going.

In reality, the ultimate goal of the human being, some would say, would be happiness, but we know that this idea is too polysemic (Marina 2022b); it is a fuzzy concept that is difficult to use. However, most of us would agree that something like happiness, personal well-being, or quality of life could reasonably fit the idea of that ultimate motivation of the human being, which would be responsible for our personal fulfillment. Flanagan et al. (2023) discuss in their work these elusive concepts from several points of view, making us doubt the very title of the book: *Against Happiness*. For the purpose of this paper, we propose that the ultimate reason for solving problems is achieving an acceptable personal well-being. Globally, the concept of well-being that interests us is that in which the person values that his or her life has meaning (see Flanagan et al. 2023). We are always considering this idea applicable to the adult population. The way to measure this meaning of personal life is with a scale or with situations in which there would be no behavior or it would be of a certain form.

In the present project, personal well-being is a feeling of satisfaction that comes from having achieved economic and emotional independence, which allows the person to achieve the goals he or she sets for him or herself while at the same time perceiving that his or her life has meaning. Let's say that it is a mixture of personal and social achievement with vital meaning. The way in which we seek to measure this personal well-being is by observing the behavior, in terms of their functioning at work and in their personal environment, and the absence of conflict or major problems that allow a calm and meaningful development in their daily life. In short, the person feels or experiences that he/she can manage his/her life and that it has meaning. Thus, achievements and problem solving provide a sense of life control that offer peace of mind and satisfaction (Flanagan et al. 2023; Marina 2022b). From the point of view of measuring personal well-being, we care about what we observe, that is, personal and social performance. However, we must recognize that we are at a very early stage in assessing personal well-being, as we still need to operationalize this scale. An important reason for this difficulty is that we avoid using self-report measures and seek to use observations or behavioral data. However, once we can move in this direction, we are using Ryff's scale (Díaz et al. 2006; Ryff and Keyes 1995).

The expression *knowledge begins with the wanting* captures very well the origin of knowledge. To know or to seek knowledge, we must have the *will to want* and the *desire to want*. The motivational and the emotional are inseparable from cognition and are what make us move or act; there is no adaptation without will and feeling (old concepts, today modern, already used in Greek anthropology by the Sophists and developed by Socrates; see Flores 1979). It would be difficult to imagine anyone, except by pathology, who would not *want* (in its double sense) *to* achieve a certain personal well-being. Therefore, we could say that this is our ultimate end or most cherished goal, and to achieve it, we must overcome the obstacles or solve the problems that arise throughout our life cycle. Now we have given meaning to the activity that we believe best integrates the different CT competencies, i.e., problem solving. But this forces us to understand, in turn, what problems we are talking about or whether there is any kind of problem that guarantees personal well-being, once they are solved, and the answer is yes (Saiz 2021). We can affirm that there are two general classes of problems linked to the dual nature of human beings: the biological and the social. As s living organisms, people must find a way to sustain themselves to survive, and as beings dependent on others, they need the group to live and progress. Consequently, the important problems that any person will always have are of only two types: *professional and personal*. If a person has a profession in line with his or her qualifications and desires and has a supportive social network, then he or she is in a position to achieve the desired personal well-being (see Saiz and Rivas 2020).

It is too often forgotten that reaching this goal, the ultimate meaning of survival and living, occurs in a critical period of our life cycle. It is not until the age of eighteen that society considers us to be full adults, that is, responsible for our actions. Society asks us to move seamlessly, overnight, from the stage of almost adolescence to full-fledged adults. In reality, it is at this point in the life cycle that our most exciting and interesting, but also critical, period begins. From the age of 18 to approximately 30-35, we must achieve the two essential objectives for every person: *economic independence and emotional independence or personal maturity*. The first is the necessary condition for that personal well-being, and the second is its sufficient condition. In this critical period of 10–15 years or so, we must achieve material solvency and personal balance to be able to go through the rest of our life cycle without too many shocks or insurmountable difficulties. The *diachronic dimension* is rarely taken into account when dealing with problems, nor is the fact of how transcendental this critical period is for the rest of the life cycle. Moreover, it is worth noting that this stage of these 10–15 years coincides with the period of higher education or professional formation studies, which offer access to the professional world in the best conditions (see Saiz 2021; Saiz and Rivas 2020).

This critical period of preparation for a professional future also coincides with the most intense years of our social development. Moreover, formative and personal experiences occur temporarily together, with the corresponding interactions and influences that will continue to occur until the end of our life cycle. These influences should make us aware of the importance of the professional aspect of our lives in today's world; moreover, the increased level of demands and professional burden today interferes with and conditions our personal lives excessively. Due to this pressure to be productive, it is often very difficult to distinguish between professional and personal problems. However, the good thing about this is that the competencies or skills that are demanded of us professionally and that we mentioned earlier are those that also serve us for personal problems. New roles and sophistication in both personal and professional relationships require good decision-making and problem-solving strategies, in short, good coping strategies (see Figure 1).

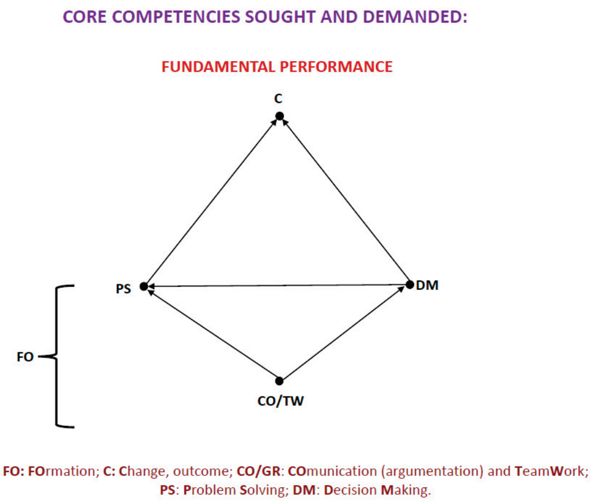

Figure 1. Core competencies sought and in demanded.

Figure 1 shows the core competencies required (i.e., a high level of CT is requested) to achieve results or produce changes, both professionally and personally. If these changes go in the desired direction, professional and personal progress guarantee our personal well-being. Let us note that this figure is represented by a diagram with nodes and arrows, which establish relationships that aspire to be causal relationships with the approval of facts. These diagrams are not only a system of didactic representation; they are a logical formulation that intends to concretize the ideas and their relationships so that they can be verified. They are representations that can be checked. To achieve this operationalization, this system of diagrams is based on graph theory, which is a logical-mathematical system (Wilson 1983) that provides us with the necessary precision to be able to develop the proposals we make of causal models and to able to validate them (Pearl et al. 2016). We will detail the significance of the elements of these diagrams later; for now, it is enough to see the direction of the arrows in terms of what determines each thing. We only want to illustrate the role of the key competencies of CT and the relationships between them.

A good part of what has been explained so far is shown in Figure 1. Competencies, training, and change or achievements are included. The competencies represented in Figure 1 are those demanded professionally, the formation that allows us to develop the CT, which makes it possible to achieve our goals, what are the desired change, and this provides us with subsequent personal well-being. But the good or the best possible results, let us not forget, have an end: our personal well-being. Therefore, we must integrate them with the rest of the determinants discussed so far to better understand the relationship between CT and personal well-being (see Figure 2).

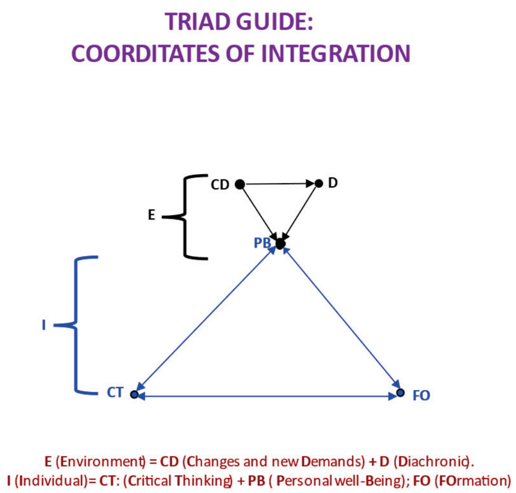

Figure 2. Integration of environmental and personal determinants of personal well-being.

In Figure 2, we can find all the determinants of personal well-being that we have analyzed so far and represented with the logical precision of a graph model as a proposal for a causal model to be further specified and demonstrated. In the following section, we will incorporate the factors that summarize each node here and that do not appear in Figure 2. In addition, we will describe some data that support the model, only a few, because this is a proposal for future studies. In this figure, on the one hand, we have the environmental causes that influence the diachronic dimension in the different stages of the life cycle, especially in the critical period already described. The causal relationship of these factors is only partially clear, as we will detail later, due to the types of connection between nodes. For the time being, we will only deal with the conceptual description. Personal well-being depends to a certain degree on these environmental factors, which must be quantified. On the other hand, we see personal causes, CT competencies, and the formation needed to develop it. Again, these causal relationships are not clear, in this case, because of those double arrows that appear. When achieved, causality is always expressed with a unidirectional arrow. Later on, we will further clarify these logical and causal precisions. For now, let us stop at the representation of the diagram, where the environmental and personal lead to the change that makes it possible to achieve well-being. The way to achieve this change is to decide and effectively solve these new challenges, acting based on the explanation that allows us to know the causes of the events to modify or adapt them. However, all this is only possible with the good development of CT, that is, with a good formation.

6. Critical Thinking and Change

The purpose of what has been discussed so far, let us remember, is to justify a proposal in which CT and its development are the best way to effectively solve real-world problems based on causal explanation and action. The identification of the causes of a problem is the diagnosis; the plan of action, the treatment, and the changes produced, this is, the elimination of the problem or the cure. In this section, we will develop our proposal for diagnosis, treatment, and solution, and finally, we will propose a verification methodology for an integral causal model.

At the beginning of this paper, we spoke metaphorically of the "Toulminian dominance" to raise a problem in many of the CT approaches. If we were to review the books cited (and others that we have omitted) as examples of the predominance of Toulmin's model, we would find the following, with minor variations. All these publications always deal with argumentation, its structure, and evaluation, the two general forms of reasoning (deduction and induction), fallacies, calculation of probabilities, legal, moral, and sometimes aesthetic reasoning, rhetoric, and some treatment of new technologies and pseudoscience. Causal reasoning and its verification (hypothetical reasoning) usually occupy a section that never has the extent of either argumentation or deduction; it is a small part of induction. The way to acquire these skills rests basically on conceptual understanding and practicing through specific exercises for each type of reasoning, with minimal application to the real world and everyday problems. Let us say that a model of teaching and, in part, of learning, as described above, is followed.

The question that arises is the following: after all the changes that have occurred so far this century—the ubiquity of screens, social networks, continuous entertainment, GAFAM, STEM, AI, neuroscience—do we still believe that a CT model like this one can serve as an answer to real-world problems? Clearly not. Let's give an example by way of analogy. As far as we know, mathematics in secondary school, in most of the countries around us, on the one hand, has always been a subject that is not understood, not seen as useful, does not raise interest, and has a high failure rate. On the other hand, this is understandable, since it is a difficult subject due to its high level of abstraction, something that has never been an easy matter. Only two decades ago, when the world was very different, the specialization routes that secondary school students chose (at 15–16 years of age) to be able to later opt for the study of certain university careers rarely included the ones involving mathematics. At that time, there were very few university students in mathematics; nowadays, the demand exceeds the capacity of these centers. What has changed? Is mathematics now easy or fun? No, but they have proven to be necessary to solve current problems that did not exist before. They are capable of providing solutions to very different fields of science; they have become transversal or horizontal competencies. Moreover, this domain of mathematics is in high demand by most companies, just like the rest of STEM. Argumentation alone cannot provide answers to the problems of daily life.

For us, this is a paradox; argumentation without action becomes useless, but if we incorporate behavior, argumentation has to be at the service of causal explanation, otherwise, argumentation and action will remain of little use. A change in the role of the protagonist and secondary actors in this CT story is needed. Fortunately, after the advances made in the cognitive sciences, new ways of understanding CT have emerged that overcome this important limitation, as already discussed. The fact of fundamentally orienting CT as a problem-solving activity makes possible not only the survival of the field but its progress too. These new ways of understanding CT are completely correct in placing the ability to solve problems as the main actor. The importance of judgment and reflection is maintained, but the ultimate goal is to provide answers to existing difficulties or problems of daily life. By endowing CT with propositivity, the action of post-decisional competencies is incorporated, and the person is faced with the need to interact with the environment, to adapt, and to try to progress.

This is the right path, but the protagonist who allows the best solutions or effectively solves the problems is still missing. The explanation, the causality, is still taken into account as a secondary actor. The causal explanation is the one that allows for solving problems effectively, not only efficiently; therefore, it cannot be a marginal actor because it is the one that tells us how to act to resolve. The same thing that happened to physics is happening to CT.

CT has made a great leap in understanding that we must be able to solve real-world problems, but it has not been consolidated because causality is not the main guide in problem solving, and neither has it combined logic and causality, as happened to physics. It begins to be decisive when science is invented and consolidated by combining two great achievements, the system of formal logic and the discovery of the possibility of finding causal relationships through systematic experimentation (see Wootton 2015). This is what CT still lacks, like physics before the Renaissance: to unite logic and causality, even though geniuses of the 19th and early 20th centuries have already shown us the way, such as John Stuart Mill, Charles Sanders Peirce, and Conan Doyle. The latter defined better than anyone else the path that CT should take and has not yet taken when he put in the mouth of his most famous creation—Sherlock Holmes—the following: "*. . . there should be no combination of events for which human intelligence cannot conceive an explanation*" (The Valley of Fear; Conan Doyle 2009, p. 706). This genius, in his first great novel *A Study in Scarlet* (Conan Doyle 2009), details his method of inquiry for the first and only time. For us, within the "canon" of Conan Doyle, this novel has special importance because it is the clearest and most explicit paradigm of what we are concerned with and propose: *observation, logic, and explanation*.

If what matters to us is dealing with real-world problems, *observation* is essential, but it is a skill we have barely developed, and today, with screens, it is much impaired (let us remember what has already been said, the 47 s, the maximum time of attention of which we are capable, experimentally verified by Gloria Mark). If observation fails, and it does so too often, there is little else that can be done. *Deduction* gives us unequivocal conclusions, and the observed will either support them or not. In reality, correct deductions can be made from the facts, and we can be right about what has produced them as long as we find neither counterexamples nor additional data that falsify such deductions; in this case, we will have a unique and certain explanation within a context or problem situation. The logical principles or rules of causality (sufficient necessary condition, SC-NC), which are structurally similar, are very powerful machinery if we let the facts be the ultimate judges. The in-depth description of the fundamental logical principles for proving causality and their structural similarity to the rules of SC and NC are especially technical, and a special section would be needed for all this. The interested reader can find this full development in Saiz (2020).

Observation requires a lot of practice because it is contaminated by our previous schemes and by the set of biases and distortions that, as we said before, mentally come to us naturally. From the point of view of instruction or formation, developing this skill takes much more time and effort than we might expect. The reasons for this difficulty lie in the fact that we think that to observe is to perceive well, but this is not correct. This can be better understood if we understand that the relevant facts are never the perceptually noticeable or striking ones, except by chance. The relevant facts are those that fit our hypotheses, and not the other way around. Facts become relevant or irrelevant only when we have a story or causal scenario that can give them an initial sense, when we can explain or make sense of the events. This is perhaps better understood if we keep in mind that to make sense is to know to a certain degree, and knowledge is inferential, not perceptual, at the level of processing that we operate (for a complete development, see again Saiz 2020).

The combination of observation and deduction to reach an explanatory hypothesis can already be found in Edgar Allan Poe, with his famous figure Dupin[1] (Poe 1988). However, formally it was born with Peirce (Umiker-Sebeok and Umiker-Sebeok 1979), who developed it within what he called abductive logic. However, for a long time, Peirce's abduction has not been given attention because logicians have been very focused on deduction. They have only begun to give importance to abduction when it has begun to have importance for the theory of science, for the discovery and evaluation of scientific hypotheses, and in the first steps of AI for medical diagnosis. Today, it has already captured the interest of cognitive science and new AI (see Magnani 2001, 2009). Are all these fundamental developments of our time being taken into account in CT? We are not aware of them. However, our interest here in abduction is purely its application, as its formulation and epistemological treatment exceed our objectives (an extensive formal investigation can be found in Aliseda 2006, 2014). From an applied perspective, it is observation or facts that consume most of the work in causal explanation, and the rest is employed in deduction. Nowadays, observation and deduction are inseparable; algorithms alone are not enough if we really want to face everyday problems (again, this technical development can be found in full in Saiz 2020). Today, there is a fever for using chess as a didactic tool; however, Allan Poe already pointed out the limitation of this algorithmic game as a model for the development of intelligence because according to him, what is needed is an uncertain game that forces us to observe, like poker (Poe 1988).

We usually tell our students that CT is 80% "look, look, and look again" and 20% deduction to make them realize how difficult it is to capture the really relevant facts. As we know, the most powerful enemy of our mind is *confirmatory bias*; data that are congruent with our ideas are the ones that catch our attention, and incongruent data hardly get it. The fact that our cognitive system is essentially inductive by adaptation and conservation has much to do with the powerful influence of this bias. Adaptation to the environment to survive creates in us a very strong need to always have some explanation of the events or problems that affect us; this need makes us make sense soon and always of what matters to us, even if we are hardly sure of it. For this reason, we seek or force the facts to fit anyway. Of course, the confirmatory bias is also affected by this need.

These are two of the ten capital sins of a cognitive nature that come to us genetically (see Saiz 2020, 2022) and impede us from thinking critically or problem solving. Continuing with the limitations of our mind, we must point out naivety, or thinking that the world is fair in the face of what logic tells us—namely that the world is not fair, it just is. This belief leads us to accept ideas or reflections lacking any basis or solidity. We can see here how the dispositional (the non-cognitive) contaminates correct thinking; this happens in part because words possess a great power of seduction due to our social nature, which causes facts to be substituted for them. Another major deficiency in problem solving comes from our insensitivity to the probable. We too often confuse the possible with the probable, and this makes the solution space very large, paralyzing almost every decision or solution strategy. Every problem depends on a context that limits the options since there are general options that do not fit in a given context, and thus to consider them is to subscribe to the failure of the solution.

We have only mentioned some of these 10 deficiencies or capital sins, but this is not the end of our mental difficulties because we can also say that we suffer from what we have called "the 10 false virtues" (see Saiz 2020, 2022). The first is believing that we have mastered correct reasoning, when Henle (1962) showed us long ago that we only handle a couple of logical principles. Another of the serious limitations we suffer from is to confuse what is true with what is correct. During reasoning, when all statements are true, it no longer matters what is concluded because we will take it as valid. Thirdly, it has long been known that all things that happen spatially or temporally together tend to be considered related, even though they may or may not be. This cognitive distortion is notably guilty of confusing correlation with causation and also of attending only to presence-presence data when we want to establish contingency relationships, as we leave out the other three kinds of data (Smedslund 1997).

Finally, for us, there are three particularly serious deficiencies that prevent us from getting a good causal explanation right. To make sense of things, we need to imagine or mentally simulate events, and we do this very well, but what we fail to do is to causally simulate these situations. Constructing causal scenarios is difficult and requires a lot of practice. Constructing a causally consistent story is key to achieving a good causal explanation. However, this is not easily achieved because it is hampered by two other important limitations: on the one hand, the enormous difficulty we have in making complete sense of events or problems since we only do so partially, and on the other hand, our deficient use of counterfactual thinking. Without the imagination of counterfactual events, we are very limited in our task of achieving a good causal explanation. A more complete description and justification of these 10 + 10 cognitive limitations can be found in Saiz (2017, 2020).

Our objective here is to expose the features of our cognitive system that must be taken into account conceptually and applicably in CT, but again, we do not see that this is considered, at least we are not aware of it. If CT aspires to solve real-world problems effectively, it is not enough to prioritize certain key skills that were not there before; we also need to know our enemy's strengths, that which, even if we proceed well, will distract, distort, or confuse us. We need to know the front and reverse sides of our cognitive machinery, or else we ourselves will be the victims of our fragile mental Achilles heel, which is confirmatory bias. Careful and attentive observation is the foundation on which all causal explanation rests. Technically, making sense of or explaining a problem follows some well-known steps. From these observations, we formulate the corresponding inductive generalizations, i.e., we bet on a first meaningful approximation to reality. Then, we propose our first explanatory hypothesis or our first conclusion from a causal reasoning; in reality, causal reasoning consists of facts plus generalizations. Once we have a proposed causal relationship, we must verify it. This reasoning is not only causal, it is already hypothetical reasoning; simplifying these technical aspects, we will say that hypothetical reasoning is causal reasoning plus verification. By obvious transitivity, observation remains the basis of causal explanation (for more information on these technical aspects, see Govier 2014). We have formulated and integrated this treatment of the causal with the developments that we will present below (see Saiz 2020).

At a less technical and more descriptive level of causality processes, we must elaborate on part of the above; to do so, we will use Pearl and Mackenzie's (2018) analogy of the causality ladder (see Figure 3). When we observe, we usually identify relationships between events that, if repeated, lead us to establish generalizations that we then can elaborate and refine to find a cause, or several causes, of a given effect. We can imagine how to proceed in a medical diagnosis—the presence of symptoms or disease combined with the presence of an agent (virus, bacteria. . .). This would be the first rung or level of the causality ladder, where we can only establish relationships by simple *observation*. Here our learning is only through observation, with which we reach contingency relationships. The next level of the ladder is that of action, *doing*, in which we can manipulate or intervene in reality. In this step, we learn by planning, and it is where we can establish or demonstrate causal relationships because we *can experiment* and modify reality to see what happens given certain conditions. In their magnificent book, *The Book of Why*, the authors point out that only humans are at this second level (an anthropomorphic bias of the authors, of little importance). One only has to see the spectacle of the Okinawan crows manipulating the environment to admit that other living organisms operate on that rung. Kabadayi and Osvath (2017) make a very interesting description of these behaviors.

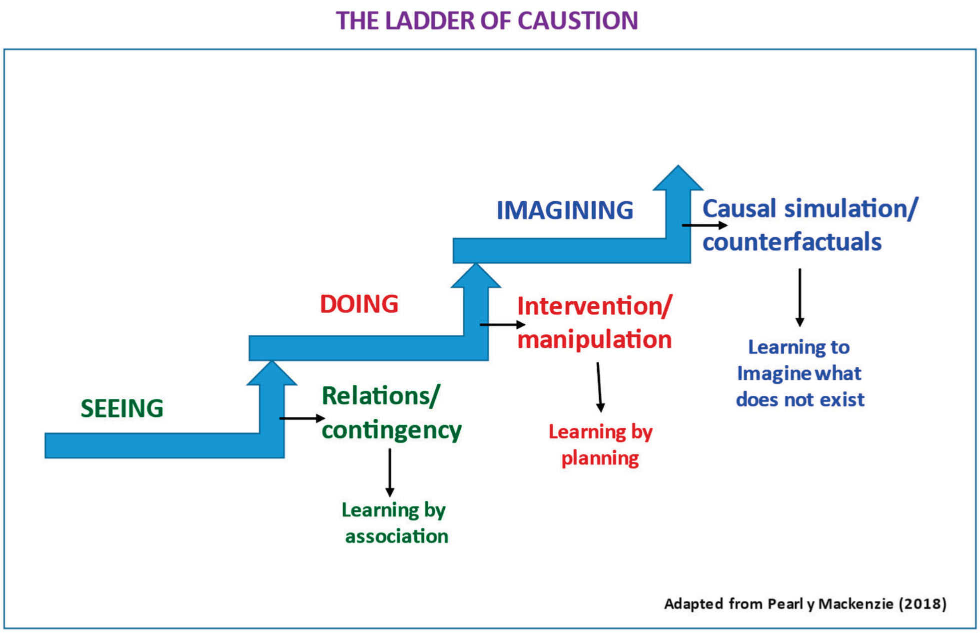

Figure 3. The ladder of causation (adapted from Pearl and Mackenzie 2018).

The third and final level of causality would be that of *imagining*. This is the most interesting step for us because it involves all our sophisticated cognitive machinery, incorporating the consciousness of oneself, of the "I". It is not within our objectives to deal with questions of animal psychology, so we will not mention exciting studies, again with corvids, on their degree of consciousness with simple experiments using a mirror. We will only mention that in neuroscience, it has been demonstrated that consciousness is located in the medulla oblongata, as this structure is the linking node between the central system and the vegetative system responsible for pain and pleasure, which are the origin of consciousness (see Damasio 2021). For our purposes, the importance of simulating reality, of recreating it internally, lies in the *ability to imagine what has not happened* and what we refer to as *imagination or counterfactual thinking*. Evolutionarily, this capacity seems to be of recent emergence, from only about 40,000 years ago (Pearl and Mackenzie 2018; the most realistic estimate is between 40,000 to 60,000). Being able to imagine what would happen if certain behaviors or events occurred allows us to causally simulate reality without the need for manipulation or experimentation. From an adaptive point of view, this is a colossal qualitative leap. This level of consciousness allows us to learn by imagining what does not exist, that is, to construct causal scenarios that lead us to causal explanations in much less time. This ability enables a level of mental representation and abstraction that has allowed human beings to dominate—and, of course, be able to destroy—their world. See Figure 3, where the causality ladder is shown schematically.

Descending to a more concrete analysis, if in a causal scenario we come to propose A as the cause of effect B, we are saying that, when A happens, B must happen. Alternatively, if B does not happen, neither does A. Simply put, we formulate a conditional proposition: if A happens, then B will happen. What we do is apply to reality the properties of sufficient and necessary condition (SC-NC), of the conditional proposition of the ideal world of deduction. In deduction, we say that "if A, then B", meaning that if A is true, B will also be true, and if B is not true, A will not be true either. In passing from the ideal world of deduction to the real world, we change the value of truth-falsity to that of presence-absence, nothing more and nothing less. This is the revolution brought to us by the genius John Stuart Mill almost two centuries ago (Mill 1973).

From an applied perspective, pointing out that any explanatory hypothesis is a conditional formulation with its properties allows us to establish a formal correspondence between causality and logical principles (see the technical development in Saiz 2020). If a doctor encounters symptoms or a disease, they will want to find out the cause, so they can cure it. Two examples: (a) a doctor has, for example, 200 patients, some of whom manifest certain symptoms or are ill—some of them have bathed in the same swimming pool, or eaten in the same restaurant, but some are ill and others are not; (b) in a hospital, a patient is admitted to the emergency room with multiple health problems (fever, internal bleeding, high blood pressure. . .). In both cases, the doctors proceed in the same way, formulating explanatory hypotheses, seeing what the symptoms tell them, and finding out what the true cause is to administer the appropriate treatment to cure the patients. The logic does not change, but the way of applying it does. In the first case, we can rule out causes by SC and by NC, but not in the second example, because in this one we can only rule out causes by NC. In practice, it is important to realize this difference because there are problems or situations where we have data on the causes, but in most cases, we do not; we can only guess, as in the second example. The other practical consideration is that the rules for discarding SC and NC can be replaced by two logical principles, which have the advantage of being more easily applied than the rules of SC and NC. We have, for example, a fever (B) and assume an infection (A); say A and B are present, or if A, then B; the patient is given an antibiotic for that bacterium, and the fever may or may not go away. In the first case, we have applied the rule of discarding NC or the logical principle of negation of the consequent. From experience with our students, we have seen that it is easier to employ logical principles than discarding rules (the full description of this procedure can be found in Saiz 2020 and its application and demonstration in Rivas and Saiz 2023).

Reaching a causal explanation requires observation and application of principles on the facts as well as subsequent verification of those principles. Being able to imagine events counterfactually allows us to construct causal scenarios that have not happened but which, if they did happen, would happen just as we imagine them. Being able to test different causal scenarios in this way considerably increases the probability of finding the correct causal explanation, which allows us to provide a complete sense of the events. Having reached this point, we can predict what will happen and see if time proves us right or wrong without cheating. This is what we call *vital verification*, for without this we cannot be sure of our causal conclusions. With our students, we started working on everything related to causal explanation with a real everyday situation (written for didactic purposes), in which a group of friends spend an afternoon at the house of one of them (see the case in Saiz 2020, p. 42). The friend telling the story liked the friend who hosted them, and after the gathering, he came to the conclusion that he had at least the same chances of going out with her as the other two boys at the meeting.

Despite being a simple everyday situation, common and frequent, our students are not able to figure out if the narrator is right or wrong. To help them in their desperation and to help them understand the importance of the last step of the methodology employed, we tell them that, if this story were happening now, and they were in a place where they could see the entrance to the friend's house, they would have to be able to test their prediction. They would have to see that, of the three boys, the one who will go to the hostess's house several times is the boy of behavior X in the meeting, while none of the other two will do so. This is what we mean by vital verification, how we must test our predictions of causality, the only way to be sure of them, because there is also no possibility of cheating (for a full description and practical demonstration, see Rivas and Saiz 2023; Saiz 2020).

CT must be able to deal with real-world problems, and for this, it is necessary to prioritize causal explanation and interaction or action to solve. In the review conducted, we see that there has been an important change in the approach to CT to solve problems, but the way to put this into practice has not yet been developed, or not enough, in the sense of solving effectively and producing the desired changes. For this reason, we say that this is a major problem in CT, which must be solved if progress or advancement is to occur. This is our diagnosis of the problem; the treatment or cure is what we are going to expose next—that is, a project of inquiry into the causal relationships that really exist between CT, personal well-being (PB), and training (FO), understood as integration of what seems to us the most important and clearly interdependent. We will refer to this project as the *CT-PB-FO causal model*. In it, we gather everything discussed so far in an integrated manner, with the proposal of the corresponding causal relationships. In Figure 2, we summarized the environmental and personal factors that determine our personal well-being (see Figure 2).

We have previously commented that personal well-being is a fuzzy concept, and we have referred to an extensive treatment of it in the work on happiness by Flanagan et al. (2023). In a study on the instruction of intelligence, Nickerson (2020) asks several questions, such as whether we can teach it and why to instruct. To answer this second question, he refers to national or social and individual well-being. Again, we will not go into sociological considerations because they exceed our objectives. However, the ethical, moral, or civic must be considered within the CT because it would be good for the instruction to achieve, in addition to intelligent people, good and responsible citizens.

Our position on this is that, of course, this is always desirable, but following the Socratic approach, virtue cannot really be taught (Dialogue of Protagoras in Platón 2018[2]). We are not aware of any demonstration that values are learned; rather, what we have seen very often is that you learn what you do, not what you say. Setting a good example seems to us a more appropriate strategy for this purpose. The controversial conclusion that follows from this is whether thinking critically should imply certain ethics, and our clear answer is that it does not. Let us try to be clear. Thinking critically must be about effective problem solving, just that. Our hands are too small to encompass so much. For example, a lawyer defending a drug dealer should try to get him acquitted, and if he succeeds, he will have done his job well, he will surely have thought critically. Regarding ethical or moral issues, the lawyer must take them into account before accepting the case, that is, when he must consider whether or not his convictions prevent him from defending a criminal. If they prevent him from doing so, that is when he must resign the case, but if he accepts, he must go all the way.

We wanted to steal some space from this question because for us it does not enter into consideration when it comes to critical thinking; we are only concerned with knowing the best way for our cognitive system to function. The non-cognitive components that are part of CT are of interest to us to prevent them from interfering with that functioning. For this reason, when we speak of personal well-being, we mean what is desirable for a person, what he or she will strive for and pursue, such as having a good job, good friends, a family that one appreciates and is appreciated by, social integration, respect, quality of life. . . In short, what each one believes is best for him is what we will call personal well-being (PB), the goal that will always move us. As we have already said, this is the fuel or the force that drives the vehicle, the one that puts the CT to work, or is it the CT that gets that PB? This is the first question that arises, which we will address later. Now, we are interested in specifying that the motivational aspect is part of this broad space of will or incentive, which can move us or not, and leads us to act. Motivation is a concept that is just as elusive as the rest of the mental processes, so we are content here to equate it with desire, will, or interest in achieving a goal. Of course, as can be seen in the literature, motivation and emotion are not easy to separate. The PB, let us not get confused, is a positive emotional state, and the energy to achieve it, the motivation, again, feeling and will. Here lies the origin of what we are, of the consciousness of oneself, of the "I", and from this *"I"* arises our abilities and skills. From here is where the evolution of our cognitive system takes place, as Damasio titled his book *Feeling & Knowing* (Damasio 2021). As we would say, feeling, thinking, and knowing (pleasure, process, and its product).

However, as we have already seen, our intellectual skills are not ideal because they are not genetically given to us. We only have elementary skills that allow us to adapt and survive; we need to develop these skills to survive the problems of today's world. We need to learn to think critically because we are not born with this expertise. It is essential to acquire higher skills and avoid their biases and deficiencies. For this, we need ongoing formation (FO), which will enable us to think well and correctly. Now we have the three essential points of view to develop CT: the descriptive, the normative, and the prescriptive

(Baron 2024). The first is the limitations of our processing system, the second is the certain causal explanation, and the third is the way to avoid the limitations and achieve the correct judgment, that is, the formation or preparation without possible rest.

In the introduction, we set an objective: "...to explore the application of CT to real-world situations and everyday life...", and now we can propose a way to achieve it, namely, using a causal model of CT-PB-FO. Figure 4 shows such a model, which we will now describe and justify. First of all, it is helpful to understand the two parts of the model that are represented. On the one hand, we have the possible hypotheses of causal relationships that we can imagine (upper right part of Figure 4); on the other hand, we specify the different factors that we must consider in this causal model, the environmental (E) and personal-individual (I). In this sense, what appears as FO in Figure 2 is what we formulate in Figure 4 as FO-2, that is, the result or performance of the formation. FO-1 is everything we have described as formation or acquisition strategies. We will see that this difference is important.

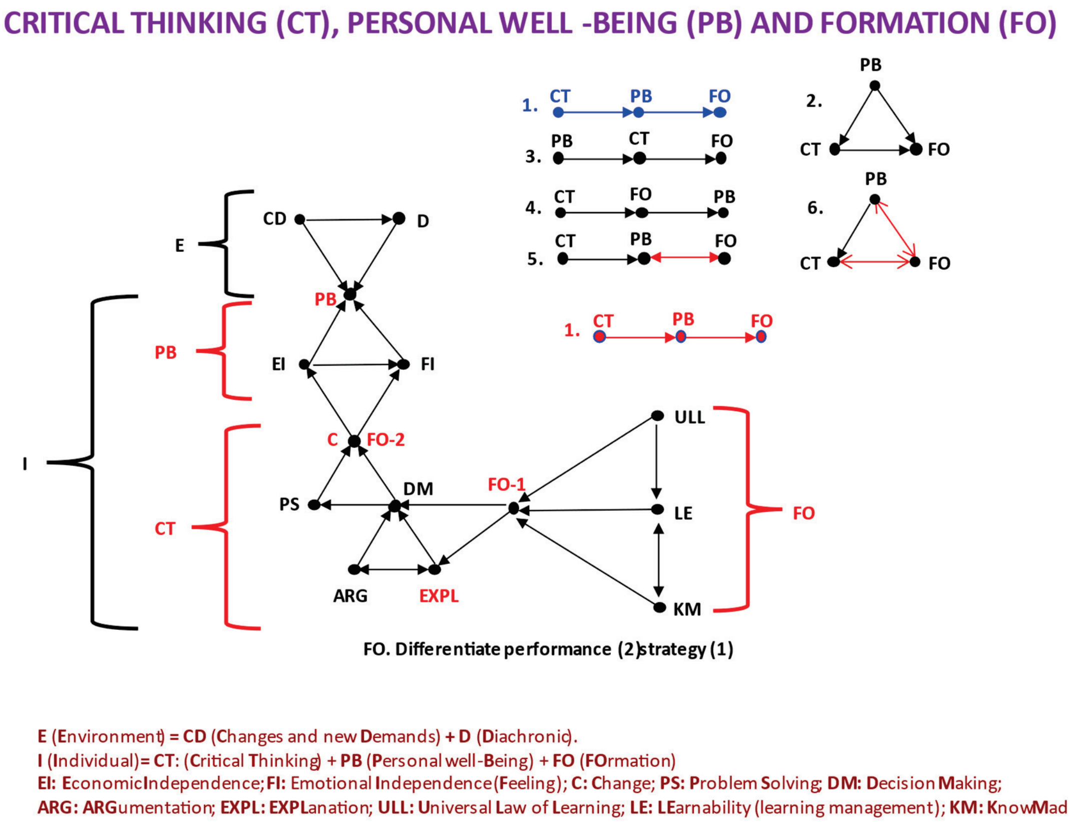

Figure 4. Project of a causal model of the CT-PB-FO.

We continue with the model in Figure 4 as a proposal to improve CT to respond to real-world problems. However, we offer an open causal proposal since there are not yet sufficient data to be able to rule out some causal relationships and propose others. The first and simplest thing is to know what causal relationships are established between CT-PB-FO. Are these relationships unique, or are there several? In Figure 4, we have represented six possible types of causal relationships that, from the existing knowledge in the field, seem acceptable (see upper right part of Figure 4). We have highlighted the first one as the most conceptually convincing, but it is a bet; we have no data to prove that it is the correct causal relationship. However, causal sequences 3 and 4 also compete with 2 in a very meaningful way. In contrast, if we look at sequences 2, 5, and 6, we see that the causal relationships are not straightforward. Technically, these relationships are confounded, and additional variable measures would be needed to achieve "de-confusion" (see Pearl and Mackenzie 2018). Sequence 5 shows another type of difficulty, as it shows an arrow joining two nodes bidirectionally. When this kind of linkage between nodes is indicated, our causal ignorance is manifested because we cannot state what causes what. Therefore, before moving on to verification, a solely unidirectional relationship, such as those in 1, 3, and 4, must be justified. Recall that this system of graphs used as a representation of causal models is a logical system that Judea Pearl employs to represent what he calls the "new science of causality"; these diagrams are simple and clear and allow us to specify all imaginable causal relationships as well as all their complications. This system is the one we are employing for our proposal. Therefore, the entire conceptual foundation is based on Pearl (2009; Pearl and Mackenzie 2018) and the measurement procedures supported by Bayesian networks in Pearl et al. (2016) since this is a manual written to facilitate the calculation of this kind of conditional probability equation. It is beyond our scope to detail the different types of calculations that must be taken into account before being able to affirm that a causal relationship exists, in our case, between three nodes (CT-PB-FO or other combinations). To arrive at the establishment of these causal relationships, bidirectional relationships between variables must be eliminated by identifying the correct mediators or confounding or lurking variables and achieving deconfusion by means of the back-door criterion. Probability measures must take into account all these complications, which are very well described in Pearl and Mackenzie (2018).

Does CT contribute to PB and PB to performance (FO-2)? The question is simple, although still difficult to answer. However, this is what it is all about, to know what causes what, to proceed from an applied point of view. As we said, logically, the first thing to do is to demonstrate which causal model works. To do this, we then need to justify the rest of the conditioning or causal factors, which are specified in the rest of Figure 4. In the rest of the figure, we find three blocks of components: environmental, personal, and formation strategies (FO-1). Regarding personal formation for the development of CT, we have previously proposed a system consisting of knowledge acquisition based on explanation, solving real problems and producing changes, a lot of inter- and intradomain practice, and a lot of individual autonomous work. This is the way to avoid the negative consequences of ULL, to optimize learning management (learnability; LE), and to increase horizontal or transversal training (knowmad; KM), currently demanded (see Figure 1), to be able to face the problems of daily life (see in Saiz et al. 2020). We have incorporated this way of developing or improving CT into in an instructional methodology that we have been able to verify recently, with very robust data, which is part of the support for the model proposed in Figure 4, specifically, the causal relationships between the CT and FO brackets (Rivas and Saiz 2023).

The next block of the causal model in Figure 4 refers to the personal components, specifically, to fundamental CT skills. As can be seen in the model, the formation is essentially focused on causal explanation, which, in turn, determines the process of decision making and problem solving. Deciding and solving are processes that are difficult to distinguish beyond the fact that in the former, the options are available, while in the latter, we must discover or create them, since in everything else they are indistinguishable (Saiz 2020). We would say that CT is to explain (EXPL), decide (DM), and solve (PS) to produce a change or achieve a goal. The relationship between the cognitive components should be in this way, the EXPL (the pre-decisional) determining DM and PS (the post-decisional). Argumentation (ARG) contributes to enhancing EXP and DM. In the instructional program that we have developed and verified, we work with this model, applied to the solution of personal and professional problems (see in Rivas and Saiz 2023).

In this block of the model, outcome, change, or academic or professional performance is fundamental. If you do not see achievement, you do not improve your CT skills. In the years that we have been working with our students on this CT development, we have found that without visualizing some kind of change, competencies are not consolidated. In our research, we have seen that what really makes CT improve is when one sees it improve (Rivas and Saiz 2023; Saiz and Rivas 2011, 2012, 2016; Saiz et al. 2015). Our data show us that motivation is highly overrated. Alfred N. Whitehead was right when he said: "There can be no mental development without interest. Interest is the *sine qua non* for attention and apprehension. You may endeavour to excite interest by means of birch rods, or you may coax it by the incitement of pleasurable activity. But without interest there will be no progress"(Whitehead 1967, p. 31). After all these years of applied research, and with the changes of the current times, our skepticism has increased considerably in the sense of seeing the few changes that are obtained from motivation. Either the interest, not just the utility, is in us, or if it is not there, it is not going to emerge. Increasingly, our work in instruction is focused on the acquisition of fundamental skills applied to real problems in which consequences, positive or negative, are observed. This can be said to work well (Rivas and Saiz 2023).

After having posited the causal relationships between FO strategies and fundamental CT skills, on the one hand, and their consequences in terms of performance and achievement, on the other, we must move on to the causal relationships of CT with personal well-being (PB). Recall that we mentioned earlier that personal growth and maturity depended on achieving the double objective marked by the dual nature of the human being (biological and social), namely, economic (EI) and emotional independence (FI). Without these two objectives, a person cannot function well in any area. Now, the adequate development of CT skills will be the fundamental tool to reach this double maturity, as long as changes or results are achieved in the solution of daily problems. Ineffectiveness always prevents PB, but the opposite enhances and stabilizes it. As we can see, despite the large number of nodes and relationships in this causal model, in the end, it all continues to be summarized in the triad mentioned in Figure 2, CT-PB-FO, although the precise causal order is still uncertain, as it requires data to be able to establish some and discard others. As we have pointed out in the PB section, we have few data (of the self-report type) that do not allow us to prove the proposed causal relationships independently. In this proposal, we only need to mention the environmental causes or determinants and how to quantify all this.

Changes and new demands, as we have already seen, influence PB insofar as we must continue to face real problems with new resources and learning strategies. The attention capacity must be recovered, and the ability to observe correctly must be developed. Screens and leisure must be controlled from CT competencies, and autonomy or personal initiative (as in the formation) and responsibility or a greater awareness that behaviors have consequences must be increased. On the other hand, the life cycle, or the diachronic dimension, has a much greater influence than we think, especially in the critical period of transition to adulthood; this is where cognitive and social competencies are consolidated in a few years to achieve the economic and emotional independence essential for PB. The diachronic dimension, and especially its critical period, is one of the most neglected in personal formation (Saiz 2021; Saiz and Rivas 2020).

Let's say that the environmental factors mentioned above always have a negative influence if we do not adapt or take advantage of these changes and demands. The ULL illustrates it very well: we must change in order not to stagnate and change much more to progress. Technologically, the current times offer extraordinary resources, unthinkable only less than two decades ago; however, at the same time, they are like a spider's web that envelops us and can immobilize us. The information available reduces exponentially the time of consultation for searches, which previously required days or months, but this ease can lead us to a huge ocean in which we end up not finding what we are looking for or finding an impostor substitute. On the one hand, all this requires good cognitive skills to acquire the knowledge that allows us to solve everyday problems, and on the other hand, non-cognitive skills, such as initiative or autonomy, enable us to apply these skills while avoiding our own limitations, deficiencies, or unconscious influences. One may have learned to analyze, for example, arguments correctly, but must, at the same time, develop sufficient sensitivity to detect the false solidity of a good fallacy. Many of our mistakes happen because we are not aware of them. We can only avoid them with familiarity, that is, with practice. Falls or missteps, for example, when riding a bicycle, are avoided with practice. There is no theory to apply to this; as an analogy, it only serves to bring to consciousness the corresponding skills with practice and application.

The important discoveries in neuroscience, the crucial contributions and help that AI is beginning to offer, the development of applications ("apps") to perform a multitude of tasks, the sophisticated mathematical models that save hundreds of experiments in fields such as cell biology, or the new methods of demonstrating causality, such as the one we are dealing with, should enrich the conception and research of CT. We propose a new or improved conception of CT, a form of logical specification of that conception, and the incorporation of a new mode of demonstration or hypothesis testing. The new mode of demonstration, as Judea Pearl himself tells us, consists of performing greater conceptual precision using logical systems such as graphs and performing node-to-node calculations using Bayes' or conditional probability theorems (Pearl and Mackenzie 2018). This system of demonstrating causality began to be used in the 1930s, and it was a great researcher, Barbara Burks, who began to use "path diagrams" to study causality, in this case, to study the heritability–environment determination of intelligence. At that time, this brilliant and ill-fated[3] social science researcher demonstrated clear causal relationships with these logical diagrams and the calculations that these diagrams demanded. Obviously, this approach went against the prevailing statistics, in which the word *cause* was taboo, for great figures such as Karl Pearson and the researchers who worked guided by his conception (see Pearl and Mackenzie 2018).

This influence and rejection of the concept of causality, and replacing it only with that of correlation, meant that these developments of causality models and their measures did not become widespread until half a century later (see in Pearl and Mackenzie 2018). Today, this approach is conspicuous by its absence in the social sciences. It has not been so in medicine because of the importance here of demonstrating causal relationships in the treatment and prevention of disease. Just as an example, until the end of the 1980s, it was not possible to demonstrate the causal relationship between smoking and cancer. This was not demonstrated experimentally—it is not possible—but through causal models, such as those extensively developed by Pearl (see again in Pearl and Mackenzie 2018). Is it time to recover the tradition of Barbara Burks in the social sciences? We believe it is. To do so, it is necessary, as Pearl suggests, to move away from the approach of the great statistician Ronald Fisher, from randomized controlled experiments and their statistical significance. "If our conception of causal effects had anything to do with randomized experiments, the latter would have been invented 500 years before Fisher" (Pearl and Mackenzie 2018, p. 62). This conception of causality forces us to specify each determinant and to perform individual node-by-node calculations using simple conditional probability formulas (Pearl et al. 2016). This is what we propose to apply to CT.

The causal model we propose in Figure 4 demands the specification of each causal relationship between factors or variables, the identification of confounding relationships and of "back doors", to block from the latter the influence of confounding variables on the causal relationship (see Pearl and Mackenzie 2018; we cannot detail all these technical aspects of the confounding or back door variables, as they are beyond the scope of our work). Achieving this conceptual specification requires a detailed deduction of possible relationships and the elimination of inconsistent ones. Once this work of logical formulation using graph diagrams is completed, we move on to the measurement of those relationships at each of the arrows or junctions between nodes. Once we have these data, we can perform the probability calculations of the whole causal model, with the corresponding formulas, for the causality, confusion, and "back door" relationships. Let us not forget that the double-arrow node connections are conceptually imprecise and must therefore be removed before any measurements can be made. It falls outside our objectives to go into further conceptual and computational details (see in Pearl 2009; Pearl et al. 2016; Pearl and Mackenzie 2018). The model we offer as a proposal for CT development and its application to real-world problems is an incipient proposal that requires justifying some causal relationships and ruling out others and then being able to measure them and demonstrate that those are the relationships and not others. The purpose here is not to offer a developed causal model but to show how it can be developed with this new treatment of causality. Therefore, the objective of this work is to offer an open causal proposal, since there are not yet sufficient data to be able to rule out some causal relationships and propose others. As mentioned above, we only have data for the relationships included in the CT and FO brackets in Figure 4 and insufficient data for the relationships within the PB and E brackets. We have only been working with this model for a short time, so we need more studies to narrow down the possible causal relationships between the different factors involved in the model. At the same time, these data will allow us to eliminate confounding and circular variables that can be proposed but cannot be debugged.

7. Discussion and Implications

Throughout this paper, we have proposed a research project that provides a solution to a substantial CT problem and have presented a causal model that seeks to better articulate fundamental CT skills to effectively solve the problems of the real world. This project should promise a relevant contribution to the field of CT, and we believe it makes good on the promise. When we talked about the CT problem, as we have been justifying it throughout this work, we pointed out a limitation, a difficulty regarding which process is responsible or the most important, when it comes to solving everyday problems or achieving our goals. We indicated that the fundamental mechanism cannot be other than the causal explanation because otherwise, it would not be possible to solve the problems of the real world well—because this imposes interaction, and action, and for this we need causality--. We saw that this is not in the foundation of CT, or not as it should be. In fact, in general, we justify a kind of ignorance or difficulty in this field of research.

The justification of a problem consists of making it clear that it exists and that it can be solved; and the solution is always a proposed response to the problem. This answer must always be given through a research project: a limitation or lack of knowledge (the problem), an explanation or solution (the proposal), and the demonstration or verification that it works (verification). This is how we understand a research project, as a relevant and original solution proposal, which has not been offered until now. The importance and novelty of the project is what makes it a research project and not something else since it has to be a contribution to the field of knowledge; to be considered a contribution, it has to be demonstrated or verified with facts (see Kerlinger 1986). Once the project has been tested, it is no longer a project but a reality. Our project has become a reality only in part. The rest must be the subject of future research.

The proposal developed throughout this work has been empirically tested in that part made reality, in particular, regarding the relevance of causality in terms of solving everyday problems and in what has to do with formation or instructional strategies for the development of CT (Rivas and Saiz 2023; Saiz and Rivas 2016). However, as this project is also a proposal for a causal model linking CT-PB-FO, many causal relationships remain to be specified and tested, something we are currently developing. In this model, a new way of formalizing causality is employed using graph diagrams, which impose different computational procedures for verification. The proposed general model only points to possible causal relationships, which must be empirically discarded to establish the true determinants to have a precise conceptual system that allows the subsequent verification of their relationships node by node.

Thus, our proposal offers relevant conceptual solutions that can make CT an effective tool for solving real-world problems. The incorporation of causality as a fundamental competence forces us to give greater prominence to post-decisional competences (action) to produce the changes that will make our objectives a reality. Continuous formation in CT development allows us to achieve personal well-being, which is essential to achieve self-reliance and personal stability or maturity, which is also expected to make us responsible citizens committed to the common good. Obviously, there are still important limitations to this project, such as the problems of measuring some of the supposedly causal factors or variables.

In this sense, it is important to avoid self-report-type instruments and look for tests that are tasks or problems to be solved. In this respect, there are measures of critical thinking whose items are everyday problems or situations to be solved. A pioneering test in this direction is that of Diane Halpern (Halpern 2018). Inspired by a part of the approaches of this test, we validated another one that adds the task analysis methodology to elucidate what process is being used to solve each item or problem posed (Saiz and Rivas 2008; Rivas and Saiz 2012; Saiz et al. 2021; Rivas et al. 2023a). Despite the availability of some measures of CT skills, we still lack several that would allow us to quantify causal relationships with instruments that are problems or performance tasks, not self-reports. Quantification is essential in verification procedures, so other ways of accurately measuring the rest of the variables in the proposed causal model, which have not yet been tested, must be developed. For this reason, the project must await the availability of behavioral measurement tools for the rest of the variables that have not yet been evaluated before it can be fully implemented. For example, one of the most problematic quantifications is personal well-being. It is not easy to obtain objective indicators of the vivencial and, as we have already said, self-reports or personal assessment of emotional states are not useful; at least, they are not when we seek to demonstrate causal relationships. At the moment, we have some incipient advances in this respect, as we have already mentioned above, which go beyond the scope of the present work.

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Notes

1. Dupin is the protagonist of some of Allan Poe's famous stories, such as *The Murders in the Rue Morgue*.
2. The sophists understood virtue as equivalent to social success, but for Socrates, virtue was the care of the soul; for him, with logos we attain knowledge; with it, virtue; and with it, happiness.
3. Barbara Burks ended up jumping off one of the bridges in New York because her colleagues closed the doors of all the universities where she applied. They never recognized her work, nor that she was right in her studies, besides making her life impossible during her doctorate.

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Article

Critical Thinking: The ARDESOS-DIAPROVE Program in Dialogue with the Inference to the Best and Only Explanation

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Abstract: In our daily lives, we are often faced with the need to explain various phenomena, but we do not always select the most accurate explanation. For example, let us consider a "toxic" relationship with physical and psychological abuse, where one of the partners is reluctant to end it. Explanations for this situation can range from emotional or economic dependency to irrational hypotheses such as witchcraft. Surprisingly, some people may turn to the latter explanation and consequently seek ineffective solutions, such as visiting a witch doctor instead of a psychologist. This choice of an inappropriate explanation can lead to actions that are not only ineffective but potentially harmful. This example underscores the importance of inference to the best explanation (IBE) in everyday decision making. IBE involves selecting the hypothesis that would best explain the available body of data or evidence, a process that is crucial to making sound decisions but is also vulnerable to bias and errors of judgment. Within this context, the purpose of our article is to explore how the IBE process and the selection of appropriate explanations impact decision making and problem solving in real life. To this end, we systematically analyze the role of IBE in the ARDESOS-DIAPROVE program, evaluating how this approach can enhance the teaching and practice of critical thinking.

Keywords: critical thinking; ARDESOS-DIAPROVE program; epistemology; explanation; inference to the best explanation

1. Introduction

The purpose of an educational intervention is intrinsically causal (Ennis 1973). Its goal is to induce changes in the student through a series of conceptual, methodological, pedagogical, and didactic proposals that translate into expected results in academic performance and student behavior (Anderson and Krathwohl 2001). The teaching and learning of critical thinking (CT) cannot be separated from this causal notion. The key questions of any CT program are as follows: what learning objectives should guide the intervention? What content should be taught? Which strategies should be implemented? And self-critically, why do it, and what changes are expected?

Through the literature on CT, essential skills, dispositions, and knowledge can be identified that define it and are reflected in the curricular designs of direct instruction (Fasko 2003; Saiz 2017). The timeline that Thomas and Lok (2015) trace from Dewey to the present day with theoretical works and practical manuals on CT shows that despite the lack of consensus on a defined concept of CT, the associated skills are a common meeting point. The classic references of CT have highlighted interpretation, explanation, analysis, inference, evaluation, and self-regulation (Ennis 2015; Facione 1990; Halpern and Dunn 2023) with varying degrees of intensity. The same has happened with dispositions such as being analytical, systematic, inquisitive, having an open mind, being willing to seek the truth and the precision that the situation requires (Ennis 2015). Necessary knowledge has also been identified, such as general knowledge, professional expertise, and knowledge in formal processes of logic, mathematics, and statistics (Glaser 1942).

Understanding this conceptual framework invites, first of all, to think that the task of training in critical thinking is infinite, especially considering that the real world has not yet appeared as the protagonist of the conceptual conglomerate. Secondly, it invites us to value the valuable accumulated knowledge that we have today about CT from philosophy, cognitive psychology, and critical pedagogy (Jahn and Kenner 2018).

In this timeline, it can be traced how some skills have been prioritized, which often undermines other skills or leaves them forgotten in instructional designs. It can be observed that the discourse of CT seems to be more holistic than linear. This explains why, even if a specific skill or knowledge is prioritized or worked on deeply, there will always be a CT expert from whom good reasons could be argued to indicate that a wrong path has been chosen.

CT, as a holistic discourse, seems to have great potential in the field of education. For this reason, severe criticisms arise, demanding that CT apply to itself the criteria it strongly defends (Mulnix 2012). These criticisms seek to commit CT not only to cognitive changes in the student but also demand that it be operational, that is, that it can offer useful tools to effectively solve real-world problems (Atanasiu 2021; Halpern and Dunn 2021; McLaren 1994).

How can we design an intervention program that allows students to develop CT skills? How can we ensure that these skills are not only applied in the academic field but also generalized to the real world? How can we make CT a useful tool for solving everyday problems, both personal and professional? Despite the importance given to CT in pedagogical discourse, these questions highlight existing gaps. The lack of effective answers is the reason why CT is sometimes perceived as a grandiloquent discourse that is disconnected from real-world problems. Perhaps this has not been intentional but simply the result of prioritizing some attributes over others. The truth is that this approach, characterized by argumentation theory, has been criticized by experts who consider that CT fails to connect thought with action (Barnett 1997; McLaren 1994; Walters 1992). It seems that the term 'critical' remains in the abstract separation of assumptions and facts, but the latter loses prominence. Alternatively, it is as if the programs focused only on cognitive objectives, making the student aware of something important and necessary to know and handle but not necessarily to apply.

For this reason, authors like Barnett (1997) chose to refer not to CT but to critique. According to Barnett, critique is structured in three dimensions. The first is linked to the analytical stage of evaluating phrases or arguments. The second is associated with an act of a metacognitive nature: self-regulation and self-examination. Finally, critique action is the realization of the will to analyze and evaluate the real world. This is aligned with an ideal of transformation that can be individual or collective, such as an ideal of social justice that can make this a better place. Therefore, critique, understood as the conjunction of the self and action, allows us to speak of a fully critical person. This makes a lot of sense to develop a CT that transforms reality and provides tools to solve problems in the real world. Paul (2018) has also questioned this traditional approach and has proposed distinguishing between weak or narrow CT and strong or broad CT. The weak CT defends, analyzes, and evaluates a set of propositions or arguments within a limited framework. Arguments that belong to that framework are considered solid or valid, and dissenting opinions are presented as fallacies. On the contrary, strong CT conceives the thinker as someone capable of transcending their framework, accepting that there can be more than one valid argument, even if they do not agree with it. This implies that CT is not only associated with the quality of judgment on the argumentative or exclusive reflection with the linguistic components but also with the referent, the real world.

In this line of argument, a CT approach that places the real world as the protagonist faces a complex task. First, it must be based on a CT concept that recognizes and connects the logical–epistemological, cognitive psychological, and critical pedagogical traditions. It is important to recognize that the conceptual heritage has had representatives from each of these branches, and the CT cannot be simplified to a single constitutive definition. The goal is to find an operational concept that can measure the skills subordinate to the student's operational change, allowing him to solve real-world problems through generalization.

Secondly, the program that is built on this concept must also recognize and methodologically resolve its limits. In this way, the CT can move to dimensions that are different from the logical–epistemological, where argumentation has prevailed as a keyword (Jahn and Kenner 2019; Jahn and Kenner 2018; Saiz 2017, 2020). Without detracting from other programs that have focused all their efforts on theories of argumentation (Morrow and Weston 2016; van Gelder 2015; Walton 2000) with exceptional achievements, making it one of the skills with the most consensus in evaluative criteria, the concept of CT we are looking for must have a different gravitational axis. As can be seen, the change in focus is not minor, and the proposal is not limited to simple descriptions. It is about highlighting the interests, personal and professional problems, as well as the social needs inherent to the individual under the conception of the CT as a theory of action. The idea would be to place social life (the facts, the behaviors, etc.) as a unit of analysis and questioning at the center of a CT instructional program to discover tensions and inconsistencies between perspectives that make the CT more original or closer to an individual with economic, cultural, political, but also everyday and professional interests.

How can we advance in a challenge that we know cannot be met with an intervention program due to the inherent complexity of (CT)? Despite the obvious limits, how can we implement an instructional program that focuses on the demands of the real world without losing methodological rigor and the historical richness of CT? Finally, how can we determine if our conceptual, methodological, and generally instructional efforts are effective in addressing the realities of the world?

This article presents the ARDESOS-DIAPROVE program, which seeks to respond to the demand for a change in focus in (CT). The program does not intend to be a definitive solution but a pedagogical effort to develop, strengthen, and promote CT in relation to the real world. Our thesis argues that CT should focus on the best explanation and not necessarily the best argumentation. Given its trajectory, background, and consolidated quantitative results, it can be considered that ARDESOS-DIAPROVE is a mature program that has been evaluated in different scenarios and is constantly improving (Rivas and Saiz 2023; Saiz 2017, 2020; Saiz and Rivas 2011).

We will focus on one of the key foundations of the program: explanation. From an epistemological perspective, we seek to place explanation at the center of the program as a possible response to a shift in focus in CT. Given that explanation has an inherent causal nature that interrelates with the real world, it is a key concept in the objectives of science. In the program, the importance of explanation strategically displaces argumentation. The methodology of CT focuses on finding the best explanation for professional and everyday problems to make accurate decisions. Logical support and the causal explanatory model are used to privilege uniqueness. These are based on the inference to the best explanation (IBE) (Galavotti and Pagnini 2010; Harman 1965; Hitchcock 1995; Lipton 2003; Salmon 1984a, 1984b) and on the inference to the only explanation (IOE) (Bird 2007, 2010).

Identifying and studying each of the foundations of the program, including those of the epistemological spiral, is part of the program's continuous improvement strategy. This includes increasing clarity, providing didactic examples, updating concepts, and debating the main challenges proposed by epistemology. In addition, the program incorporates epistemology, a central branch of philosophy that can significantly contribute to scientific literacy, a trait that should also be part of the critical thinker. After all, the epistemological debate focuses, among other things, on the true and justified beliefs we have about the real world (Bunge 2000).

2. ARDESOS-DIAPROVE Program

CT is one of the higher thought processes (Paul and Elder 2006). Its complexity lies in the fact that it relates cognitive, attitudinal, and metacognitive components (Lau 2015;

Rivas et al. 2022). Conceptual comprehensiveness and its implementation lead us not only to focus thematically on the development, strengthening, and promotion of some skills, but we must also deal with those other logically necessary components that function as the engine that mobilizes skills towards results. Thus, for example, if, as in our case, we privilege specific skills intrinsic to reasoning, decision making, and problem solving, we must also privilege non-cognitive components, such as the will to do it, really desire to put into practice the necessary and useful problem-oriented reasoning. This conceptual network is more evident in operational conceptions of CT, such as those that focus their efforts on establishing an identity between the critical and the effective, since willingness to be effective is determined by intrinsic and exogenous motivations so dissimilar and multiple that they are complex to systematize in the conceptual network of a definition. Thus, metacognition, self-regulation of skills, and motivation, the active driving force behind them, form an essential part of the program (Saiz 2020).

We think to solve problems, we make our inventive and problem-solving efforts available in the face of epistemic, ontological, ethical, and political obstacles or concerns (in general, in the face of a problem). This means that we plan, strategize, and act to achieve that solution. Decision making is key in linking the start and end of any process. It is not just about finding the best theoretical solution but also about ensuring it can be applied in reality. This creates a complex network of concepts that seem separate only in theory.

As a corollary to this conceptual framework, we have chosen to characterize critical thinking, rather than as an academic discourse, as a tool for effectively solving a problem or achieving desired goals; moreover, as a generator of change, understood as the passage from one welfare state to another. This establishes serious commitments, as it means that no effort must be spared in achieving the effectiveness of the means (the best result, the best explanation, or problem solving) to accomplish the desired change. It also implies that it is not enough to find alternative answers or solutions but to find the best among the range of options. If thinking critically is thinking effectively to achieve the desired change or goal, and this is not only desirable in the academic and professional sphere but extends to the everyday and personal sphere, CT is desirable higher order thinking. Therefore, by virtue of the conceptual network described and the relevance of critical thinking, we have proposed that "to think critically is to reach the best explanation for a fact, phenomenon or problem in order to know how to solve it effectively" (Saiz 2017, p. 19).

2.1. Methodological Foundations

The program has been modified and is the product of several years of research from its origin to the present, giving positive results and continuous improvement, as can be seen in different works (Rivas and Saiz 2023; Saiz 2020; Saiz and Rivas 2011). ARDESOS can be understood as the program's mesocurriculum, as it includes everyday situations to accommodate the activities of problem-based learning (PBL) or ecological learning (Morales et al. 2015), the argumentative tradition, decision making, and problem solving. At the methodological and didactic level, the foundations are the development of DIAPROVE. Firstly, it consists of identifying the limits of a good thinker, i.e., identifying the deficiencies and biases that prevent progress in the development of critical thinking. This is key, as we are faced with errors that can be systematic and prevent us from thinking correctly, as well as ontological and epistemic compromises that can block the search for the best explanation, such as irrelevant or isolated but striking data that can make us lose sight of the objective and create a blanket of contradictory data or details that need to be observed and analyzed (Saiz 2020). This part is therefore crucial, as it can prevent correct diagnoses from being made. After this, the search for the best explanation that can explain the facts and forecast is ensured by the suitable application of logical principles, causal simulations, and other necessary contrastive steps.

In short, the general route of the program is to identify the cognitive biases and deficiencies that sometimes prevent us from solving some problems, looking for the best explanation of the problem, and making sure it is the best. The following are some of the most relevant foundations of the program:

(a) We think in order to survive. Biological nature determines what we are on a physical and mental level, the latter feature emphasizing that the essential mental actions (perceive–learn–retain) are a function of the *telos* as a species: to survive (Saiz 2020).

(b) Thinking, willing, and acting are inherent actions. If (a) is accepted, then the concept of "thinking" does not refer to just any word but to critical and effective thinking: it is not about finding the solution but the best solution. However, the links between thinking and acting are the non-cognitive components of CT (dispositions, motivations); therefore, neither skills nor dispositions alone are sufficient for a CT program (Saiz 2017).

(c) Thinking is inferential. The best solution can only be arrived at by a correct inferential process, which, within its own complexity, contains instances of contrast (verification/falsification) with the facts.

(d) The deductive machinery is necessary, though not sufficient. It is necessary because it warns us and helps us to correct our biases and cognitive limitations. Understanding the complexity of the inferential process (c) requires knowing the basic rules of logic and adopting a more semantic than syntactic stance so as not to confuse the sufficient condition with the necessary condition and vice versa. However, it is neither necessary nor sufficient, as the formal scaffolding must be complemented by causal scenarios to be resolute (Saiz 2020).

(e) The connection between CT and metacognition is reciprocal. Critical thinking does not arise randomly; it only manifests when we are aware of our actions, whether they are correct, to repeat and improve them, or incorrect, to amend them (Rivas et al. 2022).

(f) It follows that metacognition is what enables us to be aware of our cognitive process and, in turn, to transfer it to other areas of life, to reflect on how we learn, and to select, monitor, and evaluate our own strategies.

(g) From (e) and (f), it follows that the program incorporates the non-cognitive component (b) through the treatment of metacognition and motivation, which are sequentially linked to each other since skills can only be organized, planned, and goal-directed once they have started to function, i.e., motivation must activate skills for metacognition to function.

(h) For this last reason, and to bridge the gap between theory and practice, sometimes criticized in intervention programs, or what in practical terms is the gap between training and what the professional environment demands of students (Casner-Lotto 2006), the program uses relevant situations so that students have the possibility of applying what they have learned (Saiz and Rivas 2008). Under the premise that we can only know what we apply and that there is no point in perfecting critical skills if they are not used, the activities characterized as relevant in the program are based on PBL (problem-based learning). This is mainly because it is problem-based learning in which the student must apply processes of research, reflection, and analysis that are evident in the delimitation and understanding of the problem, interpretation, decision, and, obviously, solution.

2.2. Epistemological Foundation

The first distinctive feature of the program is that it distances itself from the logical–epistemological tradition if the latter is reduced solely to the theory of argumentation. What we have argued in this respect is that CT is at the service of the best explanation and not of the best argumentation as an end in itself. This break is better understood if we consider the dilemma of understanding CT as a theory of argumentation or as a theory of action (Saiz 2017, 2020).

As a theory of argumentation (Hitchcock 2017; Morrow and Weston 2016; Toulmin 2003; van Gelder 2015), the identity between knowing or training in CT and achieving goals inherent in human life itself (such as happiness or well-being) is questionable. As a theory of action, the identity between knowing and solving effectively in practice must be a principle. This nexus is unquestionable in a theory of action; it is not enough to make the argument the best product of reasoning, but at most, a feasible means to ends that require problem solving.

The aim of the program is to achieve effectiveness through the best explanation. In the face of a fact, explanation takes precedence over argumentation. Through the description of the process and the incorporation of strategies of order and clarity, the latter appears to justify what is found in the explanatory process; it proceeds to discursively substantiate why it is that cause and not another. Thus, argumentation is subordinated to explanation. The conceptual and operational linkage of the critical concept is with the indicator of effectiveness; one is effective to the extent that one is talking about a better way of doing things, which means that it is not possible to be critical and not effective.

The focus of the program is on explanation, which means that it is a core concept around which the other concepts of the method orbit with multiple relationships to achieve change as an objective of critical thinking. Explanation is the heart of the program due to its direct link with reality. Imagine a situation where there is compelling evidence but no response to a phenomenon that is not explained by our current beliefs. To understand and solve this, we need to identify the cause.

Argumentation requires activating this response. But even so, outside the problem, argumentation could appear in a simulated situation or to sustain a conviction or belief that does not arise from a problem of reality. Explanation as a concept proper to inquiry is conceived as a mechanism that engages with the deductive machinery to establish the combinations of deductions with the facts and to unconfirm alternative explanations so that the objective of CT is fulfilled, namely, to find the best explanation and with it, once the decision making takes place, to bring the explanation as a solution into the practical realm (Saiz 2017, 2020).

A program like ARDESOS-DIAPROVE can only be nourished by science, its data, and methodologies. Science is distinguished by the constant search to understand and explain the phenomena we observe in the world. Studies of scientific practice show that it is not limited to pure observation but often involves the search for testable hypotheses. This activity is carried out with the precision of data obtained through experimentation (Bunge 2000). For this reason, science describes events and links seemingly unconnected propositions into a coherent system of explanations. This ability to link and abstractly formulate structural properties is what differentiates science from common sense and elevates it to a deeper and more systematic level of understanding (Nagel 1987). With the conviction that it is not simply a matter of observing and recording but of understanding, of looking for patterns, of formulating hypotheses, and testing them, science advances by providing explanations that are both rigorous and capable of refinement (González and Guamanga 2022). This commitment to explanation defines and distinguishes science and is the reason it determines the program.

Scientific explanation is a crucial tool in the development of critical thinking. By understanding how foundations in science are constructed and validated, it is possible to strengthen essential skills for logical reasoning and the evaluation of claims. In this section, we will focus on three epistemological approaches to scientific explanation: the theories proposed by Wesley Salmon, the concept of IBE, and IOE. Through this analysis, we intend to provide some of the epistemological foundations of the ARDESOS-DIAPROVE program, especially those dealing with the scope and limits of explanation. This is to deepen the challenges to be considered when looking for ways to develop the ability to explain to promote critical thinking. For this, it is significant to distinguish between the conceptualization of explanation and how it is achieved and, of course, to establish that a request for an explanation of an everyday or professional situation is not necessarily a scientific explanation but an explanation that emerges from the epistemological standards of science.

2.2.1. The Spiral of Explanation

Wesley Salmon has been a leading figure in the debate on scientific explanation (Galavotti and Pagnini 2010). His approach focuses on the causal nature of explanation, a perspective that seeks to go beyond classical analyses, as those proposed by David Hume (1739). In the *Treatise on Human Nature*, Hume puts forward an empiricist view of knowledge, arguing that many fundamental ideas, such as causality, have no direct impression to derive from and are therefore mere chimeras. With the example of billiard balls, Hume questions the traditional notion of causality, arguing that we cannot perceive a necessary connection between events but only certain circumstances: contiguity, priority, and constant conjunction.

Contiguity refers to the specific order in which we perceive events in space and time. Priority indicates that cause always precedes effect, although this does not imply a direct causal relationship. Constant conjunction suggests that, given certain conditions, the same effects will follow the same causes. However, Hume argues that, beyond these circumstances, we cannot discover a necessary connection between cause and effect. In his view, our idea of causality arises from habit and the expectation that the future will resemble the past rather than from necessary connections.

Whereas Hume regards causality as an epistemological and psychological construct based on habit, Salmon (1984a) tries to establish the existence of objective causal relations in the real world. Salmon's aim is to show that these causal relations can satisfy the explanatory demands of science. For Salmon, scientific explanation goes beyond the simple connection of relationships, so he proposes that a true explanation must identify complete causal processes and structures. This perspective differs from other approaches by stressing the importance of objective causality rather than simply observed regularities.

Salmon stresses that not all causal relations are compatible. For a causal relation to serve as an explanation, it must be part of a complete causal structure. This structure must be able to show how particular events or conditions give rise to the phenomena being explained. Salmon proposes an alternative notion of causality that aims to satisfy the demands of explanation in science. Unlike Hume (1739) and Mackie (1965), Salmon suggests that it is not adequate to speak of "the cause" of an event since an effect can have multiple causes. Instead of presenting individual causes, Salmon introduces the concept of "causal process", which refers to the transmission of an effective entity, such as energy, information, or electric charge (Salmon 1984a; Gómez and Guerrero 2020).

Salmon uses Newton's theories to reconstruct Hume's illustration of billiard balls, contending that physical laws offer an objective method to evaluate the relationships between objects. He presents the idea of causal interaction, a term used to describe scenarios where processes of cause and effect intertwine, leading to enduring transformations. He further underscores the phenomenon of mutual modification, which transpires when two such processes intersect, resulting in reciprocal changes. An illustrative example is the collision of two billiard balls: each trajectory is a causal process, and the collision is a causal interaction. If a ball bears a mark, such as a scratch, and continues its trajectory after the collision, it demonstrates the continued transmission of the mark, reaffirming the causal nature of the process (Salmon 1984a).

Finally, Salmon's causal mechanistic model of explanation is based on several key points. These include the distinction between causal processes and pseudo-processes, the counterfactual notion of transmission of a mark, and causal interaction. Explanation within this model traces the causal processes and interactions that lead to a specific event, allowing for a deeper and more nuanced understanding of causality in various phenomena. In this model, a causal process is a physical phenomenon that can transmit a "mark" on a continuous basis. These processes are distinguished from pseudo-processes, which cannot transmit marks. In addition, Salmon introduces the idea of causal interaction to account for two causal processes that intersect and modify each other. In the model, explaining an event involves tracing the causal processes and interactions that lead to it (Gómez and Guerrero 2020). Although the model of explanation proposed by Salmon succeeds in accounting for many phenomena and, in some respects, overcomes the problem of causality proposed by Hume, it is not without its critics. In this regard, Christopher Hitchcock (1995) argues that Salmon's model does not fully capture the essence of what we consider relevant in an explanation. For example, in the case of billiards, although the model may identify the movement of the balls as a causal process, it does not distinguish which aspects of that process are, in fact, relevant to the explanation, such as the mass and speed of the balls, as opposed to other less relevant factors.

Christopher Hitchcock (1995) also points out that the model faces similar challenges in other contexts, such as the example of birth control pills. Although taking a pill can be considered a causal process, the model does not adequately distinguish between the relevance of taking a pill for a man (which is irrelevant to preventing pregnancy) and for a woman (obvious relevance). Thus, Salmon's model, while useful for identifying causal processes, does not provide an adequate tool for discerning which features of a process are actually relevant to an explanation.

Another significant criticism focuses on the inclusion of pragmatic and contextual elements in his model. Although Salmon attempts to establish a notion of objective causality, his proposal seems to compromise this objectivity by relying on the interests or views of users. To illustrate this point, consider the example of the 40-year-old man who faces a series of unfortunate circumstances on a stormy morning. His old car, the storm, the bad road, the faulty brakes, his work-related stress, and the lightning striking a tree all contribute to a tragic accident. Hours later, three experts arrive on the scene: a medical examiner, an insurance mechanic, and a road engineer. Each, from their professional perspective, could identify a different cause of the accident. The doctor might point to a heart attack, the mechanic might focus on faulty brakes, and the engineer might criticize the road design. In this case, the objectivity of causation is challenged by the different perspectives and areas of expertise.

The ARDESOS-DIAPOVE program tries to take the best of existing theories of explanation and adapt them to meet the specific needs of its pedagogical approach. In this case, the program emphasizes, from Salmon's approach, the importance of identifying objective causal relationships in the real world. The distinction between causal processes and pseudo-processes provides a valuable tool for the program, as it allows for a deeper understanding of facts beyond appearances. However, the program cannot follow Salmon's model point by point, especially as it opens the door to different perspectives, leading to different explanations. Moreover, although the mechanistic causal model of explanation is useful for identifying causal processes, it does not always provide an adequate tool for discerning which features of a process are relevant to an explanation.

Salmon's model focuses on causes and stipulates necessary features of the explanation, such as showing which factors are relevant for the occurrence of the event and excluding irrelevant factors; however, the central difference with the program is that in Salmon's model, the event is placed in a network of statistical relationships of factors that are relevant for its occurrence without this implying finding the best explanation. While Salmon's model does not conceive the explanation under the structure of an argument and the fact remains in a geometric network of relevant interactions, from the ARDESOS-DIAPROVE program, it can be questioned, in Galavotti's words (Galavotti 2018), that it is still not indicated which properties should be taken as explanatory, it is like a telephone network that does not account for the specificity of the messages, while in the program it is crucial to get to the message, to the best explanation.

2.2.2. The Inference to the Best Explanation: Better?

IBE, first proposed by Gilbert Harman in 1965 and later extended by Lipton (2003), emerges as an essential epistemological methodology in hypothesis selection in science. Harman argued that not all inductions are based on guarantees of non-deductive inference. Instead, it is necessary in many cases for scientists to infer a hypothesis not because it is possible but because it provides the best explanation for the available evidence (Harman 1965).

Unlike traditional approaches that rely exclusively on direct observations or deductive logic, IBE foregrounds the explanatory power of a hypothesis.

This intrinsic process of IBE begins with the identification of hypotheses that might make sense of certain evidence. Given the plurality of hypotheses that can often explain the same evidence, it becomes imperative to evaluate and test these hypotheses against each other. Harman emphasized that the choice of the "best" hypothesis is not an arbitrary act but is governed by specific criteria. These criteria include aspects such as the simplicity of the hypothesis, its ability to address and explain a variety of phenomena, and its consistency with the established body of knowledge.

To further illustrate how this process works in practice, consider the following example: in a small village, the eucalyptus trees, symbols of the locality, started to become diseased, with dark spots on their leaves and discoloration of their bark. The scientists proposed several hypotheses: H1, a new pesticide affected the trees; H2, an unknown fungus infected the eucalyptus trees; H3, climatic changes stressed the trees; and H4, invasive insects damaged the eucalyptus trees. After evaluation, only hypothesis H2 was retained, supported by the presence of a fungus in diseased trees that was absent in healthy trees.

To validate hypothesis H2, the fungus was introduced into a healthy tree in a controlled experiment, and the tree began to show symptoms similar to those of the diseased eucalyptus, confirming the cause of the disease. This process demonstrates the effectiveness of IBE in scientific research, highlighting the importance of rigorously proposing, evaluating, and validating hypotheses in order to reach accurate conclusions (Laudan 2007).

The IBE has established itself as a valuable tool in the scientific landscape by enabling researchers to deduce the most likely cause behind an observed phenomenon. This methodology is characterized by a series of criteria that determine what is considered a "best" explanation. These criteria, which include simplicity, consistency with established theories, explanatory scope, and plausibility, allow scientists to select hypotheses not only on the basis of observations or pure logic but also on their intrinsic ability to provide a coherent and plausible explanation in the face of the evidence presented. IBE is an essential methodology in science that guides researchers in selecting hypotheses based on the available evidence.

However, this tool is not without its critics. One of the most prominent objections is the "bad lot" argument, which postulates that all available hypotheses may be inadequate in certain circumstances (Fraassen 1989). An illustrative example, following the eucalyptus case, where a hypothesis not initially considered turned out to be the true cause of a disease (H5: a specific type of water contamination affecting eucalyptus trees), shows that the original hypotheses were insufficient.

IBE faces epistemological challenges, especially when it comes to inferring truth from criteria such as simplicity and coherence. While these virtues are useful for assessing the quality of an explanation, they do not guarantee its truthfulness. Therefore, while IBE remains central to scientific reasoning, it is crucial to recognize and address its limitations and potential with a critical approach.

The ARDESOS-DIAPROVE program, like IBE, values the importance of explanation as a central tool for understanding and solving problems. Both seek to identify and validate the best possible explanation for a given phenomenon or problem. However, while the IBE focuses on virtues such as simplicity and coherence to judge the quality of an explanation, the ARDESOS-DIAPROVE program emphasizes the practical and applied relevance of explanations and, above all, the process of eliminating possible explanations to obtain not only the best but the only one that can explain the event.

2.2.3. Inference to the Only Explanation: The Only One?

The difficulties that conceptually arise have tried to be studied by advocates of this inferential process characteristic, according to them, of science. Among them is the philosopher of science, Alexander Bird (Bird 2007, 2010). Bird's proposal moves from IBE to IOE. For our purpose, understanding this approach is key, as the correlation with the ARDESOS-

DIAPROVE program would be in the central thesis, unlike the relationship with Salmon and the IBE, with which relationships are established between some premises.

Bird's thesis is that if the IBE allows the selection of a single potential explanation, then that is the only explanation (Bird 2010). He is, therefore, committed to the uniqueness of explanations. Bird (2007) calls this inference "Holmesian inference".

By inference to the only explanation (IOE), I intend something quite specific: at the end of the inquiry, we can be in the position to infer the truth of some hypothesis since it is the only possible hypothesis left unrefuted by the evidence. It is the form of inference advocated by Sherlock Holmes in his famous dictum, "Eliminate the impossible, and whatever remains, however improbable, must be the truth". Of course, one requires the auxiliary hypothesis that there is an explanation of the phenomenon in question (p. 425).

It is an IOE because all but one explanation can be eliminated from the evidence. In structural terms, we would have an argument that goes from determinism, through hypothesis selection and eliminative inference, and ends in a single conclusion. In this way, it seems a more categorical bet than the Hartman–Lipton IBE by not resorting to other explanatory goodness, and therefore, Bird will argue this initiative through scientific practice in medicine, for which he reconstructs the classic case of Semmelweis.

Bird's interpretation does not supplant Lipton's explanation (Lipton 2003) but shows the complement of the IBE in Semmelweis' case. For Bird, this case obeys more a Holmesian inference than a Liptonian IBE, and as proof of this, the "explanatory charm" of the inferential study can be omitted. Holmesian inference structurally starts from a fact that has an explanation; there is a collection of hypotheses that can explain it, and the hypotheses have been falsified by the evidence, except for one. It follows that the hypothesis that survived the eliminative process is the hypothesis that explains the fact. As can be seen in the scheme, there is no other criterion or explanatory goodness beyond having passed the process of testing against the evidence.

In following Lipton's approach, Bird also accepts the basic IBE principle of discarding the null or zero hypothesis, i.e., the deterministic idea that for every intriguing piece of evidence, there is an explanation. Bird emphasizes the process of progressive refutation, i.e., eliminating rival hypotheses until the true explanation remains, hence the name Holmesian inference: "Eliminate the impossible and what remains, however improbable, must be true".

Bird's case study is Semmelweis. Between 1844 and 1848, Semmelweis worked at the Vienna General Hospital. The scientific concern that made him famous and a reference in epistemological studies was why a large number of women contracted a terrible and sometimes fatal disease called puerperal or postpartum fever with a higher preponderance in one division than in the other. The investigation led Semmelweis to consider various hypotheses, from the most scientific to the least plausible, each of which was tested by experience.

The difference with other analyses is traced by Bird in determining what is selected in this case as intriguing evidence (explanandum) to understand the correspondence of this with the *explanans*. Either E1, "The existence of puerperal fever in division 1", or E2, "The preponderance of puerperal fever in division 1". The former is much more general, as it can be understood as speaking of the existence of the disease elsewhere. The following hypotheses emerge from the first phase of the IBE: H1, the cause of the high mortality is the overcrowding of division 1; H2, the cause is an epidemic or climatic influence; H3, the culprit is the careless examination of medical students in division 1; H4, the cause is the terrifying effect of the priest passing through division 1 before anointing dying patients; and H5, the cause of the disease in the division is that women gave birth on their backs. Once the possible *explanandum* and *explanans* have been determined, it is essential, Bird points out, to determine the *explanandum* to correctly understand the phases of the IBE. If, for example, it is E2, H1 and H2 can be ruled out since divisions 1 and 2 share much of the same healthcare practice conditions and, division 1 being infamous, then division 2 was more overcrowded. In the contrastive explanation, there is no particularity that is unique to division 1. According to Bird, H3 is an implausible hypothesis that even Semmelweis could dismiss based on initial knowledge, namely that there was no significant difference between the care of students and midwives in division 2 versus natural childbirth injuries. In the case of H4, Semmelweis convinced the priest not to go through division 1, and this was not significant with the results: the large preponderance of postpartum fever, i.e., the evidence was inconsistent, and H4 can be falsified. The same was true for H5, given that women gave birth sideways without this constituting a decrease in mortality. This means that no H can explain E2. The case that accidentally made another hypothesis possible was the death of a colleague of Semmelweis, Dr Kolletschka, who died of a wound sustained during an autopsy. Semmelweis observed that Kolletschka's symptoms were similar to those of women dying of postpartum fever. This allowed him to posit H6: the women were infected with "cadaveric matter" by medical students performing autopsies before examining the women in division 1.

In this regard, Bird states that, from this hypothesis, there are two divergent hypotheses, only one of which is supported by the evidence and the Kolletschka case: the first (H6a), the women were infected during the examination by the medical students; and the second (H6b), the infectious agent was the "cadaveric matter" imported by the students. Bird's claim is that only H6a is verified by the evidence, while H6b is plausible, but with the data, it cannot be verified; otherwise (bearing in mind that Semmelweis suggested that the students wash with a chlorinated lime solution and this measure caused the deaths to decrease), the cause lies in some property of the students' hands that is removed by washing them. With this, Bird asserts that the evidence leads not only to the best explanation but sometimes to the only explanation and that it is arrived at by eliminating all potential alternatives. From this statement, it is relevant to note, "sometimes", to limit the claim of universality or extension to all phenomena in science.

The ARDESOS-DIAPROVE program focuses on finding the best explanation for professional and everyday problems involving decision making. Moreover, it has a logical underpinning and a causal explanatory model. Thus, the inference referred to is not in an epistemological gap but is an inference that seeks uniqueness in the same way that Bird has proposed. Now that we have an identified foundation with which there are conceptual and methodological relationships, what does the program gain by identifying an epistemological foundation? From the perspective that this is a program underpinned by scientific data and validated pedagogical practices, the gains can be debated. What is unquestionable is that it provides greater conceptual clarity and foundations to a program whose didactic route is to achieve better results through Holmesian inference, as we have pointed out on other occasions, at that point without the need to descend theoretically down the explanatory spiral. On the other hand, the search for the causes in the science of phenomena or problems in which life is at stake is a component that enriches the program didactically. Within the didactics, a unit on these achievements in science and how they have been a successful illustration case shows the strength of how we are in line with the most accurate description of science and how a professional also solves problems effectively.

The points of agreement with Bird that can be noted are as follows: first, the premise that every phenomenon requires an explanation, and this explanation is causal, material, and objective, is not disputed. Bird's analysis of the classic Semmelweis case illustrates this: faced with a multiplicity of hypotheses, some of them dominated by a set of unfounded beliefs, they are dismissed by the inscrutable strength of the facts. Secondly, both in Bird and in the program, there is this need to arrive at the best explanation through the procedurally correct elimination of logical principles in combination with the contrast with experience. In Bird, we can also observe the need, as in our program, to attend to relevant, contradictory, and extraneous data in order to propose an alternative solution, a reason that resembles the ongoing process of knowing how to handle data with the deductive machinery. Thirdly, although Bird accepts that his case of arriving at a single explanation is an exceptional case of the IBE, this is not a limit to the program; as Bird detailed above, the issue is not understanding the problem but determining which *explanandum* is the one to be solved. It may be the case that curricular activities do not have this causal relationship or that they are, in principle, posed as multi-causal when, in fact, the question or problem has not been adequately defined.

Finally, it can be seen in Bird's proposal that his cases are set in reality and not in the imaginary; he shows cases that happened and were transformative for some sciences. In the same way, the program proposes real activities of ecological situations that, if not resolved, have implications in the real world. It can therefore be concluded that we are faced with an epistemological reference that also supports the program's proposal. This is certainly not costless, as it requires a deepening of the reserves as the bad lot to avoid in the hypothesis construction phase to ensure that you really understand the problem to be solved. There is, therefore, more common ground between Bird and the ARDESOS-DIAPROVE program than with other proposals. The limits pointed out are precisely pedagogical warnings so that the didactic material and instructions, the PBL, and other pedagogical foundations are well-aligned curricularly with the purpose of the program.

2.2.4. Conceptual Circuit

In the ARDESOS-DIAPROVE program, the conceptual circuit that complements the IOE is based on heuristics and decision making. An epistemological pillar may have little value if it fails to apply to real-world problems, becoming a mere static ornament. It must establish cooperation networks with other concepts to achieve an effective connection with reality where decision making stands out as the key concept.

The definition of CT that we use as a starting point for this program has a clear intention: to find effective solutions to problems. However, it is evident that finding solutions and executing them are two different things. The IOE, along with its entire process, provides us with a guide on how to reach these alternatives and the criteria to choose one of them. This is a crucial step, as it ensures rigor and transversality in the search for an explanation. Ideally, the process should go beyond the abstract solution of the problem, and transversality should be evident in a well-made decision. However, the principle of reality about how we make decisions, especially when we collect data about our mistakes when deciding, confronts this ideality. The issue of the limits of our cognitive machinery arises in the program with the same naturalness with which we accept our fallibility. For this reason, we have decided to integrate real cases into the conceptual configuration. These cases are designed to challenge the student to face future professional problems, some of which will require transcendental decision making in practical terms. These decisions will not only test the professional quality of the student but will also influence the decisions that others will make based on the professional's criteria. To illustrate this, we will use the Lilly case (Saiz 2020).

Decision making is a skill that is perfected after having made the decision. There is a path, whether intuitive or rational, that has been followed to select and carry out a solution. It is possible that a specific alternative has been chosen as a result of the extensive path described in the IBE process or that this path has been shortened. In any case, the decision arises as a result of the application of one or several pre-decisional skills. To a large extent, the dilemma determines the quality of the decision: the greater the identification and monitoring of pre-decisional skills, the greater the self-regulation in case it is necessary to intervene to correct any error in decision making.

The high recurrence of failures in decision making could contradict the essentialist definition of man as a being given with logos: language and reason (Gadamer 2004). However, this definition is quite far from the results proposed by Kahneman and Tversky, who, through extensive experimental work, demonstrated that there is no such rational purity or essentialist category of rationality (Kahneman 2013; Kahneman et al. 2022; Kahneman and Tversky 1984; Tversky and Kahneman 1974).

According to the data, the opposite occurs: in different professional scenarios, where agreements and correct decisions should predominate, such as medicine and law, decisions are easily classified into random scatter plots (noise) or systematic deviation (biases) (Kahneman et al. 2022).

What is the role of CT in the face of obstacles that lead to wrong decisions? The answer seems clear: it must incorporate them into an instructional design to expose students to these deficiencies of cognitive machinery, both at a descriptive and normative level. This exposure should facilitate the identification of these deficiencies and the generation of strategies to reduce them in the decision-making process. The program takes on this challenge and, through specific cases, exposes the student to situations in which, if they do not overcome these deficiencies, they will not be able to solve the problem and, as a result, will probably make a wrong decision. In this thematic content, the explanation again takes precedence over the argument. Although the latter could arise even after reaching a wrong alternative, the explanation directly precedes decision making. The action of arguing can be activated even in defense of a wrong decision. Given a point of view that wants to be defended and an intention, it is possible to develop an argument with a logical emphasis, oriented to the quality of the relationship of the propositions, dialectical, focused on the correct dialogic processes, or rhetorical, focused on the universes of beliefs accepted between the speaker and the audience (Tindale 2004). However, these approaches do not correct the possible error but can amplify it. Therefore, there must be other paths that lead us to decision making or on which the hygiene of decisions falls (Kahneman et al. 2022).

Hygienic decision making is based on disciplining intuition. It is not about prohibiting it but resisting premature intuitions and balancing them according to the context that requires explanation, factual data, causal scenarios, and forecasts. These are necessary steps, among others, to arrive at the only explanation (Saiz 2020). It is important to distinguish between the generation of explanation alternatives and the choice between them. Although the distinction is simple, clarification is necessary to avoid confusing problem solving with decision making (Halpern and Dunn 2023). The central point is to have and master clear and solid criteria for choosing an alternative and, in a strict sense, excluding the others, thus advancing towards decision making with an explanation alternative as the protagonist. These criteria and procedures have been provided to us by the epistemological debate in this article illustratively by IOE.

From an analytical point of view, it could be argued that without the best and only explanation, we are unlikely to be making a good decision. This statement supports the inclusion of heuristics and biases in the program, in particular, the representativeness heuristic. According to Kahneman (2013), "The technical definition of heuristic is a simple procedure that helps find adequate, though often imperfect, answers to difficult questions" (p. 271).

This suggests that heuristics can lead us to make incorrect judgments and establish a hierarchy of events that is not necessarily based on solid foundations. An example of this is the representativeness heuristic, which uses a personality trait as a basis to estimate the probability of expected behavior, giving priority to this trait as if it were representative of the entire personality structure (Saiz 2020).

With the aim of completing the conceptual cycle of the ARDESOS-DIAPROVE program in relation to IBE, real-world decision making, and the representativeness heuristic, we propose the Lilly case for integrated analysis. In this case, the tragic death of a company manager occurs under suspicious circumstances. The manager's sister, also a co-owner of the company, plays a crucial role. With a history of mental health problems (depression, suicide attempts, emotional independence) and the consumption of sedatives on a tragic night, she shoots her brother, mistakenly believing he was an intruder in the house they shared. Despite her acquittal due to the accidental nature of the incident, questions arise about her ability to lead the company and her possible involvement in the fact. As the new manager, she has made significant business decisions without consulting the board of directors. The same happens in her personal life; she has set the date of her wedding without consulting her fiancé. The company's executive board commissions a psychology professional to prepare a report to determine whether or not the new manager is qualified to run the company. The professional is asked to decide with an exclusive response, yes or no.

The professional is at a crossroads to make a decision. Let us analyze the first path, which originates from the representativeness heuristic. By focusing on personality traits such as emotional dependence and low self-esteem during the patient's study, it is natural to conclude that she is a person with a tendency to self-harm. Evidence of a suicide attempt could reinforce this assessment, even leading to rule out that she is prone to harm others. By establishing a personality profile based on the observed traits and behaviors, the professional could overlook relevant information, such as the patient's involvement in the accidental or intentional death of her brother. As a result of this diagnosis, the professional would consider it unlikely that she is an aggressive and violent person, as the observed traits are representative of certain behaviors. The professional's categorization can cause other relevant data to go unnoticed, focusing only on one aspect of the case. This demonstrates how labeling can limit our perception and understanding of a situation.

There is an alternative path that the professional could choose. Although less intuitive, it is more complex and encapsulates the methodological component of the ARDESOS-DIAPROVE program. This sequential process requires the professional to recognize the general limitations that hinder correct or resolutive thinking, which could obscure the required decision making. However, it is not enough to just recognize these limitations; it is also crucial to identify them. In the program, this step is known as DEFISESGO, which refers to the identification of deficiencies and biases. By correctly applying this step, the professional would not focus solely on diagnoses and personality categorizations. Instead, she would analyze additional information, such as the sister's behavior and business decisions after the incident. In this way, the representativeness bias is recognized and overcome, avoiding basing the analysis solely on the psychological profile, the police report, or the court decision.

In a later stage, the professional should explore alternative explanations that transcend the simple collection of third-party data. This process is called BUSEXPLICA (search for a unique explanation). This process is conceptually aligned with IME, at least in its first phase. In this process, the professional should explore alternative hypotheses that consider family and business dynamics to provide a better explanation of the observed facts and contribute to decision making. To accomplish this, she could meticulously examine all available data and evidence, including forensic reports, testimonies, and business records, and combine them with the data she has collected herself. However, one thing is to seek the explanation, and another very different thing is to obtain a single explanation verified by the judge, which is the facts. This last step is called MEXPLICA (to have the best explanation and seek to unequivocally explain a fact or problem). It is at this moment that the powerful but sometimes complex machinery of deduction (Govier 2010) and causality is set in motion. This last stage is associated with IBE by the categorization of unequivocal explanation, but above all, because there can be no doubt that it is this explanation and not another that should be the protagonist in decision making. With the data logically integrated, the professional has all the elements of judgment to make a decision based on the two hypotheses at stake. Hypothesis 1: the emotional instability of the new manager makes her incompetent to lead the company, backed by her mental health history, reasonable doubts about her responsibility in the death of her brother, and her behavior after the incident. Hypothesis 2: the new manager is able to lead the company, demonstrated by her ability to handle crisis situations, the forensic experts who exonerated her of any intentionality in the death of her brother, and her adaptability shown after the incident.

The ARDESOS-DIAPROVE program highlights in its analysis of the Lilly case, presented here in a summarized form, the relevance of basing explanations on evidence and observable facts. This approach underscores the need to overcome cognitive biases to facilitate decision making based on rigorous explanations derived from various sciences. The cases studied in the program are characterized by their ability to simulate reality, representing challenges that professionals must face. For this reason, the methodology focuses on the objective reality of the case, seeking to improve accuracy in the decision-making process. The application of the inference method to the best and only explanation, in this context, is especially effective. It facilitates the identification and support of the hypothesis that best aligns with the available evidence, leading to a more structured and logical analysis. This allows for a deeper and more precise understanding of the situation.

3. Conclusions

The aim of this article was to comprehensively expose one of the fundamental pillars of the ARDESOS-DIAPROVE program: inference to the best explanation. This aspect is crucial as it directly connects with the real world and refers to intriguing evidence that requires a cause to satisfy its explanatory character. The program focuses on the development of problem-solving skills through explanation. However, it is not about any explanation, but the best one. In this sense, it is essential to consider the reflections and challenges that the concept has faced in the epistemological approach.

An explanation is a powerful tool for understanding and solving problems, but only if it is accurate, relevant, and evidence-based. Unlike argumentation, explanation directly links to decision-making and real-world issues. Therefore, in teaching and practicing CT, it is essential not only to teach students to question and evaluate explanations but also to generate them effectively. For this, we take scientific activity as a reference. This involves understanding the criteria, methods, and scientific standards that allow obtaining the best explanation and, at the same time, being aware of the complexity and limitations of the explanation process itself. The ARDESOS-DIAPROVE program has solid foundations drawn from psychology and the most outstanding developments of the rich tradition of critical thinking and, above all, has incorporated successful pedagogical practices and strict compliance with scientific standards. Therefore, it is not surprising that, as a result of the dialogue between the epistemological approach and the program, there is a high degree of coincidence. To the extent that an educational intervention program incorporates scientific results and applies scientific methods in search of explaining and predicting reality in a rigorous, replicable, and objective way, the dialogue with any epistemological approach will be constructive.

With the Lilly case, we have tried to emphasize the importance of seeking reasonable explanations and grounded in concrete evidence to guide decision making. We certainly recognize that the nature of a good explanation varies according to context and discipline, indicating the need for a more detailed and contextualized analysis. In addition, CT, as manifested in this analysis, goes beyond simple first-order reasoning. It involves a deep and methodical reflection on one's own thought process, including both the generation of conclusions through direct reasoning and the continuous evaluation of our cognitive abilities to overcome possible cognitive biases. The Lilly case demonstrates that an evidence-based and cognitive-bias-free approach, which prioritizes reasonable and contextualized explanations, is essential in knowledge processes and problem solving, but above all, it should guide decision making.

The ARDESOS-DIAPROVE program is an integrated system that relies on precise explanations to solve problems and substantiate informed decisions. The process begins with the identification and understanding of the problem. A misunderstanding at this stage can result in inadequate solutions or incorrect decisions. The program also promotes the creation of various explanations or hypotheses to discover viable solutions. This step requires creative exploration and logical reasoning. The proposed solutions undergo a critical analysis, considering factors such as coherence, applicability, and consistency with prior knowledge. Finally, the program highlights the need for rigorous evaluation to ensure that decisions are based on solid explanations. In summary, the program links decision making and explanation in a continuous cycle. Effective explanations arise from problem solving and guide future decisions. This process highlights the importance of critical thinking and the inference of the best and only explanation in the generation, evaluation, and selection of solutions, resulting in effective decisions and well-founded explanations.

Finally, epistemology, understood as a study of scientifically justified true beliefs, establishes conceptual spirals that reinforce scientific practice, especially highlighting methodological rigor. We have established dialogues within this explanatory spiral with selected authors. However, we could have extended these dialogues to other contemporary authors and established necessary contrasts, for example, with topics such as causality and probability or directly with abduction. These dialogues not only validate and conceptually strengthen the program but also allow us to participate in debates about these conceptual achievements. In recent years, we have not had the opportunity to participate in epistemological dialogues, mainly because the objectives of the program have been practical. We seek changes in students, their persistence over time, and their generality in reality. This sometimes leads us to assume practical commitments with applied research in CT without this being interpreted as a critical stance against the purely conceptual.

As has been demonstrated in this text, there are still many issues to debate, not only with this program but also with others. In addition, the door remains open to continue investigating the epistemological foundations of the proposals on CT and how they relate to the real world. An important direction for future research is how the role of CT, linked to epistemological debates, can mitigate cognitive biases in problem solving and decision making beyond the factual field of psychology. Perhaps the most relevant thing is how and under what conditions to measure the effectiveness of the program beyond a test that, although it can be predictive of behaviors in the world, is not the real world. These areas of research not only expand the scope of the current article but also open new avenues for understanding the practical application of critical thinking and epistemology in real life.

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Breaking Down the Concept of Students' Thinking and Reasoning Skills for Implementation in the Classroom

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Abstract: Various skills related to critical thinking, reasoning, and scientific reasoning are defined as essential for students in policy documents and curricula around the world as essential both in school and in everyday life. However, these concepts are often too vaguely defined and explained for a clear implementation in the classroom. In this conceptual article, the authors propose the following questions: (1) How are the concepts of thinking and reasoning as defined in policy documents reflected in curriculum descriptions across different disciplines? (2) To what extent do reasoning activities and processes overlap across different disciplines? (3) How can reasoning skills (particularly: analysis, evaluation, and creation) be described based on reasoning activities or processes and the outputs or products? Based on the literature review, it is concluded that researchers in various science disciplines have defined the aspects of reasoning that are typical for their respective disciplines, considering content, procedural knowledge, and epistemic knowledge. Meanwhile, looking from the perspective of cognitive psychology, it is concluded that reasoning processes (deductive, inductive, and analogical reasoning) are activated in the mind while students engage in reasoning activities (such as analysis, evaluation, and synthesis). Thus, similar cognitive processes occur in the mind, despite a student working in different disciplines. A conceptual framework is offered in this article showing (1) how reasoning processes and activities manifest themselves in different study domains both from a theoretical perspective and in everyday classroom work; and (2) what kind of outputs could be expected from students based on various reasoning activities. The importance of interdisciplinary collaboration is justified so that students develop their reasoning skills holistically, not fragmentarily.

Keywords: reasoning; thinking skills; interdisciplinary; sciences; social sciences; curriculum; policy papers; cognitive processes; HOT skills

1. Introduction

Critical thinking, scientific reasoning and other general skills related to thinking and reasoning are defined as essential skills for students to develop in many education systems around the world (e.g., Australian Government 2014; Suto and Eccles 2014). Large-scale international education projects are dedicated to defining the development and assessment of these skills. For example, the international project of the Organisation for Economic Co-operation and Development (OECD) called "Critical and creative thinking" (Vincent-Lancrin et al. 2019), aims to look at these skills more broadly and from an interdisciplinary perspective—so that they can be equally included in various study subjects, with an aim to also apply them in everyday settings. In addition, in each cycle of the PISA international educational assessment study, students' essential reasoning skills are assessed. For example, mathematical reasoning as a part of mathematical literacy (OECD 2018), scientific literacy, including scientific explanations, evaluations, and interpretations of data and research (OECD 2013), and other skills are assessed. In Latvia, the country of focus for the current paper, the acquisition of "critical thinking", "problem-solving", and the various skills essential for scientific reasoning are defined as crucial learning goals for students in the latest curriculum (Cabinet of Ministers Republic of Latvia 2018). Further materials are being created that contain explanations of how these skills can be developed in specific disciplines (e.g., in natural sciences—see Logins et al. 2020). It can be seen that while politics provide the vision and the big goals, psychologists perform research to understand how thinking works, and educators think of how they can practically teach these skills. However, there is a question of how well and to what extent the priorities defined in policy documents are brought to life at the operational level, that is, in the classroom during daily learning activities (Vincent-Lancrin 2023). One of the goals of this article is to examine how students' skills as defined in policy documents are reflected more concretely in the content of the everyday learning processes that are reflected in curriculum programs or lesson plans. In addition, how students' reasoning manifests itself in the content of different learning disciplines will be explored. The goal is to bring the perspective of psychologists and researchers in education to the forefront, making their ideas more accessible to practitioners in the field.

A major challenge for the in-depth acquisition of critical thinking and reasoning skills is the fragmentation or overlap of study content, which can lead to unnecessary time spent that could instead be used purposefully to better consolidate what has already been learned in another lesson (e.g., Fogarty 1991). Therefore, the next essential goal for researchers is to precisely analyse how students reason in different disciplines, finding both the similar and the unique aspects specifically at the level of the everyday learning content, not only in theoretical or general descriptions, as in the policy papers. This is essential to reach such important goals as "interdisciplinary collaboration" and cooperation between the teachers of various disciplines, as well as a mutual understanding of what it means to foster "thinking". Recent international education projects have focused on this issue and tried to solve it by creating both domain-general and domain-specific rubrics for teachers (Vincent-Lancrin 2023). In order to successfully reach the goal of finding the uniqueness and commonalities in various disciplines, it is necessary to clearly demonstrate where such overlaps in reasoning exist. And it is also important to show what is unique and different, and where each of the disciplines can enrich a student's thinking. Taking this into consideration, the second goal of this paper is to demonstrate how reasoning skills manifest themselves in different learning domains, offering a framework that should lead to a more effective collaboration in developing students' reasoning skills. By showing how reasoning activities and processes manifest themselves in different disciplines, the rationale for the need for interdisciplinary connection can be conceptually confirmed. Students need to develop their critical thinking skills and reasoning abilities holistically, not fragmentarily, to be able to transfer them and apply them to situations in their daily lives.

Focus of the Current Paper

The aim of this conceptual paper is to break down the concepts of thinking and reasoning skills to make them approachable at the level of everyday classroom work, based on the perspective of student's reasoning activities in various disciplines. In order to achieve this, several questions have been raised by the authors:

(1) How are the concepts of thinking and reasoning as defined in policy documents reflected in curriculum descriptions across different disciplines?
(2) To what extent do reasoning activities and processes overlap across different disciplines?
(3) How can reasoning skills (analyse, evaluate, and create) be described based on the reasoning processes and the outputs of reasoning?

The authors follow the approach for designing conceptual articles, by analysing and synthesising the ideas found in the existing theories, data, and documents and performing a conceptual mapping of the existing ideas to offer a novel view on the issues (Jaakkola 2020; Maxwell 2013). Within the scope of this article, the educational areas considered for analysis are natural sciences, mathematics, social sciences and history, as well as the field of Technology and design—as defined in the content of Latvian education curriculum (Cabinet of Ministers Republic of Latvia 2018). Latvia's education content was chosen as a context for a specific analysis for the purpose of this study to provide concrete examples; therefore, the education system of Latvia is very briefly explained further in this paragraph. In Latvia, general education is acquired in 12 years, during basic (primary) education (grades 1 to 9) and secondary education (grades 10 to 12) (Cabinet of Ministers Republic of Latvia 1998). There are several options for the secondary education level, including regular secondary schools (high schools), gymnasiums with at least two profiles of specialization (e.g., focusing on humanities or exact sciences), and vocational schools (source: https://www.izm.gov.lv/en/education-system-latvia, (accessed on 30 October 2024)). At the national level the Cabinet of Ministers and the Ministry of Education and Science are the main decision-making bodies regarding education and the general content of the curriculum. A novel competency-based approach to the curriculum is currently being implemented in the schools in Latvia (called the project "School2030"), with a focus on developing students' knowledge and skills in their study fields, as well as their transversal skills (Cabinet of Ministers Republic of Latvia 2018).

It has to be noted that when analysing policy documents, the term "thinking" tends to dominate the term "reasoning". For example, "critical thinking" is defined as one of the essential transversal skills for students in Latvia (Cabinet of Ministers Republic of Latvia 2018), and similar skills are defined in other countries and international programs (e.g., Australian Curriculum, Assessment and Reporting Authority [ACARA] 2017; Finnish National Board of Education 2014; OECD 2018). However, as it will be discussed further, this umbrella term, "critical thinking", contains all the typical aspects of the concept of "reasoning". When examining the concepts mentioned in policy documents, it can be concluded that they largely reflect various higher-order thinking and reasoning processes that are reflected in the concepts of analogical reasoning, deductive reasoning, and inductive reasoning (Demetriou et al. 2023; Richland and Simms 2015) and are related to the skills (or "reasoning activities") of *analysis, evaluation, and creation*, a division very commonly used in the field, based on the framework described by Anderson and Krathwohl (2001). These ideas are conceptually compatible with the earlier work of Ennis (1987) and Paul and Elder (2010) who have stated that critical thinking involves an analysis, evaluation, and improvement of thoughts, while coming to solutions and defining important questions. The authors of this article define reasoning as a competence that includes a set of purposefully activated cognitive processes of analogical, deductive, and inductive reasoning, while performing various reasoning activities (analysing, evaluating, creating), and using subject-specific knowledge and skills. Thus, reasoning as a competence in schools includes the essential aspects of thinking actions and outputs both from the perspective of psychology and from the core of specific study disciplines.

2. Reasoning Explained from the Perspective of Psychology and Educational Context

2.1. The Concept of Reasoning in Psychology

It is important to look at the concepts of thinking and reasoning, based on the approaches of psychology and education. In order to provide readers with a more complete theoretical overview, this article examines both research approaches that use the term *thinking* and approaches that use the term *reasoning*, taking into account the overlapping use of both terms. We start with an insight into the psychological perspective and then continue with considering these concepts from the educational perspective and from the perspective of various science disciplines in the next section.

First, it important to understand that thinking and reasoning can be viewed from various theoretical and methodological approaches, even if one field of science—psychology—is considered. For example, researchers have based their understanding in a more cognitive view (e.g., Demetriou et al. 2023), have considered the distinction of "higher-order thinking" (e.g., Lewis and Smith 1993), and have considered reasoning in a classic deductive form, rooted in logic, where coming to conclusions based on given premises is important (e.g., Goel 2005). Further, the authors attempt to give a brief overview of these various approaches, without claiming to provide a fully detailed and comprehensive overview.

In psychology, "thinking" is defined as a cognitive activity during which ideas, images, mental representations, or other elements of thought are experienced or acted on, and in addition, it is studied through various, conceptually different approaches (APA Dictionary n.d.; Sternberg and Funke 2019). Thinking includes imagining, remembering, problem solving, daydreaming, free association, concept formation, and other processes. Thinking is characterised by the fact that (a) it is hidden—not directly observable, it can however be inferred from the actions of a person or a self-report (thus, based on a product or output by a person—for example, a product by a student in the context of this article); and (b) it is symbolic (it includes the operations with abstract mental symbols and representations—for example, using concepts of a certain study discipline). Thus, thinking is inherently a broad construct that also includes aimless daydreaming. In order to deal with this issue (purely theoretically), various "types of thinking" have been distinguished and defined, giving a notion about *how* one thinks, thus providing the term "thinking" with a purpose or a more concrete form. For example, the term "critical thinking" is often used and is defined as the application of the cognitive skills and strategies that contribute to the achievement of a desired goal state, or it can also be called goal-oriented thinking, which must be separated from simply "imagining, wondering, daydreaming" (Halpern 1997). Another concept - "complex thinking" - is also studied (Vázquez-Parra et al. 2023), conceptually separating it from automatic or simple cognitive activities. Recently, various researchers have discussed the commonalities of "critical thinking" and "intelligence" (Bensley 2023; Halpern and Dunn 2021). It must be noted that researchers already addressed the issue of "how to make thinking visible" decades ago (e.g., Collins et al. 1991), and how to assess students' thinking based on the outputs or "visible" products, considering that the processes in mind are not directly observable. Lewis and Smith (1993) have characterised reasoning as a "productive thinking", also conceptually supporting the view that various reasoning actions should end with a product or output.

There are various divisions of the types of thinking. For example, it can be separated into divergent and convergent thinking. Divergent thinking can be witnessed when trying to come up with several different and new ideas, while convergent thinking is trying to come up with one correct solution (Raščevska 2020). Here, we encounter the first challenge—the type of thinking (*how* to think) varies depending on the context in which one thinks and the goal of this thinking behaviour. Historically, the term "logical thinking" has also been used, based on the cognitive development approach and is considered an essential step in the development of the stages and ways of thinking. For example, in Piaget's theory the concept is rooted in the idea that the way, *how*, a person thinks changes as the person develops mentally and physically. Gradually one becomes able to reason hypothetically, that is, about abstract ideas and concepts, not only about physical, visible objects and simple classifications (Ginsburg and Opper 1988; Piaget 1964). Reasoning in highly abstract and hypothetical categories (the stage of "formal operations" according to Piaget) develops on the basis of previously developed reasoning in the stage of concrete operations. We can observe in educational curricula that the abstractness of the content also gradually increases, in accordance with the ideas of cognitive development.

Reasoning is also included in the definitions of intelligence; for example, intelligence has been defined as a general ability to reason abstractly (see Hunt 2011), and researchers use reasoning and intelligence as conceptual synonyms, as they refer to the same construct (Peng et al. 2020). Reasoning is included in the specific models of cognitive abilities as an essential cognitive ability (part of intelligence). Some of the models of cognitive abilities define reasoning as an aspect of intelligence that can be further divided and measured accordingly, as verbal, mathematical, or quantitative reasoning and visual–spatial or non-verbal reasoning (e.g., Bergold et al. 2015; Kretzschmar et al. 2017; Schneider and McGrew 2012). Another model of intelligence, the "g-VPR" model, divides cognitive abilities into verbal, perceptual, and spatial rotation abilities (Johnson and Bouchard 2005). The latter is especially important in learning areas such as natural sciences and mathematics (Newcombe 2017), since the content of these areas includes spatial awareness and the ability to rotate objects mentally (e.g., Whitehead and Hawes 2023). A unique relationship between math skills and visuospatial abilities has been found, existing independently of the student's level of other relevant cognitive abilities (Atit et al. 2022). Generally, it can be seen that the classification and arrangement of cognitive abilities in theoretical models is related both to the type of information to be processed and to whether reasoning takes place based on already acquired knowledge or in a new, unfamiliar situation by processing relatively new information. For example, verbal reasoning would typically occur when using already learned concepts and reasoning about their relationships (also in new, previously unknown situations), while non-verbal reasoning would occur when trying to understand new, previously unlearned patterns, systems, and relationships, but both of these can be considered "logical reasoning" activities, if viewed from the developmental perspective.

Another division of reasoning in psychology is the division into inductive and deductive reasoning, complemented with a concept of abductive reasoning (Josephson and Josephson 1996), or the division of reasoning into three types: inductive, deductive, and analogical reasoning (e.g., Sternberg 1977, 1986). All three reasoning processes can be activated during various school tasks. Inductive reasoning occurs by drawing a general conclusion based on a specific case—from the observed to the unobserved (Sloman and Lagnado 2005). For example, when a student infers based on a given example in the classroom. On the other hand, deductive reasoning takes place by drawing a conclusion based on true premises. Thus, when some general fact or knowledge is known, one can apply this knowledge to a specific case (Evans 2005); for example, when a student applies a known theory to a concrete task. However, abductive reasoning can be briefly explained as finding the best possible explanation, inference, or prognosis—a skill that is crucial when developing new hypotheses (Josephson and Josephson 1996), especially those used in the fields of the social sciences and history. Analogical reasoning can be explained by the process of comparing similar cases or situations and making the inference that what applies to one case will apply to the other (as an analogy). The concepts of "inductive and deductive reasoning" are explicitly integrated in the context of the "mathematical reasoning" concept (OECD 2018). Empirical studies also investigated the development of such skills in students (e.g., Soeharto and Csapó 2022), once again confirming the close bond and the importance of the reasoning concept both in the fields of psychology and education.

It must be mentioned that in psychology, reasoning can be also characterised both from the point of view of the "classical reasoning theory" and from the point of view of the dual-process theory. Within the framework of the first approach, analytical reasoning is typically measured by approaching this concept generally, without the specifics of a certain discipline. Research shows that analytical reasoning acts as a protective factor against misinformation, which is particularly relevant nowadays (Ross et al. 2021). Within the framework of the second approach (the dual-process theory of reasoning), two types of processing information that are both useful in certain situations and for different purposes are distinguished: (1) fast, unconscious, associative processing and (2) effortful, slower, and conscious processing (Kahneman 2013). For example, research in the discipline of physics has revealed that it is essential for students to purposefully develop reasoning skills and cognitive reflection, so that they can "move" from intuitive reasoning to conscious, in-depth reasoning, critically evaluating various information aspects to work with the problems in physics (Speirs et al. 2021). In addition, a lack of reasoning skills can be decisive for not being able to transfer a strategy for solving a task about already learned material to an analogous task, even if the level of content knowledge of the person is adequate (Stetzer et al. 2023). Thus, we see the importance of reasoning skills even in the near transfer. The concepts developed in psychology are applied to education; for example, in the large-scale international education project for fostering critical thinking and creativity the concept of "critical thinking" is linked to the previously mentioned "slow thinking" by Kahneman and is defined by having several sub-skills: inquiring, imagining, doing, and reflecting (Vincent-Lancrin 2023).

When performing any mental activity, such as thinking and reasoning, or learning something new, various cognitive processes are always present and active—attention, perception, memory, and language (Sternberg and Sternberg 2012). Based on the perspective of cognitive psychology, a student's basic thinking processes and the processes behind cognitive abilities do not change when moving from one lesson or study subject to another, or from one classroom to the next. For example, a student uses their working memory in an English lesson, in mathematics, and in a chemistry lesson. Similarly, a student evaluates information and uses verbally expressed and defined concepts in both the natural sciences and social sciences, involving the use of language. Anderson and Krathwohl (2001) have previously explained in detail how a student's actions are related to cognitive processes (or specific "activities")—that is, what exactly each of the reasoning actions includes cognitively in terms of what the "mind does". Some of them are obvious; for example, simple memorization requires the use of memory, but that alone is not enough. Effective learning also requires an understanding of what has been learned and the ability to transfer what has been learned from one context to another. Therefore, using one's higher-order thinking skills (analysis, evaluation, and creation) is crucial.

Reasoning at the highest level (for example, evaluating and creating conclusions or analogical thinking) is separated from basic cognitive processes (for example, attention control, working memory, and language processes) (Demetriou et al. 2023). From an empirical perspective, these basic cognitive processes are often studied under the umbrella term of "executive functions" (e.g., Miyake et al. 2000). "Reasoning", on the other hand, refers to inductive, analogical, and deductive reasoning, as well as problem solving (Demetriou et al. 2023). In this sense, the concepts overlap with the already mentioned divisions of higher-order thinking (HOT) skills, which in education are also known as the skills to evaluate, analyse, and create (based on Anderson and Krathwohl 2001) and the mentioned authors have offered extensive explanations on how cognitive activities are related to a student's skills and practical actions in a class. However, as previously discussed in the field (e.g., Richland and Simms 2015; Sternberg 1986), these ideas must be complemented by an explanation of the involved cognitive processes, adding that deductive, inductive, and analogical reasoning processes are activated during various learning activities. Wijnen, with colleagues (Wijnen et al. 2023), approached HOT skills as the ability to think critically, solve complex problems, and the ability to be creative, further referring to the complex cognitive skills as analyzing, evaluating, and creating. Based on the definition of Wijnen et al. (2023), higher-order thinking can be fostered by offering students "assignments, questions, problems, or dilemmas where students need to use complex cognitive skills (such as analyzing, evaluating, and creating) in order to find a solution or make a decision, prediction, judgment, or product" (p. 549). According to Newman (1990), higher-order thinking "challenges the student to interpret, analyse, or manipulate information" (p. 44), also conceptually overlapping with the explanation of thinking into the skills of analysis, evaluation, and creation, as Anderson and Krathwohl (2001) have discussed.

The integration of explaining students' reasoning as activating and representing the processes of inductive, deductive, and analogical reasoning (e.g., Demetriou et al. 2023; Richland and Simms 2015), when performing reasoning activities in the classroom (that include various sub-skills of analysis, evaluation, and creation), and using subject specific knowledge and skills will be used further by the authors of this paper. Thinking competences, based on these various skills taken together, become especially important in situations that are new and unprecedented, and in which it is not enough to simply repeat some memorised information (Gottschling et al. 2022). In practice, this means that these skills are essential in new learning situations and situations where one needs to be able to transfer a specific skill or strategy to another context.

As the complexity and depth of the study content increases with each school year, reasoning and HOT skills become especially important because highly complicated learning content cannot be fully learned only by memorizing or learning to perform only one kind of simple task. But the question is how exactly does reasoning vary in different study subjects or in different scientific disciplines and what are the aspects that are similar or the same? Is reasoning in mathematics entirely different from reasoning in chemistry? To explain this, we turn our discussion to the definitions of reasoning from the perspective of different disciplines in education and the sciences.

2.2. The Concepts of Thinking and Reasoning in Various Science Disciplines

In this section, the authors aim to map out the various definitions and concepts of "thinking" and "reasoning" that are relevant, exist in the education field, and describe reasoning in a certain study field or explain reasoning beyond each separate field of science. By providing this analysis, the authors address the second question posed in this article to show the overlap of the aspects of reasoning in various study fields. Further, various types of reasoning and thinking concepts in education and the science fields are listed, without claiming to provide a complete overview of the matter.

First of all, it is important to outline the broader concept of "scientific reasoning"—a specific type of reasoning that can be applied to various disciplines of science and learning. Krell et al. (2022) have already discussed the ambiguous explanations of this concept. For example, scientific reasoning can be defined as a mental process in which reasoning *about the concepts* of science, or the content of a specific science discipline takes place (for example, explaining the concept of "force" in physics). Or it can be explained as *an act of reasoning or a procedure* that is characteristic to the specific science discipline where it is used (for example, the deduction process in mathematics). Empirical research results show that students' scores on the "scientific reasoning" test at the beginning of their higher education studies are able to predict their study results later on, thus generally indicating how important it is to be able to generally reason scientifically (Sapia et al. 2022). In addition, three types of knowledge are essential in order to be able to correctly "scientifically reason"—content, procedural, and epistemic knowledge of the specific discipline (Krell et al. 2022). Thus, purely theoretically, it is assumed that there are differences in how reasoning is typically performed in the different sciences—considering both the reasoning process and the content, as well as the epistemics—the aim and means of getting to new knowledge and "discoveries" differ in the various disciplines. Many researchers study the concept of "reasoning" in education from the disciplinary perspective, thus looking at it as precisely as possible. However, this also means an isolation from the other disciplines and does not show the connection with reasoning in other disciplines. Finding commonalities would be very important from the point of view of the practical issue of the fragmented teaching of students on a daily basis.

Scientific reasoning is also referred to as a form of problem solving (Dunbar and Fugelsang 2005), meaning as a way of solving scientific problems. Within the framework of mathematical literacy, solving problems has an important connection to the ability to reason mathematically: a person is able to look at a real-life problem or a vaguely described situation and express it as a mathematical problem or mathematically, thus making it clearly solvable. The concept of mathematical reasoning is paid increasing attention within the PISA international study (*PISA 2022 framework*, OECD 2018). Mathematical literacy includes reasoning in mathematics and problem solving, which together form the capability to assess a situation, choose strategies, form logical conclusions, develop solutions, describe and justify how these solutions can be applied, as well as the actual application and evaluation of a solution. Mathematical reasoning includes both inductive and deductive reasoning, which are described in more detail in the previous section, thus directly connecting this concept to the cognitive processes of reasoning that are activated during mathematical reasoning.

Another construct that can be found in the literature is algorithmic thinking. It is defined as thinking based on concepts, principles, and approaches characteristic of computer science (Wing 2006). The main emphasis here, however, is on the thinking activities, rather than programming or any other specific computer science-related skill. Computational thinking includes a variety of activities and strategies of the mind (e.g., modelling, abstraction) (Li et al. 2020). Computational thinking as an action includes the cognitive processes with the aim of solving problems through a computational system approach (Robledo Castro et al. 2023). Computational thinking (Li et al. 2020; Wing 2006) is related to mathematics and mathematical content knowledge, but not only that. It is a skill largely related to *the way of thinking*—how an individual thinks in various areas of life—but it is especially important in the STEM disciplines for the effective development of students' skills, and especially is important in today's technology-rich world. It also includes the ability to articulate problems and precise questions to assign them to technologies such as AI programs. Computational thinking as a way of thinking and approaching problems becomes essential in the context of mathematics, where it is no longer important to only be able to perform certain types of calculations (OECD 2018).

Researchers also focus on other specific types of reasoning, based on the discipline. For example, "reasoning in biology" is distinguished, which differs not in terms of the reasoning processes or actions, but in terms of the content that is reasoned about—in this case the main concepts of biology (Schellinger et al. 2021). This again emphasizes the content through which the procedural and epistemic knowledge of the discipline can be applied. Also, the concept of "data reasoning" is considered separately as another important section of scientific reasoning (Masnick and Morris 2022) that involves reasoning about the available quantitative data (both evaluating and analysing them) in order to make further decisions or make reasonable conclusions. It has to be noted that quantitative data are widely used in various disciplines, and the data for various content can be the basis for drawing conclusions in a wide variety of disciplines—in the context of social, natural, and engineering sciences. The concept of "clinical reasoning" can be also found in the literature—a process that refers to making accurate clinical judgments, using evidence-based assessments and one's critical thinking ability during the process. Recent studies address the issue of fostering the implementation of clinical reasoning during the assessment process (Wilcox et al. 2023).

The discipline of engineering in technology nowadays includes another special and separately defined way of "thinking"—design thinking. Design thinking is defined as a specific type of thinking and the application of cognitive processes during the act of creating a design (Wrigley and Straker 2015). It is well known, but needs to be stressed once more, that the concept of "design" is understood not only as "a visual design", but also as the usability of a product or service, and the authors emphasize the difference between the terms "design" as the final product created, and "design thinking" as a process. In addition, modern ways to facilitate the better learning of design processes are also being explored (Chang et al. 2022). Design thinking is essential in the engineering discipline, which is currently defined in the Latvian education system as the discipline "Design and technology" (Cabinet of Ministers Republic of Latvia 2018). Design thinking is also essential in prototyping and testing, as well as in interdisciplinary problem solving, thus as an approach to problem solving it is emphasised as one of the teaching methods of this discipline (Wrigley and Straker 2015).

The social sciences have also turned to discipline-specific reasoning by describing "thinking historically", "historical reasoning", and other related concepts (van Boxtel and van Drie 2018). In addition, during the "Historical thinking project" the "Big six" model or the model of six concepts of historical thinking has been developed (Seixas and Morton 2012). Within the framework of this model, students' historical thinking can be developed by reasoning through the prism of six aspects (or by judging these essential aspects): (1) historical significance, (2) continuity and change, (3) an evaluation of the evidence, (4) causes and consequences, (5) the historical perspective, and (6) the ethical dimension. The authors define "historical thinking" as a creative process during which historical sources, evidence, and processes are interpreted. Historical reasoning (or reasoning that is specific to the discipline of history) is essential for students to be better able to infer information about historical events, including understanding the cause-and-effect relationships in history (van Boxtel and van Drie 2018). It is the reasoning itself that is important in order to better understand historical events, processes, and known historical facts, as well as to interpret what is currently happening in the world. Therefore, we can conclude that in the disciplines of the social sciences, the reasoning process also goes hand in hand with the content—thinking as a process closely interacts with the content that is being covered. The content knowledge and epistemic aims of the discipline are integral parts of this equation—we see that they play an essential role in learning to "reason historically". It has been recently concluded that several macro-dimensions also have to be considered in the social sciences–history discipline; for example, the ethical–political dimension (Muñoz and Balmaceda 2022).

Looking at the essence of the already mentioned specific concepts of reasoning based on the perspective of cognitive processes, it can be said that reasoning in various disciplines include analysis, evaluation, and creation processes (or activities), connecting with the ideas explained by Anderson and Krathwohl (2001), which are rooted in the well-known Bloom's taxonomy. Thus, inductive, deductive, and analogical reasoning as cognitive processes are activated and used to reach the epistemic aims of the discipline. What differs significantly from one discipline to another is the content and type of information with which and about which the reasoning activities take place, as well as the nuanced prism through which the reasoning process itself and its procedures are viewed, related to epistemics of the discipline.

From the literature on various specific types of thinking and reasoning defined in the disciplines, we can conclude that within each branch of science there are attempts to build and substantiate a theory about the reasoning that is specific to this discipline—emphasizing what is unique to the discipline and looking through the prism of this branch. There are authors, on the other hand, who try to look at the types of reasoning as a whole, arranging them in a certain structure. For example, Osborne and his colleagues explain the differences in reasoning in the sciences in their model by defining six scientific reasoning styles, which are traditionally used in different disciplines (Kind and Osborne 2017). Based on this theory, the reasoning styles characterising the different science disciplines are as follows:

1. Mathematical deduction (numerical calculation to arrive at a solution);
2. Experimental evaluation (reasoning through an experiment and its results);
3. Hypothetical modelling (theoretical modelling, simulations, etc.);
4. Categorizing and classifying (by arranging, separating);
5. Probabilistic reasoning (based on correlations, patterns);
6. Historical-based evolutionary reasoning.

Researchers have already discussed the broad spectrum of types and classifications of scientific reasoning (Krell et al. 2022), whether there are really different dimensions or aspects of scientific reasoning, to what extent it is a discipline-specific or general skill, as well as what specific skills fit into the broad concept of "scientific reasoning" and are measurable (e.g., generating hypotheses, generating evidence, evaluating evidence, and drawing conclusions) (Opitz et al. 2017). The various ambiguities have also led to difficulties in comparing and connecting different concepts of reasoning from different branches of science, as well as distinguishing what is unique in each type of reasoning (Krell et al. 2022).

What exactly is unique and what is common to reasoning in the different disciplines? One can try to look at this question from several points of view. We know that each discipline of science and learning consists of relevant content, procedural knowledge, and epistemic knowledge (see e.g., "PISA 2015 Draft Scientific Framework", OECD 2013). Therefore, we can conclude that the content about which a student is reasoning is one aspect that varies—and as we have seen, content is an essential aspect emphasised in the various definitions of "domain-specific reasoning". This is clearly the unique aspect that changes as a student "goes from one classroom to another". The typical procedures of how new knowledge is created, and how conclusions are made is the second difference, if we think specifically about the emphasis and nuances that are characteristic to one or the other discipline. The discipline-specific way in which a conclusion or "new knowledge" is arrived at, would be the third difference, which is characterised by the epistemic knowledge of the discipline and also the different style of scientific reasoning (Kind and Osborne 2017). Referring to this approach, the difference in how a researcher or a student typically reaches a conclusion in a particular discipline is clearly visible. For example, this might be through a carefully planned and implemented experiment in a chemistry lesson or through the analysis and evaluation of long-standing sources in a history lesson. The approaches are extremely different, but appropriate based on each scientific field. But the fact that the style of reasoning conceptually differs between the sciences does not mean that at the operational level the specific reasoning actions, based on the perspective of cognitive processes, do not overlap. The previously stated reasoning activities (analyse, evaluate, create) can be found in every discipline, but they are characterised by various concrete manifestations and examples, outlined by Anderson and Krathwohl (2001), and, as explained by Kind and Osborne (2017), they are characterised by the differences in the epistemic aims of each discipline.

3. Students' Reasoning in Policy Documents

The aim of this section is to assess how the terms "thinking", and "reasoning" are defined and mentioned in the various policy documents for education. The general purpose of the authors of this article is to look at how the reasoning and thinking skills that are defined in policy documents and at the global level as crucial for students are compatible with what actually happens in the classroom, in everyday school life, and in various disciplines. This challenge has already been pointed out elsewhere in the literature (Krell et al. 2022), and it was concluded in the previous section of this article that the skills related to reasoning are defined and labelled very differently—from the theoretical perspective of various study disciplines.

Countries around the world have been focusing on similar ideas (Harvard Advanced Leadership Initiative 2014), defining various thinking skills that students need to acquire. For example, *evaluating, researching, producing, generating ideas, creating, problem solving, analysing, and synthesizing* are defined, among others, in Finland (Finnish National Board of Education 2014). *Justifying strategies and conclusions, analysing, evaluating, synthesizing explaining, and generalizing* are defined in Australia (Australian Curriculum, Assessment and Reporting Authority [ACARA] 2017). *Thinking and reasoning* skills are also stressed in the OECD document "Future of Education and Skills 2030", among other crucial skills (OECD n.d.). Further, in this section we elaborate on how thinking and reasoning are defined in the policy documents specifically in Latvia.

To reach the aim of this research, the authors decided to focus in-detail on the curriculum of one country, Latvia, by analysing examples from the policy papers and detailed programs from this particular country. This was justified by the idea to further provide specific and real examples of how reasoning activities and processes can be manifested in concrete tasks for students in a classroom, based on the curriculum of this country. The curriculum content of Latvia—the programs based on the curriculum project "School2030"—were screened and analysed to search for the content, and the keywords related to reasoning and its sub-skills, as defined previously (analyse, evaluate, create). As already outlined in the introduction of this article, in the educational curriculum in Latvia, students' reasoning is most accurately reflected in the transversal skill group "Critical thinking and problem solving", and these skills, transversal in nature, can and must be developed in all the study disciplines according to the law (Cabinet of Ministers Republic of Latvia 2018). The documents also prescribe what the student should be able to do at the end of a certain learning stage. It is further explained in more detail exactly what these skills entail and how they are reflected in the policy papers.

The specific skills reflecting reasoning are defined in Latvia's education curriculum by the overarching term "critical thinking" and are divided into three aspects, linking them to the higher-order thinking skills from the previously mentioned theoretical model (Anderson and Krathwohl 2001) and similar to the other countries mentioned before:

(1) Analyse;
(2) Evaluate;
(3) Synthesize (the term “create” is used in Anderson and Krathwohl’s (2001) model; however, the term “synthesize” is used in the seminal work of Bloom’s taxonomy). This also justifies the decision of the authors of this article to further use this theoretical approach, combining it with the view that the cognitive processes of deductive, inductive, and analogical reasoning are activated during learning (Richland and Simms 2015; Sternberg 1986).

It is stipulated by the Cabinet of Ministers Republic of Latvia (2018) that a student who has completed the 9th grade (or the end of elementary school in the Latvian education system) is able to do the following using the mentioned transversal skills: “*Formulates open, knowledge-oriented questions in problem situations [..] Describes the results and one’s activity in detail and in a planned manner. Learns purposefully, analyses, evaluates and combines various types of information and situations, understands their context. Aspires to obtain comprehensive and accurate information [..] Forms logical judgments, judges from the specific to the general and from the general to the specific. Abstracts, generalizes in simple situations. Distinguish a fact-based statement from an assumption, facts from an opinion. Presents arguments and assesses their relevance. Concludes whether the reasoning is sufficient and correct. Formulates reasonable conclusions*” (Cabinet of Ministers Republic of Latvia 2018).

In addition to that, the learning objectives related to reasoning skills as a part of the transversal skills in Latvia are also defined in the documents and programs for specific subjects. For example, at the end of the 9th grade, a student must be able to “scientifically “explain” (e.g., explain various concepts, theories, and physical processes), “classify” (e.g., substances based on some criterion), “organise a justified experiment” from what one learned *in the natural sciences*, “to conclude”, to express a “phenomenon of physics with a mathematical formula” (here we clearly see an example of what the PISA 2022 means by “mathematical reasoning”), “to model”, “to represent with an equation, verbally or with models” (for example, represent the chemical process of transformations), “create research questions or hypothesis”, “analyse”, “compare”, “determine connections”, “find regularities [connections]”, etc. *in mathematics* (Project “Skola2030”, available at: https://skola2030.lv/lv/skolotajiem/macibu-prieksmeti/dabaszinibas (accessed on 30 October 2024)).

Similar key words can also be found in the learning objectives in the social and civic discipline of study (*social sciences* subject): “conclude”, “compare” (for example, compare against a criterion or based on the differences and values of different groups), “justify”, “analyse”, “evaluate” (for example, using various sources of information), “evaluate the impact on [..]”, “perceives, reveals, and analyses causal relationships in historical processes and uses them to explain social processes”, “explain”, etc. (Project “Skola2030”, available: https://skola2030.lv/lv/skolotajiem/macibu-prieksmeti/vesture, (accessed on 30 October 2024)). In the discipline of *design and technology*, the essential learning objective is “to be able to apply the design thinking process” (Cabinet of Ministers Republic of Latvia 2018).

Based on the objectives that students have to achieve and that are described in the study programs, it can be concluded that similar elements of reasoning are embedded in the policy documents defining the different disciplines of study in Latvia, confirming the overlap and the transversal nature of these skills. The next goal is to provide more specific examples of how these aspects of reasoning are manifested in the different subjects.

4. Conceptual Mapping of the Aspects of Reasoning in Different Disciplines

Previously, we presented how thinking and reasoning are positioned and defined in policy documents, particularly in Latvia, and how reasoning is characterised in the various disciplines of study and the sciences. These notions of reasoning are social constructs developed with the aim of explaining, understanding, and developing reasoning in the various disciplines of science. And yet, it is shown that, from the perspective of psychology, the cognitive processes that take place in a student's mind (for example, working memory, an analysis, or acknowledging the patterns in the given information) are the same, regardless of whether the student is in a history or chemistry classroom. The difference is in the type of information or content a student works with, the typical reasoning style characteristic of a specific science, and the way in which it is customary to arrive at knowledge. We concluded that similar and even the same aspects characterising "reasoning" and the specific processes that occur in the human mind are found in the policy documents concerning various disciplines, but the content, specific topics, and big ideas within which reasoning takes place are significantly different. In this sense, the policy documents are closer to a theoretical view of reasoning; however, the accent on the need for developing transversal skills definitely goes in the direction of interdisciplinarity.

Our goal was to break down the terms used in the education policy documents for use in daily school practices. In order to do this, the first step was to conceptually summarize and represent how the defined cognitive processes and activities of reasoning aligning with Latvia's curriculum (analysis, evaluation, creation, or synthesis) are most typically reflected in the different disciplines (see Table 1). The division of reasoning activities into the three main groups (*analyse, evaluate, and create*) in Table 1 was based on the previously described framework of HOT skills, while also taking into account that during these activities various cognitive reasoning processes are activated (such as deductive, inductive, and analogical reasoning) (Demetriou et al. 2023; Richland and Simms 2015; Sternberg 1977, 1986). Each of these skills or so-called "activities" has several sub-skills and such a division is necessary for the precise explaining and understanding of each skill. For example, "analysis" has several sub-skills: understanding the relevant constituent parts, categorizing and recognizing connections, and understanding the causal relation. Additionally, the process of visuospatial and mental rotation was added to the process with the purpose of classifying such aspects of the study disciplines that did not match the three initial groups.

The division of the disciplines in Table 1 are based on the theoretical division of the study fields, as well as the current curriculum (based on the example from Latvia). Next, the authors conceptually mapped and sorted the relevant contents found in the various discipline-based theoretical frameworks with the appropriate skill of reasoning in the table. For example, based on the framework of mathematical reasoning we can find the contents applicable to the cognitive processes of various skills: analysis, evaluation, and creation.

Table 1 confirms the overlap of the cognitive processes and reasoning activities (analysing, evaluating, creating), based on the theoretical perspectives of reasoning, among the various study disciplines (Anderson and Krathwohl 2001). The table shows that for each reasoning activity a respective approach in all the study disciplines can be found. For example, one can find the skills and processes concerning an "analysis" in each of the defined study fields: mathematics, sciences, social sciences and history, and technology. It must be noted that another important cognitive skill set (visual–spatial and mental rotation) was added to this table as we concluded that several aspects of reasoning that appear in theoretical frameworks cannot be included in any of the three reasoning activities that were initially defined (analyse, evaluate, create). However, visual–spatial skills are crucial to specific study disciplines, especially mathematics. Overall, the mapping of the concepts presented in Table 1 enables us to clearly see the interdisciplinary nature of reasoning by mapping the reasoning aspects, based on a theoretical viewpoint, and answers the second question raised by the authors of this paper.

Table 1. Conceptual framework: mapping and explaining the interdisciplinarity of reasoning skills based on cognitive processes.

Cognitive Processes	Sciences	Mathematics	Social Sciences/History	Design and Technologies/Engineering
Analyse: -understands the relevant constituent parts -categorize -recognize connections and causal relation (inductive, deductive, and analogical reasoning is activated)	-"Data reasoning" (Masnick and Morris 2022): analysing data to make grounded conclusions; -Biological reasoning: experimental evaluation relates to empirical investigations to establish patterns, differentiate objects, and test predictions (Schellinger et al. 2021); -"Categorisation and classification"; -Evolutionary reasoning—seeing connections between developments (Kind and Osborne 2017)	-Reasoning about change and relationships (PISA2022 framework, OECD 2018); -"..pattern recognition, decomposition, determining which (if any) computing tools could be employed in the analysing or solving the problem, and defining algorithms as part of a detailed solution" PISA2022 (OECD 2018); -"Computational thinking is using abstraction and decomposition when attacking a large complex task or designing a large complex system" (Wing 2006); -"Mathematical deduction" (Kind and Osborne 2017).	-Analysis of cause and consequence; -Judging about continuity and change, thus understanding individual elements and their relationships (Seixas and Morton 2012); -Argumentation through analysis (van Boxtel and van Drie 2018).	"Identify constituent parts and functions of a process or concept, or de-construct a methodology or process, making qualitative assessment of elements, relationships, values and effects; measure requirements or needs" (Wrigley and Straker 2015).
Evaluate: -evaluating info (of various types or forms) -comparison -perspective taking -making decisions (inductive, deductive, and analogical reasoning is activated)	-Experimental evaluation, e.g., in "Biological reasoning" and in other sciences (Schellinger et al. 2021; Kind and Osborne 2017); -"Data reasoning" (Masnick and Morris 2022) on available quantitative data: evaluating it to make decisions; -"Recognise, offer, and evaluate explanations for a range of natural and technological phenomena" (Scientific literacy) (OECD 2013).	-"[mathematical reasoning] includes making judgements about the validity of information that bombards individuals by means of considering their quantitative and logical, implications"; -"interpret and evaluate", "evaluate the mathematical solution"; -Reasoning about quantity [that is in basic level comparing quantity], (all from PISA2022 framework, OECD 2018).	-Evaluation of evidence; -Assessing the ethical dimension (Seixas and Morton 2012); -Historical significance: evaluation aspect of this concept (Seixas and Morton 2012); -Developing argument through evaluation (van Boxtel and van Drie 2018).	"Assess effectiveness of whole concepts, in relation to values, outputs, efficacy, viability;" -"strategic comparison and review" (Wrigley and Straker 2015) -Evaluation of prototypes.

Table 1. *Cont.*

Cognitive Processes	Sciences	Mathematics	Social Sciences/History	Design and Technologies/Engineering
Create: -hypothesising/forecasting -modelling -planning (of a research) -interpreting (inductive, deductive, and analogical reasoning can be activated during these activities)	-"Hypothesising" and hypothetical modelling (Kind and Osborne 2017); in natural sciences; e.g., as a part of "Biological reasoning" (hypothetical modelling relates to the construction of models) (Schellinger et al. 2021); -Interpreting data scientifically (OECD 2013) ("Scientific literacy").	-"Explain and predict phenomena", "formulate [real world situations] in mathematical terms"; -"Reasoning about uncertainty and data" PISA2022 (OECD 2018); -"Probabilistic reasoning" (Kind and Osborne 2017).	-Historical significance: interpreting and assigning significance to a historical process; creating the meaning within a historical narrative (Seixas and Morton 2012); -Abductive reasoning to develop hypotheses.	"Develop new unique structures, systems, models, approaches, ideas;" "Develop plans or procedures, design solutions, integrate methods, resources, ideas, parts; create teams or new approaches." (Wrigley and Straker 2015)
Other cognitive processes (Visual–spatial skills; mental rotation)	-Visual–spatial organization of elements (in Chemistry); -Visualising structures, thinking spatially (Farran 2019; Newcombe 2016).	-Reasoning about space and shape: using geometrical representations [in the mind]; -"..interpreting views of three-dimensional scenes from various perspectives and constructing representations of shapes" (PISA2022, OECD 2018); -"Spatializing the curriculum" (Newcombe 2017).	-Historical perspective—different views of event (Seixas and Morton 2012);	-Visualisation of designs, prototypes.

5. Breaking Down Students' Reasoning Skills into Processes and Outputs (Products) of Reasoning

After the theoretical mapping of the reasoning activities and their "sub-skills", presented in Table 1, the next step was to break down reasoning into more specific sub-skills or cognitive actions and their outputs, and to connect them to specific examples from various study fields. To answer the third research question proposed in this paper it was important to present these ideas from a student's perspective in classroom work, by understanding what cognitive actions and reasoning activities the student performs during a specific task under the general term "reasoning". This is important because theorists and researchers are mostly discipline-centred and not student-centred. However, we have to understand how this arrangement looks in the mind of a student that goes from one class to another and has to understand if, for example, the process of "analysing cause and consequence" in chemistry can be somehow related to "analysing causes and consequences in history". The main ideas that we considered were: *what does the student have to produce as an output* which we have defined as "a product" (e.g., written, drawn, told, or created and shown in another form) and *what processes and activities are going on in one's mind while doing that*?

The skills of thinking and reasoning should be viewed as a complex phenomenon that consists of both the reasoning process itself (and includes the already discussed cognitive processes and activities) and the result of reasoning—the final product or "the output". The product is a visible and measurable result, that is particularly relevant in the school context. The idea of defining what the outputs of reasoning processes are has been discussed before in King et al. (1998) where the importance of such "outputs" as solutions, decisions, predictions, judgments, or other products are stressed. A student's "reasoning" in their mind cannot be directly assessed until it is verbalised or otherwise made visible, as was discussed at the beginning of this article when defining the broader concept of thinking. The fact that an individual has the ability to reason is evidenced by their ability to manage an appropriate reasoning process and their ability to create an adequate product. For example, the output or product of an analysis as a reasoning activity (or process) can be a reasoned judgment that is spoken or written—and therefore, visible and assessable based on the relevant criteria. The students can explain, tell, or write how they arrived at the final result in their mind, so we can also assess their reasoning process and their train of thought. And vice versa—the teacher can directly talk about the reasoning process in order to model how to solve a specific task and reach a goal, thus enlightening the student on how to reason. In the learning process, it is important to talk and bring up the importance of both the process and the product. In other words, both the result and the process of arriving at the result are important.

Therefore, we offer a schematic representation including all the previously explained processes (we define them as "specific reasoning activities" completed by students) important to reasoning (analyse, evaluate, create), its subprocesses, and its concrete products, with examples of what exactly a student does in various subjects (see Figure 1), based on the mentioned curriculum of Latvia. In the illustration, we follow the ideas by Sternberg (1986) and Richland and Simms (2015) about how deductive, inductive, and analogical reasoning processes in the mind can be simultaneously or exclusively activated during various tasks that require students to either (1) analyse, (2) evaluate, or (3) create new information or meaning. Thus, we connect conceptual understanding and the interdisciplinary overlap shown in Table 1 to a practical-daily-lessons level. We offer a view about the processes and the end products or the visible results of reasoning that a teacher can actually see and evaluate. As already mentioned, we have kept the division of three large groups of reasoning activities: analyse, create, and evaluate, because this is aligns with both the "critical thinking" domain as it is defined in the policy documents in Latvia and the vastly used theory of thinking skills and cognitive processes essential for reasoning in the educational context (Anderson and Krathwohl 2001; Richland and Simms 2015). Further, the three broader activities of the students' thinking were broken down into the more specific activities that a student does in the learning process. When analysing the curricula in Latvia, we looked for specific examples from different study subjects, which are reflected in the illustration in the "product" section, thus providing concrete, not only hypothetical, examples of the classroom work for teachers. Naming specific products and examples was important, because various and different products (or outputs) are actually expected from the students when they perform one or another actions of higher-order thinking and reasoning.

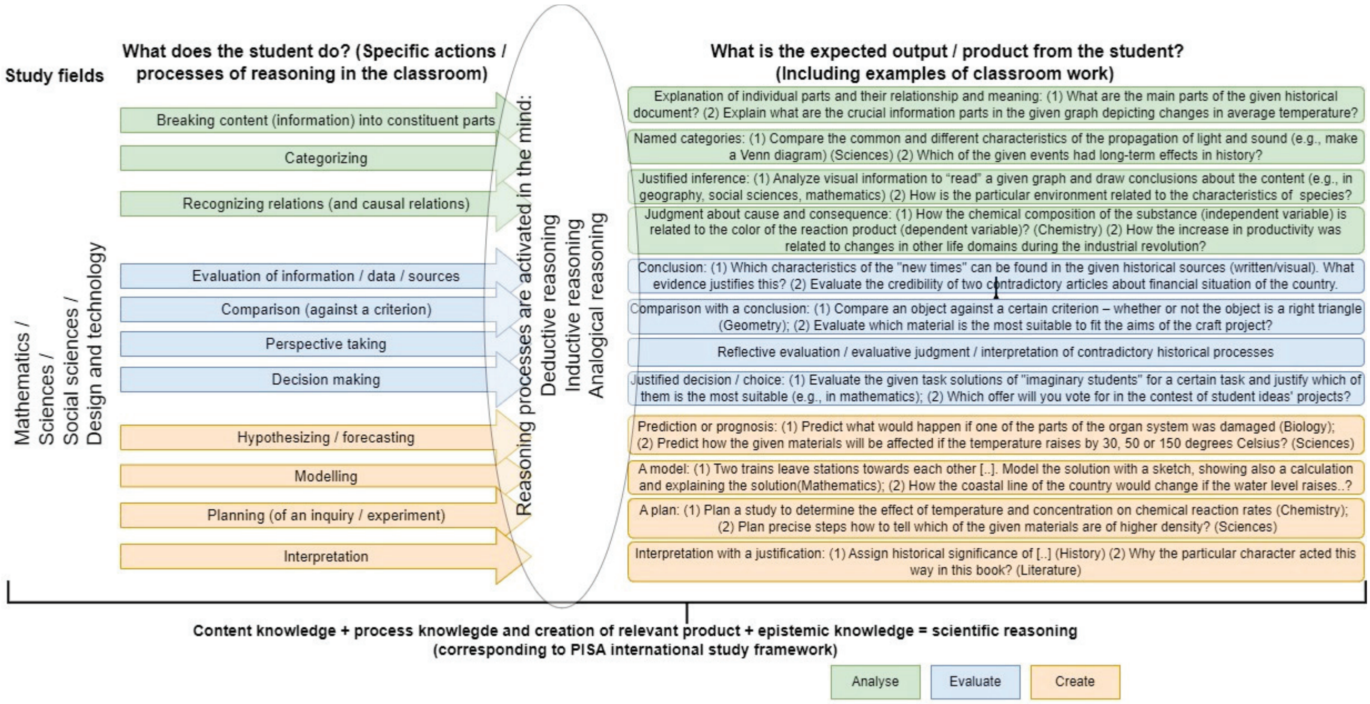

Figure 1. Reasoning activities (processes) of students and the outputs (products) of students' thinking and reasoning in various study subjects.

For clarity purposes, the students' reasoning activities belonging to each of the three previously defined types of reasoning activities (analyse, evaluate, create) are coloured in different colours, thus also visually grouping them. It has to be noted that only a selection of examples from various disciplines are presented in the "Output/product" Section to keep the figure visually comprehensible. From the examples included in the depicted structure, it can be seen how the different aspects of reasoning are reflected in the different learning areas, thus once again emphasizing the interdisciplinarity of reasoning. The examples that are added in the "Product" Section could be elaborated on and more examples could be added based on various study subjects. For example, we can find examples in school programs for a "comparison", "hypothesising", "decision making", and a "categorisation" of various subjects; however, we can conclude that some processes are typical in specific disciplines—there are some especially typical in the social sciences or in the exact sciences. For example, "perspective taking" is a typical process of reasoning that takes place in the social sciences and history; however, the "planning of an experiment" is a typical process taking place in the sciences.

Thinking and reasoning cannot be directly observed. Therefore, to be properly developed in the educational context, it is important to "make the reasoning visible" by clearly defining what reasoning processes and concrete activities are present in a student's mind and what are the outputs of these reasoning processes. By visually organizing the reasoning activities and processes and their products in Figure 1, the authors of this paper have attempted to break down the policy-level aim of "developing students' thinking" in specific activities that can be performed in the classroom.

6. Conclusions

After setting the goal of conceptually breaking down thinking and reasoning skills, it was essential to first look at the concepts of reasoning and thinking theoretically; then, to link them with a view toward the perspective of specific study disciplines; to analyse the appearance of the concepts in the curriculum of Latvia; and finally to reflect on how these aspects of reasoning are manifested in classroom activities from the students' point of view, based on what specific cognitive processes and reasoning activities are taking place in each student's mind when performing each of the activities and what thought product is expected from students.

The aim of the authors was to show how the crucial reasoning and thinking skills of students that are formulated in political documents all around the world are reflected at the operational level, i.e., how they are manifested in daily classroom work, focusing in detail on the Latvian curriculum. Specific examples from the curricula in the context of Latvian educational content were analysed focusing on reasoning in the disciplines of natural sciences, social sciences, mathematics, and design and technology. In general, it can be seen that the terms included in the policy documents can be found in more specific documents (for example, programs of the curriculum), and the framework presented here shows how to look at reasoning from the perspective of a student's thinking processes (and the concrete reasoning activities that can be performed in daily classroom work) and products. By distinguishing the reasoning activities and main skills into sub-skills and defining the processes and products of these sub-skills, the authors offer an operationalization of the general concept of "reasoning". Researchers have also tried to look for relations between the 21st century skills defined in policy documents and the actual teaching content; for example, assessing whether creative thinking skills are sufficiently reflected in it (Dilekçi and Karatay 2023).

The authors of this article wanted to explore and offer their perspective on how reasoning skills overlap in different disciplines of study, by clearly separating the specific sub-skills and activities of reasoning that are present in specific cognitive processes and linking them to theories about reasoning skills from the point of view of different disciplines. It can be concluded that, the memory process that a student constantly uses in social studies, mathematics, or any other context is the same "memory process" (referring to it as a cognitive process); similarly, the process of formulating a conclusion is similar across different subjects. What is fundamentally different is the content, the specific procedures, and the way in which conclusions are reached (for example, through a scientifically accurate, designed experiment or by evaluating a historical artifact). A connection can be drawn here to the concepts of the three essential parts of scientific reasoning, of which epistemological knowledge is one of the essential aspects (Yang et al. 2018), as well as the concept of scientific reasoning styles, which are typically characteristic and different for each of the sciences (Kind and Osborne 2017). However, these conceptual differences in *how* one comes to a conclusion in each area does not mean that at the operational level, i.e., everyday activities, students' activities and reasoning processes do not overlap. And this leads to the next challenge for researchers and practitioners—what are the most effective ways to transfer a student's acquired reasoning skills between subjects?

The connection between subjects and the necessary interdisciplinary cooperation of teachers in teaching transversal skills has already been discussed, emphasizing the need for a common theoretical understanding among teachers, as well as the use of common materials, such as reminders and performance level descriptions, in different subjects (France and Krieviņa 2022). It was emphasised that unified and explicit explanations to the students are also needed, including about what it means to analyse or conclude, and what is expected of students, linking it with what they have done previously in other lessons. This highlights the practical importance of the current paper. However, for this to be possible, close communication and mutual awareness among teachers is necessary. However, it has to be mentioned that the support for promoting discipline-specific reasoning skills is also discussed in the literature, and, for example, in the English language, several styles of reasoning are researched—genre-based reasoning, analogy-based reasoning, and language-based reasoning (Oliver and Higgins 2023). However, this division is based on the content rather than on the cognitive processes related to what is going on in the minds of studentsIn addition, the authors present several concrete tasks for thinking skills in language classes that are also successfully used in other disciplines (Oliver and Higgins 2023), actually proving that similar processes during tasks can be carried out in various disciplines. It is unlikely that we could speak of the complete transfer of skills from one area to another, but it is essential that the overlaps in a student's reasoning activities are clearly defined and recognised where they do exist. And it is important that schools also discuss this overlap at the level of daily learning and reflect it in the learning process.

By precisely defining the activities of students' reasoning processes and the expected products, the teaching of specific reasoning skills, as well as critical thinking skills in general, can be more precisely targeted in each study subject, and students' performance can be assessed more clearly, thus operationalizing it. The authors of this article illustrated how various reasoning activities can be implemented in various study subjects (based on concrete examples from the curriculum of Latvia). The authors followed the ideas of Sternberg (1977, 1986) and Richland and Simms (2015) about how deductive, inductive, and analogical reasoning processes can be simultaneously or exclusively activated during the various school tasks that require students to either (1) analyse, (2) evaluate, or (3) create new information or meaning (division by Anderson and Krathwohl 2001). It can be concluded that the schematic mapping of the overlap and manifestation of various reasoning skills in the different disciplines presented in this article justify the practical need for an interdisciplinary connection between the disciplines, as well as the need to strengthen the transfer of skills between subjects. So that the use of essentially similar cognitive skills in different subjects does not occur fragmentarily, but holistically—connecting with what has already been performed before, only in another lesson, and thus strengthening the students' competences and promoting their ability to apply their skills or critical thinking and reasoning to everyday settings.

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Assessing Students' Critical Thinking in Dialogue

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Abstract: Critical thinking has been widely considered an important skill in the 21st century. In view of the value attached to critical thinking, various quantitative instruments have been developed to assess critical thinking, which only provide a product of critical thinking and cannot reveal the critical thinking process of test takers. Hence, this paper proposes a coding scheme facilitating a qualitative analysis of critical thinking exhibited in interaction. The coding scheme consists of five categories of critical thinking skills, i.e., analysis, comparison, evaluation, inference, and synthesis, each of which is coded at low, medium, and high levels. The use of this coding scheme is then illustrated by applying it to authentic classroom dialogue. This coding scheme is hopefully conducive to the assessment of critical thinking in educational settings.

Keywords: critical thinking; assessing; qualitative; dialogue

1. Introduction

Critical thinking has been widely considered as an important skill for success in learning, working, and life in the 21st century (Angeli and Valanides 2009; Halpern 2014; Paul 1993; Rear 2019; Teo 2019). Characterized by a list of skills and dispositions (Ennis 1987), critical thinking helps individuals avoid being egocentric (Wright 2002), enables individuals to think independently and guard against being manipulated (Vieira et al. 2011), and mediates the relationship between essential skills, such as algorithmic thinking, creativity, digital literacy, and effective communication, and problem solving (Kocak et al. 2021). Furthermore, critical thinking is related to ethics. A critical thinker will not confine his thinking only to his own interests but consider the interests of all related persons (Paul 1993). Critical thinking is arguably more and more important with the advances in online technologies such as ChatGPT (Dumitru and Halpern 2023).

Given all these values attached to critical thinking, it has seized significant and sustained scholarly attention. The intellectual interest in critical thinking can be traced back to Socrates, who "ask[ed] probing questions in an effort to expose the values and beliefs which frame and support the thoughts and statements of the participants in the inquiry" (Reith 2003, p. 1). This critical spirit was inherited and passed down to scholars over the generations such as Plato, Kant, Marx, and Dewey (Coney 2015; Vieira et al. 2011). Though Dewey is widely recognized as the father of modern critical thinking with his concept of 'reflective thinking' (Fisher 2011; Sternberg 1986), it was Edward Glaser who stoked the academic enthusiasm for critical thinking with his 'Experiment in the Development of Critical Thinking' (Glaser 1941; Paul 1985, 1993). This renewed interest in critical thinking culminated in the so-called 'critical thinking movement' (Paul 1985) in the 1980s and the inclusion of critical thinking in 21st century skills (Hilliker and Loranc 2022; Partnership for 21st Century Skills 2006; Taar and Palojoki 2022).

In line with this intense interest in critical thinking, educational researchers and practitioners have been proposing and experimenting with ways of developing students' critical thinking in the classroom. For example, Mercer and his colleagues have proposed the practice of 'thinking together' to promote students' critical thinking in 'exploratory talk'

(Mercer 1995). In contrast to 'disputational talk' (in which students only talk to dispute with each other without making constructive contributions) and 'cumulative talk' (in which students uptake others' contributions without any critique), exploratory talk encourages students to engage in constructive critique of one another's ideas and thus engages students in collective thinking and critical thinking (Mercer 1995; Mercer and Littleton 2007). Other scholars have also agreed that classroom dialogue is a viable avenue for students to practice and develop critical thinking (Alexander 2006; Barnett and Francis 2012; Brookfield 2011).

Considering the value of dialogue in the development of critical thinking, there is a pressing need for the evaluation of critical thinking in dialogue. Currently, such assessment tools are scarce in spite of a myriad of standardized tests for the purpose of education and recruitment, such as the Watson-Glaser Critical Thinking Appraisal (Watson and Glaser 1980), the California Critical Thinking Skills Test (Facione et al. 1998), the Cornell Critical Thinking Tests (Ennis et al. 1985), the Halpern Critical Thinking Assessment (Halpern 2007), and the HEIghten Critical Thinking Assessment (Liu et al. 2018). Moreover, these standardized tests only provide a product of critical thinking and cannot give us a glimpse of the critical thinking process of test takers. There are also some concerns about the validity of such standardized tests as critical thinking is sometimes viewed beyond precise quantification and measurement (Frisby 1991) and about their reliability since some test takers can fake on these tests by answering in a way that does not reflect their true opinion but makes them seem like a critical thinker (Silva 2009).

Hence, this paper proposes a coding scheme of critical thinking, initially developed for the analysis of classroom dialogue yet potentially useful for analyzing qualitative data in many other contexts, such as dialogues in everyday life.

2. Conceptualization of Critical Thinking

Although critical thinking has been discussed for centuries and has been gaining traction in the current educational landscape across the globe, there is little consensus over the definition of this multifaceted and elusive construct. Numerous definitions have been given to the term critical thinking. For example, McPeck (1981) suggested that "critical thinking is the appropriate use of reflective scepticism, and that this is necessarily linked with specific areas of expertise and knowledge" (p. 19). Ennis (1987) defined critical thinking as "reasonable reflective thinking that is focused on deciding what to believe or do" (p. 10). Paul and Elder (2012) defined critical thinking as "thinking explicitly aimed at well-founded judgment, using appropriate evaluative standards in an attempt to determine the true worth, merit, or value of something" (p. xxv). Halpern (2014) defined critical thinking as "the use of those cognitive skills or strategies that increase the probability of a desirable outcome…in solving problems, formulating inferences, calculating likelihoods, and making decisions" (p. 8). To Dumitru and Halpern (2023), critical thinking "encompasses intellectual skills such as reflection, self-regulation, analysis, inference, explanation, synthesis, and systematic thought" (p. 3).

There is also a lack of consensus on the nature of critical thinking. Some (e.g., Petress 2004; Vaughn 2005) believe that critical thinking involves following certain procedures and satisfying some criteria. Lipman (1988), for example, thinks that critical thinking is "skillful, responsible thinking that facilitates good judgment because it (1) relies upon criteria, (2) is self-correcting, and (3) is sensitive to context" (p. 39). Others view critical thinking as more a form of 'knowing how' than a form of 'knowing that', more "a possession of certain skills" (Mulnix 2012, p. 468) than a possession of certain knowledge. This is why Paul (1990) disagreed when McPeck (1990) argued that training of critical thinking skills does not work since critical thinking needs subject knowledge and therefore cannot be transferred across disciplines. This is echoed by Rickles et al. (2013), who believe that "critical thinking can be conceived of as a skill or a process, rather than a body of knowledge" (p. 272). However, Willingham (2007) pointed out that "critical thinking does not have certain characteristics normally associated with skills, in particular being able to use that skill at any time" (p. 15). He explained that a new skill such as reading music is available for use at any time after it has been learned, but critical thinking is not the case. Even after extensive training, people may still fail to become critical thinkers.

Such disagreements are due partly to the fact that discussions about critical thinking are rooted in different disciplines. There are three main disciplines in which critical thinking has been conceptualized, i.e., philosophy, psychology, and education (E. Lai 2011). The philosophical approach focuses on the qualities of ideal critical thinkers and their thoughts; the cognitive psychological approach focuses on the behaviors of critical thinkers and procedures of critical thinking; and the educational approach focuses on fostering learners' skills necessary in solving problems and making decisions (E. Lai 2011; Sternberg 1986).

This lack of consensus on the conceptualization of critical thinking is also a result of three different perspectives towards the nature of critical thinking as trait, emergent, and state (Halonen 1995). Researchers adopting a trait perspective interpret critical thinking as an inherent disposition to think critically; the emergent perspective suggests that children's critical thinking abilities emerge naturally during their interaction with the environment; and the state perspective explicitly regards critical thinking as a set of skills and abilities (Halonen 1995). Though different in nature, these three perspectives of critical thinking seem not to be mutually exclusive but complementary, as they stress different aspects of critical thinking. The trait perspective focuses on the trait or disposition of critical thinking, while the emergent and state perspectives focus on the abilities or skills of critical thinking. The abilities of critical thinking may be latent or manifest, which are explained by the emergent perspective and the state perspective, respectively. The latent critical thinking abilities refer to individuals' potential for critical thinking as a result of natural development, which relies little on instruction, while the manifest ones refer to individuals' abilities to employ and exhibit their latent critical thinking abilities, which may develop as a result of instruction.

Therefore, at the heart of the three perspectives on the nature of critical thinking is the differentiation between critical thinking disposition and critical thinking abilities. According to Watson and Glaser (1980), critical thinking is "a composite of attitudes, knowledge, and skills" (p. 1). Many other scholars also agree that critical thinking is composed of both disposition and skills (Ennis 1987; Facione 2000; Paul and Elder 1997). Hence, critical thinking arguably has a dual nature, one that is relatively static and the other more dynamic: (1) the disposition of critical thinking that is relatively stable and less susceptible to change; (2) the abilities of critical thinking that are susceptible to change as a consequence of environmental impact or formal instruction.

Recently, there is a holistic and integrated view in which critical thinking is a composite of skills, dispositions, and action in disciplinary contexts (Yuan and Liao 2023). Conceptualized in this way, critical thinking is not merely limited to certain skills and dispositions but "embraces an action orientation with an overriding focus on changes and transformation within individuals' situated realities" (Yuan and Liao 2023, p. 545). Therefore, critical thinking is closely linked to critical pedagogy, and the goal of critical thinking is not just cognitive enhancement but social change.

3. Assessment of Critical Thinking

Various tools have been developed to assess critical thinking (Butler 2024; Fisher and Scriven 1997; Liu et al. 2018). Some, such as the California Critical Thinking Disposition Inventory (Facione et al. 2001), aim to assess critical thinking disposition, that is, to test a person's tendency to think critically, while others are used to assess critical thinking abilities, that is, to test a person's actual performance or application of critical thinking.

The Watson-Glaser Critical Thinking Appraisal (WGCTA) is perhaps one of the most widely used examples of the latter. Using 80 items, or 40 items in the short form, the WGCTA assesses five critical thinking abilities: making inference, recognizing assumptions, making deduction, interpreting arguments, and evaluating arguments (Watson and Glaser 1980). In the WGCTA, examinees are asked to read a number of scenarios of statements, arguments, or problems, each of which is followed by a list of items in the form of inferences, assumptions, deductions, conclusions, and arguments. The examinees have to make a specific judgment of these items on the basis of each scenario, and these judgments are then scored so as to numerically gauge their five critical thinking abilities. A similar standardized measurement is the California Critical Thinking Skills Test, which assesses critical thinking on six scales: analysis, evaluation, inference, deduction, induction, and overall reasoning skills (Facione et al. 1998). By generating a score, these assessment tools are useful for quantitatively measuring and ranking critical thinking abilities. Furthermore, these instruments are not context-dependent and can therefore be applied in various contexts.

However, a number of researchers harbor reservations about the use of such quantitative instruments in educational establishments due to several reasons. First, these instruments do not consider contextual factors such as classroom conditions, which may compromise their validity (Norris and Ennis 1989). Second, they only measure the product of critical thinking and pay little attention to the process of critical thinking (Norris 1985). In other words, a score yielded by these quantitative instruments only indicates whether or to what degree a person thinks critically, but not how a person thinks critically. Third, they fail to detect students' growth or development in critical thinking abilities (McMillan 1987).

In view of these limitations of tools that focus exclusively on the product of critical thinking, a more qualitative approach to the assessment of critical thinking is sometimes preferred. The authenticity and depth of qualitative data may entail creating a naturalistic and information-rich environment that is conducive to studying the manifestation of critical thinking and hence allows researchers to gain more insights into the complex nature of critical thinking.

There are different forms of qualitative assessment available in educational settings. White et al. (2011) used open-response questions asking students to handle, interpret, and analyze a set of complex and conflicting data so as to test science students' critical thinking abilities to deal with conflicting data, resolve research ambiguity, and conjecture different interpretations of the same data. Argumentative writing (Stapleton 2001) and online discussion (K. Lai 2012) were also used to assess students' critical thinking. For instance, Stapleton (2001) asked students to write argumentatively in response to a provocative essay, and these writings were then judged in terms of critical thinking based on five elements: arguments, evidence, opposite viewpoints, refutations, and fallacies. K. Lai (2012) utilized online discussion to evaluate her students' critical thinking by asking her students to discuss a selected text and then assessing these discussions based on certain criteria of critical thinking skills. Tsui (1998) also suggested that classroom observation, which has been largely neglected, should be adopted since this qualitative method enables a researcher to examine and evaluate the process of students' critical thinking.

Few methods have been proposed yet to systematically analyze students' critical thinking exhibited in classroom interaction, which is a fitting venue for the observation and development of students' critical thinking. One exception can be found in Fernandes et al. (2024), who developed an analytical framework of critical thinking to evaluate the effects of a teacher's facilitation in an English listening and speaking classroom. This analytical framework focuses on five types of students' practices that are believed to facilitate the development of students' critical thinking, i.e., to evaluate and determine the credibility of given information, to find and generate key ideas from given information, to embark and clarify key ideas, to organize and manage given information, and to analyze and synthesize given information. Each of the five practices will be evaluated in terms of its clarity, relevance, depth, and coherence. However, this analytical framework does not attempt to differentiate the levels of students' critical thinking. Hence, our purpose in this research is to propose a coding scheme to facilitate a qualitative assessment of critical thinking abilities in dialogue.

4. A Coding Scheme of Critical Thinking

In spite of some coding schemes for analyzing dialogue, few are specifically devoted to critical thinking. For example, the Conversational Argument Coding Scheme developed by Seibold and Meyers (2007) is mainly focused on argument, while Multiple Episode Protocol Analysis (MEPA) developed by Erkens (2005) is used to code dialogue acts. Hence, our study is aimed at developing a coding scheme specifically targeted at critical thinking. This coding scheme includes five skills of critical thinking, i.e., analysis, comparison, evaluation, inference, and synthesis, which have been widely acknowledged as being the most important critical thinking skills (e.g., Coon and Mitterer 2010; Dwyer et al. 2014; Ennis 1987; Facione 1990). Among these five skills, analysis, inference, and evaluation are regarded as the core skills of critical thinking (Dwyer et al. 2014; Facione 1990). Paul and Elder (2012) also agree that critical thinking is analytical, inferential, and evaluative thinking. In particular, evaluation is at the heart of critical thinking, and it is not an overstatement to say that critical thinking is evaluative thinking (Facione 1990; Yinger 1980; Young 1980). Critical thinkers evaluate not only other persons' ideas and thoughts but also their own thinking. This means that the skill of evaluation has an aspect of reflection, which aligns with Ennis' (1987) definition of critical thinking as "reasonable reflective thinking that is focused on deciding what to believe or do" (p. 10). Comparison is also an important critical thinking skill, as a critical thinker will weigh up the advantages and disadvantages of an idea or issue and compare multiple perspectives and ideas (Moon 2008; Phillips and Bond 2004). Synthesis is important considering that critical thinking is "an orientation to transform learning and society" (Benesch 1993, p. 546). That is, critical thinkers not only critique others' ideas but also provide an alternative. This alternative is not created solely based on critical thinkers' thoughts but a result of collective intelligence/thinking. It is building on others 'thinking, or an extension of others' thoughts. In other words, critical thinkers synthesize others' ideas based on their evaluation and the available information (Jacobs et al. 1997).

Some models of critical thinking (e.g., Facione 1990) also regard mental activities such as understanding, comprehension, and interpretation as a sub-skill of critical thinking. It is true that critical thinking would be like a castle in the air without these basic skills. If these basic skills were included, however, critical thinking would be arguably equivalent to thinking in a general sense (Dwyer et al. 2014). Thus, basic skills such as understanding, comprehension, and interpretation were not included in this coding scheme for critical thinking. In this coding scheme (see Table 1), each skill can be manifested in student talk on three levels, that is, low level, medium level, and high level.

When using this coding scheme to code student talk in terms of critical thinking, the coder should first of all examine whether the students have made an attempt at critical thinking so as to distinguish student talk with critical thinking from student talk with no critical thinking. That is, if students display an awareness of critical thinking and attempt to analyze, compare, evaluate, infer, or synthesize, their talk would be deemed to have demonstrated critical thinking. For student talk with a display of any of the five critical thinking skills, the coder would then evaluate the level of these skills.

Table 1. Coding scheme for critical thinking.

Category	Code	Description
Analysis	Al	Students manage to break down information, issues, opinions, ideas, or arguments into their organic constituent elements or to identify/establish their relationships. But their analysis is not deep either because they treat the information, issues, opinions, ideas, or arguments superficially or because the information, issues, opinions, ideas or arguments are so simple that no sophisticated analysis is needed and hence manifested.
	Am	Students succeed in breaking down information, issues, opinions, ideas, or arguments into their organic constituent elements or to identify/establish their relationships. Their analysis is deeper than the low-level analysis, but it still has some problems.
	Ah	Students succeed in breaking down information, issues, opinions, ideas, or arguments into their organic constituent elements or identifying/establishing their relationships. And their analysis is deep and clearly expressed.

Table 1. *Cont.*

Category	Code	Description
Comparison	Cl	Students manage to identify similarities or differences among different information, issues, opinions, ideas, or arguments. But their comparison is not deep either because they treat the information, issues, opinions, ideas or arguments superficially, or because the information, issues, opinions, ideas, or arguments are so simple that no sophisticated comparison is needed and hence manifested.
	Cm	Students succeed in identifying similarities or differences among different information, issues, opinions, ideas, or arguments. Their comparison is deeper than the low-level comparison, but it still has some problems.
	Ch	Students succeed in identifying similarities or differences among different information, issues, opinions, ideas, or arguments. And their comparison is deep and clearly expressed.
Evaluation	El	Students manage to judge the credibility, validity, value or significance of information, issues, opinions, ideas, or arguments. But their evaluation is not deep either because they treat the information, issues, opinions, ideas, or arguments superficially or because the information, issues, opinions, ideas, or arguments are so simple that no sophisticated evaluation is needed and hence manifested.
	Em	Students succeed in judging the credibility, validity, value or significance of information, issues, opinions, ideas, or arguments. Their evaluation is deeper than the low-level evaluation, but it still has some problems.
	Eh	Students succeed in judging the credibility, validity, value, or significance of information, issues, opinions, ideas, or arguments. And their evaluation is deep and clearly expressed.
Inference	Il	Students manage to draw logical conclusions from information, observation, experience, judgment, theory, or hypothesis. But their inference is not deep because they treat the information, observation, experience, judgment, theory, or hypothesis superficially.
	Im	Students succeed in drawing logical conclusions from information, observation, experience, judgment, theory, or hypothesis. Their inference is deeper than the low-level inference, but it still has some problems.
	Ih	Students succeed in drawing logical conclusions from information, observation, experience, judgment, theory, or hypothesis. And their inference is deep and clearly expressed.
Synthesis	Sl	Students manage to combine information, opinions, ideas, or arguments from diverse sources to create a new opinion, idea or argument. However, it is not deep either because they treat the information, opinions, ideas, or arguments superficially or because the information, opinions, ideas, or arguments are so simple that no sophisticated synthesis is needed and hence manifested.
	Sm	Students succeed in combining information, opinions, ideas, or arguments from diverse sources to create a new opinion, idea, or argument. Their synthesis is deeper than the low-level synthesis, but it still has some problems.
	Sh	Students succeed in combining information, opinions, ideas, or arguments from diverse sources to create a new opinion, idea, or argument. And their synthesis is deep and clearly expressed.

When deciding the level of critical thinking displayed in student talk, the factor of depth is taken into consideration. It is concerned with whether a student's critical thinking is superficial or sophisticated by reference to the logic and the contextual information.

5. Applying This Coding Scheme to Authentic Student Talk

In order to assist the understanding of this coding scheme and better illustrate its application in specific classroom dialogue, the five skills of critical thinking, i.e., analysis, comparison, evaluation, inference, and synthesis, are defined in reference to the various literature, such as Dwyer et al. (2014), Ennis (1987), and Facione (1990). Following that, excerpts of authentic classroom dialogue are taken from a large project on Chinese college students' English classroom talk to exemplify the analysis of the five skills of critical thinking exhibited in student talk. In this English classroom, these Chinese students, around the age of 18, participated in English dialogues based on some texts on certain topics in order to improve their English proficiency as well as their thinking skills.

The unit of analysis when coding students' critical thinking displayed in these classroom excerpts is the individual discourse move "defined as a single utterance or a string of uninterrupted utterances with a common function", which is commonly employed as the unit of analysis in the study of classroom discourse (Lefstein et al. 2015, p. 870).

5.1. Analysis Exhibited in Student Talk

Analysis refers to the ability to break down information, issues, opinions, ideas, or arguments into their organic constituent elements or to identify/establish the relationships among information, issues, opinions, ideas, or arguments (Dwyer et al. 2014; Ennis 1987; Facione 1990).

Low-level analysis can be found in Excerpt 1, when the teacher asked students to come up with some important skills in the 21st century.

Excerpt 1

Turn	Speaker		Code
1	T:	Anything else [that is important in the 21st century]? (Silence for 9 s)	
2	Si Mei:	Reading skill.	
3	T:	Reading skill. Why do you think reading skill is important?	
4	Si Mei:	People need reading skill not only reading books but also reading people's mind.	Al

In this excerpt, Si Mei demonstrated her skill of analysis when asked to explain the importance of reading skill. It can be noticed from her reply in Turn 4 that Si Mei first of all broke the issue of reading skill into different constituent parts, i.e., reading books and reading minds, and emphasized the part of 'reading people's minds' by means of the syntactic structure 'not only. . . but also. . .'. Thus, Si Mei's talk in Turn 4 revealed her effort to make an analysis of the importance of reading skills. However, such analysis was not deep since Si Mei did not elaborate on the role of reading skill in reading books and people's minds and failed to focus her explanation on the specific role of reading skill in the 21st century. She could have raised the level of her analysis if she had pointed out why reading minds was needed for people and why such a skill was especially important in the 21st century. With such elaboration, a clearer relationship between reading skill and the 21st century would be established, and thus a higher level of critical thinking in terms of analysis would be displayed.

In comparison, Excerpt 2 provides an example of students' analysis at a higher level.

Excerpt 2

Turn	Speaker		Code
1	T:	What are you afraid of?	
2	He Wei:	I'm afraid of talk face to face with the opposite sex. The reasons are the following. Firstly, I'm very shy. I don't like talk with others, especially the opposite sex. I have little chance to talk with girls from childhood. Secondly, I lack confidence. The ways of overcoming these are as follow. First, I should talk with the opposite sex more. Second, I should lift up my confidence. Last but not the least, I should take part in many events to talk with people.	Am

In this excerpt, He Wei demonstrated his skill of analysis at a high level by breaking down the issue of fear of talking with girls. In his analysis, he identified the reasons for such fear and solutions to overcome it by establishing causal relationships between the issue of fear of talking with girls and the factors that he had argued. In other words, he first of all separated the issue of his fear of talking with girls into its constituent parts and focused to scrutinize its reasons and solutions. Then he related such fear to various factors, among which shyness, diffidence, and little practice were identified as factors attributing to his fear of talking with girls. His analysis was deep in terms of his elaboration on these factors and clearly expressed in terms of his use of such words as 'reasons' and 'ways' as well as the discourse markers such as 'firstly' and 'secondly'. However, He Wei's analysis still has some problems. For example, the reasons he offered were not specifically for the fear of talking with girls but for the fear of talking with people. Therefore, He Wei's talk in Turn 2 displayed his skill of analysis at a medium level.

5.2. Comparison Exhibited in Student Talk

Comparison is the ability to identify similarities or differences between different information, issues, opinions, ideas, or arguments (Ennis 1987; Facione 1990). Excerpt 3 is an example of students' comparison at a low level. Based on a text about traveling solo, the talk in this excerpt followed Li Jun's interpretation of the meaning of Paragraph 7 in this text.

Excerpt 3

Turn	Speaker		Code
1	T:	OK. According to you and your group members, the author [in Paragraph 7] wants to demonstrate that culture sometimes is able to be reflected from the way they made contact with others. Right?	
2	Li Jun:	Yes.	
3	T:	OK.	
4	Li Jun:	Paragraph 9, I think the meaning is the same with Paragraph 7 because I think different place has different understanding. And maybe the people in the Italy think they take their serving for granted, but in China the local people think they want to dedication. So I think the meaning is same with Paragraph 7	Cl

In Turn 4, Li Jun made an attempt to point out the similarity between Paragraph 7 and Paragraph 9 in terms of their meaning. Such an attempt at comparison was especially commendable considering that Li Jun spontaneously made such a comparison between the two paragraphs. Although only asked to interpret the meaning of Paragraph 7, Li Jun went a step further to compare it with Paragraph 9, probably trying to validate his interpretation of Paragraph 7. However, despite his effort, Li Jun's comparison in Turn 4 was not deep since he made no attempt to identify any differences between the two paragraphs. Furthermore, his comparison was not clearly expressed since it was difficult to understand from his comparison the meaning of Paragraph 9 and the similarities between the meaning of Paragraph 7 and Paragraph 9. Hence, Li Jun's comparison displayed in Turn 4 was only at a low level.

Excerpt 4 is an example of a medium-level comparison in which Wang Chen was asked whether physical injury or psychological trauma sustained in a war is more severe.

Excerpt 4

Turn	Speaker		Code
1	Wang Chen:	We think psychological trauma is more damage than physical injury. Because physical injury can be cured but psychological trauma never disappears. And psychological trauma can cause physical injury. They may hurt themselves when they suffer the pains from the war. And psychological trauma may have bad influence on their family and friends who are familiar with them. When a war breaks out, it will bring the fear to the people. So we think the psychological trauma is more damage than physical injury.	Cm
2	T:	OK. Good, very good. I totally agree with one sentence you have mentioned. Psychological trauma can also lead to physical injury. They may hurt themselves, they may hurt others. Right? They may hurt others. Since there are so many cases in the real life, there is no need for us to give any example to demonstrate.	

In Turn 1, Wang Chen made a deep comparison between physical injury and psychological trauma caused by war by identifying the differences between the two kinds of war damage on three aspects. The first aspect was the curability. She asserted that physical injury can be cured but psychological trauma cannot. The second aspect she compared was their mutual relationship. Wang Chen pointed out that psychological trauma can result in physical injury since victims of psychological trauma may hurt themselves. Third, she compared their influence on other people. She highlighted the negative influence of a person's psychological trauma on their family and friends.

The depth of Wang Chen's comparison is reflected not only in the number of differences between physical injury and psychological trauma but also in the significance of these differences. The differences in the three aspects are critical rather than trivial between the two kinds of war damage. According to Wang Chen, there is a causal relationship between psychological trauma and physical injury. Since psychological trauma can cause physical injury, it is a more severe damage compared to physical injury. The third aspect of comparison (negative influence on others) reflects the potential damage of psychological trauma and physical injury on society.

Though Wang Chen's comparison is deep, it still has some problems. When comparing the curability of the two types of war damage, Wang Chen was not persuasive to say that physical injury can be cured while psychological trauma cannot. Such a statement is not applicable in all cases since some physical injuries, such as loss of limbs, are permanent, while some psychological trauma can be overcome with therapy and counseling over time. In such cases, it may be inaccurate to say that psychological trauma is more damaging than physical injury. It is also fallacious to assume that the causal relationship between psychological trauma and physical injury is unidirectional. Based solely on the common life experience, 'once bitten, twice shy' for example, it is not difficult to realize that physical injury can result in psychological trauma as much as the other way around. In other words, psychological trauma and physical injury go together in certain cases. In this regard, it is difficult to say from this comparison which one of them is more severe. As for the third aspect of her comparison, Wang Chen also was not accurate to emphasize the negative influence of psychological trauma on other people while ignoring the negative influence of physical injury. Both psychological trauma and physical injury of war victims can negatively influence people around them, subjecting others to unpleasant or even dangerous situations. Thus, comparing the two types of war damage in this way cannot help one decide which one is more harmful. From the above analysis, it can be seen that Wang Chen's comparison was only at a medium level.

5.3. Evaluation Exhibited in Student Talk

Evaluation, a skill sitting at the heart of critical thinking (Yinger 1980; Young 1980), refers to the ability to judge the credibility, validity, value, or significance of information, issues, opinions, ideas, or arguments (Dwyer et al. 2014; Ennis 1987; Facione 1990).

The following excerpt is an example that demonstrates students' low-level evaluation. This excerpt was situated in a whole-class discussion of various characteristics of a job, such as job pay, job location, and the prospect of promotion. The discussion was preceded by a pair interview in which two students interviewed each other to find out which job characteristic was the most important factor to consider when seeking a job. After the pair interview, the teacher asked some students to share what they had found out from their interview. For example, before this excerpt, a student, Meng Jia, shared his choice of pay as the most important factor to consider during his job selection. His rationale for such a choice was that he needs money to support his family since he, as a man, should be the breadwinner in his family. Excerpt 5 started with the teacher's elicitation of Sui Rui's own attitudes towards those job characteristics.

Excerpt 5

Turn	Speaker		Code
1	T:	OK. How about yourself?	
2	Su Rui:	I think the job pay and responsibility is the most important because I want to make my finance independent.	El
3	T:	Financial situation.	
4	Su Rui:	Financial independence. For example, he thinks, I think woman could be independent in the family, so. . . (Here 'he' refers to Meng Jia who said earlier that men should earn money to support the family.)	El
5	T:	(interrupting Su Rui) You don't agree with him.	
6	Su Rui:	Yeah. I don't agree with him. If you have more responsibility, you have to be more seriously and maybe more stress. If I have the responsibility, I will try my best. If it's beyond my responsibility, I will not. I will have too much stress.	El

In this excerpt, Su Rui was asked about the most important job characteristic to her after she shared the choice of her interviewee. Her reply demonstrated her skill of evaluation in two instances. In the first instance, Turn 2, Su Rui deemed pay and responsibility to be the most important factors when seeking a job, and she also tried to justify such an evaluation. In another instance in Turn 4, Su Rui exhibited this skill by evaluating Meng Jia's opinion. In this turn, she argued that women could also be financially independent in their family if their pay was good, and therefore Meng Jia's opinion that men should be the primary, if not the sole, bread earner for their family was wrong.

Despite Sui Rui's attempt to evaluate, her evaluation was not deep and well supported. Her evaluation of the significance of pay and responsibility in Turn 2 was not supported by her statement that she wanted to be financially independent, which shows that the evaluation exhibited in Turn 2 was only at a low level. In Turn 4, Su Rui's evaluation of Meng Jia's opinion was also at a low level since her evaluation was not well supported. As can be seen in this turn, Su Rui's rationale for her evaluation of Meng Jia's opinion was that women could be financially independent with a well-paid job. This can be put in the form of an argument, that is, Meng Jia was wrong to say that men should be the bread earner in the family because women could be financially independent with a well-paying job. In this argument, the reason seems not sufficient to arrive at the conclusion since Meng Jia was talking about men's (and hence suggesting women's) responsibility of earning money while Su Rui was talking about women's ability to earn money.

The disconnect between the reason and the conclusion in Su Rui's argument might not be a result of her lack of reasoning but rather a result of her neglect of repairing her reasoning chain. A closer look reveals that Su Rui was interrupted by the teacher in Turn 4 before aligning herself with what the teacher elicited in Turn 5, that is, the evaluation of Meng Jia's opinion. Su Rui explicitly expressed her evaluation, or her disagreement in this instance, only after the teacher's elicitation for clarification in Turn 5. In other words, Su Rui's evaluation in Turn 6 might not be what she initially wanted to say. She did attempt to make a conclusion in Turn 4, which was indicated by the reasoning word 'so', before she was interrupted by the teacher. After the sidetrack, Su Rui did not justify her evaluation or resume the chain of her reasoning about pay and financial independence. Consequently, her claim of her disagreement with Meng Jia was left without solid support.

Students' low-level evaluation can also be illustrated in Excerpt 6, a conversation between the teacher and a student with regard to an idea proposed by other students.

Excerpt 6

Turn	Speaker		Code
1	T:	As this group and that group have mentioned, they are afraid of snakes. So they try to get more exposure to snakes. Is it a good method of overcoming fear? If you are afraid of something, you should try to get more exposure to it. Is it useful?	
2	Xue Hua:	I think it is not useful. If you are afraid of snakes, it is bad to play with snakes. Sometimes you will feel more fear than before.	El

In Turn 2, Xue Hua made an evaluation that the idea of overcoming fear of something by means of more exposure to it was not valid. She also tried to justify her evaluation by pointing out the danger of this idea. Although Xue Hua demonstrated her attempt to evaluate, her evaluation was not well justified. Since being exposed to snakes can take many forms, such as observing them from a safe distance in a zoo or even watching educational documentaries, it is not necessarily 'playing with snakes' as discussed by Xue Hua. Therefore, Xue Hua's argument about the danger of playing with snakes cannot justify her evaluation that overcoming fear of something by means of more exposure to it is not useful.

5.4. Inference Exhibited in Student Talk

Inference is another core critical thinking skill, which means the ability to draw logical conclusions from information, observation, experience, judgment, theory, or hypothesis (Dwyer et al. 2014; Ennis 1987; Facione 1990).

In Excerpt 7, when asked about the relationship between Steven Spielberg and his father, a student made a low-level inference based on the information provided in the text.

Excerpt 7

Turn	Speaker		Code
1	T	What is the relationship between Steven Spielberg and his father like?	
2	Lin Shan:	For he and his father, sometimes he would miss his father when he left home, but when he returned home, he would again furiously argue with his father. I think their relation is a little bad.	Il

Based on the information in the text that Steven argued with his father when at home but would miss him when Steven was away from home, Lin Shan inferred that their relationship was 'a little bad'. This demonstrated Lin Shan's attempt to reach a conclusion based only on partial information in the text. However, since Lin Shan did not elaborate on her inference, it was not clear how she drew such a conclusion. Specifically, when inferring that their relation was 'a little bad', Lin Shan emphasized the fact that Steven argued with his father when at home, ignoring another fact that he would miss his father when leaving home. Thus, the inference made by Lin Shan in this excerpt was not deep and thus at a low level.

This low-level inference could be elevated to a higher level if Lin Shan had elaborated her inference to some extent. One possible way is for Lin Shan first of all to concede Steven's love towards his father before highlighting the tension between the two. In doing so, she would demonstrate that her inference was based on all available information and not just partial information. Then she could explain her reasoning process so as to lend more support to her inference. For example, she could have referred to the fact that the arguments between Steven and his father were not occasional but regular and argued that this would not happen if they enjoyed a good relationship. Such elaboration would make her inference more logical and deeper, thus elevating it to a higher level.

Low-level inference can also be illustrated in the following dialogue, which transpired when the whole class brainstormed important factors for a person's success.

Excerpt 8

Turn	Speaker		Code
1	T:	Anything else [that is important for a person's success]?	
2	Gu Lan:	Interest.	
3	T:	Interest. Good. Interest.	
4	Gu Lan:	Because on our way to success, it may take much time. If we don't have interest, we may give up.	Il

In Turn 4, based on her judgment that success may take much time, Gu Lan drew a conclusion that people may give up and hence will not succeed if they lack interest in their work. There are seemingly two problems with Gu Lan's inference. One is that success does not necessarily take time. It is not surprising to see some cases of instant success due to opportunities or sheer luck. The other problem with Gu Lan's reasoning is that she was assuming that spending time on something entails interest. In other words, according to Gu Lan, if people do not have interest, they would not spend much time to pursue something and may give up prematurely. It is not necessarily true since people sometimes spend time on something out of obligation, a sense of duty, or even habit rather than interest. Therefore, Gu Lan's inference in Turn 4 is at a low level.

5.5. Synthesis Exhibited in Student Talk

Synthesis is the ability to combine information, opinions, ideas, or arguments from diverse sources to create a new opinion, idea, or argument (Anderson and Krathwohl 2001; Ennis 1987).

The following excerpt is part of a whole-class discussion over the reasons for classroom reticence.

Excerpt 9

Turn	Speaker		Code
1	T:	Do you want to share with us some of the reasons why some of us don't like to talk in the classroom?	
2	Sun Miao:	We don't know well.	
3	T:	We don't know each other.	
4	Sun Miao:	We are shy to talk with each other.	
5	T:	OK. Good. This is a good reason. We don't know each other. We are strangers. We don't have a group. Especially for Chinese, we are not much extroverted. If we don't know each other well, we are reluctant to talk.	
6	Chu Ying:	It's a culture.	Sl
7	T:	Culture.	
8	Chu Ying:	We don't have the habit.	Sl
9	T:	Habit. We don't have the habit of sharing. Good.	

In Turn 6, Chu Ying displayed her skill of synthesis by connecting the ideas given by the teacher in Turn 5 to generalize that a reluctance to speak up is culture-related. However, she did not elaborate on her synthesis so as to expose her reasoning process of combining the teacher's ideas with her own to create a new argument. Although she made more contribution in Turn 8, she failed to add more substance to her argument of culture so as to elevate her synthesis to a higher level. In fact, her contribution in Turn 8 is a downgrading from 'culture' to 'habit' since 'habit' is at a lower level compared to culture. Thus, by saying 'habit', Chu Ying was displaying a low level of synthesis.

6. Discussion and Conclusions

The universally acknowledged value of critical thinking in both schools and workplaces has inspired relentless efforts from researchers and practitioners to develop tools of assessing critical thinking. Given the preponderance of quantitative instruments and researchers' concerns over the quantitative assessment of critical thinking, this paper has proposed a coding scheme to facilitate a qualitative analysis of critical thinking exhibited in interaction. The coding scheme has been applied to some excerpts of authentic classroom dialogue to elaborate its meaning and illustrate its use.

The coding scheme consists of five categories of critical thinking skills, i.e., analysis, comparison, evaluation, inference, and synthesis, each of which is coded at low, medium and high levels. These skills align well with the high-order skills in Bloom's taxonomy (Anderson and Krathwohl 2001), categorizing the goals that should be aimed at both in and outside the classrooms. In addition, similar to Bloom's taxonomy, it is assumed that knowledge, whether in general or in specialized areas, is the indispensable precondition for these critical thinking skills to be applied in practice. Hence, the level of knowledge about the topic concerned should be taken into account in the use of this coding scheme since "good critical thinking is not possible without considerable prior knowledge of the issue or concept concerned" (Dinsmore and Fryer 2023, p. 19). That is to say, the absence of critical thinking is sometimes due to the shortage of relevant knowledge rather than inadequate critical thinking skills.

Although this coding scheme focuses on the skills involved in critical thinking without explicitly covering the disposition of critical thinking, such dispositions should be given due attention while using this coding scheme, as critical thinking has been operationalized as both a set of skills and dispositions (Bailin and Siegel 2003; Dunne 2018). In natural dialogues, the display of critical thinking is spontaneous since no prompts will be given to the participants of dialogue for the use of critical thinking. In other words, people should apply critical thinking skills, such as those covered in this coding scheme, on their own initiative rather than passively. This is in line with Kuhn's (1999) argument that critical thinking is closely related to metacognitive competencies. That is, critical thinkers always regulate, reflect on, and adjust their thinking consciously. After they develop into an accomplished critical thinker, however, they would have deeply internalized these critical thinking skills so that their use of critical thinking skills is not just conscious but highly intuitive (Elder and Paul 1996).

Moreover, the cultural factor should be borne in mind when using this coding scheme. As our coding scheme is based on the normative context in which critical thinking is a western construct (Dinsmore and Fryer 2023), its conceptualization may be different in some non-Anglo-American cultures. Hence, this coding scheme may be adapted for the assessment of critical thinking in such cultures.

This research has several potential limitations to be noted. First, although our efforts are aimed at minimizing the one-size-fits-all limitations of standardized assessment in critical thinking (Rear 2019), this research has raised the concern of subjectivity as the illustration of this coding scheme is subject to the authors' subjective interpretations. In order to avoid the potential bias incurred by such subjectivity, methods of triangulation should be adopted in future research. For example, the subjective interpretations of dialogue participants' critical thinking can be member-checked by the participants to see whether the interpretations are faithful.

Second, we have not considered the influence of others when developing this coding scheme to evaluate a person's critical thinking in dialogue. Since dialogue is a chain of interaction in which a turn builds on the previous turn (Bakhtin 1981), one participant's dialogue acts will very likely influence the way other participants respond. Hence, some display of critical thinking skills may not be spontaneous but a result of others' enlightenment. In future research, such a coding scheme may be improved by taking account of the degree to which a person's display of critical thinking results from others' dialogue acts.

Third, this coding scheme has not been empirically tested or validated. As the main purpose of this study is to propose a coding scheme for critical thinking, it has not assessed the reproducibility and applicability of the coding scheme. Future research may test the coding scheme by evaluating the inter-coder reliability, consulting expert panels, or comparing the coding results with those of a well-established quantitative assessment of critical thinking.

In spite of these limitations, the potential of this coding scheme is not confined to the assessment of critical thinking exhibited in the classroom dialogues. It can also be used to assess critical thinking in dialogues in everyday life in view of its resemblance with dialogues in the educational setting. All dialogues in a real sense emphasize reciprocity, that is, people involved in a dialogue take account of, react to, and add to each other's contributions in order to deepen and develop the dialogue. In both the educational setting and real life, people engaged in dialogues interpret information, evaluate opinions, and express ideas. Communicators are also expected to display logic and reasoning in both settings. Such resemblance between classroom dialogues and dialogues in real life shows that this coding scheme is also applicable in the assessment of critical thinking displayed in everyday dialogues.

Hence, individuals can evaluate and reflect on their critical thinking skills by applying this coding scheme to dialogues in everyday life. By this means, they will increase their understanding of critical thinking, especially the different levels of critical thinking skills that can be used as a yardstick of analysis, comparison, evaluation, inference, and synthesis. Individuals can also practice applying these critical thinking skills to situations in everyday life to improve their judgment and facilitate their decision-making. In doing so, they are able to develop critical thinking habits and cultivate critical thinking dispositions.

Besides these critical thinking skills, people keen to become critical thinkers in everyday life should also improve themselves on several other aspects. First, they should try to expand their knowledge widely and develop themselves into experts in some areas so that their use of critical thinking skills can be substantively supported. Second, they should enhance their metacognitive awareness, for example, by monitoring and exerting control over their thinking process (Halpern 2014) and their mood, considering its impact on critical thinking (Lun et al. 2023). Third, they need to overcome the cultural constraints that may constitute a barrier to their critical thinking. This is especially true for people in east Asian countries deeply influenced by Confucianism, which attaches great importance to hierarchy and authority (Ziliotti 2022). People in these cultures should not be reluctant to be critical thinkers by realizing that thinking critically does not amount to having no respect for authority and therefore does not contradict their cultures.

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Review

Predicting Everyday Critical Thinking: A Review of Critical Thinking Assessments

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Abstract: Our ability to think critically and our disposition to do so can have major implications for our everyday lives. Research across the globe has shown the impact of critical thinking on decisions about our health, politics, relationships, finances, consumer purchases, education, work, and more. This chapter will review some of that research. Given the importance of critical thinking to our everyday lives, the fair and unbiased assessment of critical thinking is useful for guiding educators in their classrooms, for the sake of self-improvement, and in employment decisions. This chapter will also review the psychometric properties of several critical thinking assessments, with a special emphasis on the everyday behaviors predicted by these assessments. The practical challenges faced by test adopters and future directions in the assessment of critical thinking will be discussed.

Keywords: critical thinking assessment; critical thinking skills; critical thinking disposition; everyday outcomes of thinking; reasoning; logic; cognitive bias

1. Introduction

In 2022, a poll conducted by the Pearson Institute for the Study of Resolution of Global Conflicts revealed that 91% of citizens of the United States believed misinformation was a significant problem (Klepper 2022); the same poll found that only 44% of them believed they had been involved in spreading misinformation. It seems that people recognized that there was a problem but did not believe they were contributing to the problem. When asked who was to blame for the spread of misinformation respondents identified the government (72% identified U.S, politicians, 48% the U.S. government, 54% Russia, 53% China, 39% Iran, 41% other foreign governments) and social media (77% identified social media users, 73% social media companies) as the main culprits. It is wise for respondents to be concerned about the spread of misinformation on social media; it has become a major source of news and is largely unregulated. A 2022 survey conducted by the Pew Research Institute (Liedke and Wang 2023), found that more than half of the adults in the United States regularly get their news from social media sites such as Facebook (31%), YouTube (25%), Twitter (14%), Instagram (13%), TikTok (10%), and others. Many scholars have voiced their concerns about the growing use of social media sites as a source of information due to concerns about echo chambers and the ease with which misinformation can be spread (Bakshy et al. 2015).

It is estimated that people across the world spend an average of 2.5 h per day on social media (Ali and AJLabs 2023), but the information consumed during that time is not a balanced representation of all viewpoints. All mainstream social media websites use algorithms that push content to you based on your usage (e.g., videos you have watched completely or repeatedly, posts you have interacted with by sharing or liking them). These algorithms learn enough about you that they begin to feed you information that is consistent with your interests or preexisting beliefs. For example, at the time this chapter was written, the author was pregnant with her first child and the algorithms fed her content about pregnancy, labor, and parenting. The algorithms were so savvy that they even triangulated which trimester she was in and fed her content accordingly. Some of this content was produced by reputable sources who were experts in their fields and cited credible sources (e.g., a doctor who is board-certified in fetal medicine citing quality empirical research), but most of it was not (e.g., medical advice being given by a chiropractor that was not based on any research), and some of the questionable content directly contradicted the evidence-based medical advice given by the reputable doctor while insinuating that the credible information should not be trusted. It was alarming to see bad medical advice being given so freely by these content creators, but it was also clear that many consumers of this content were uncritically accepting the information based on their comments and were likely exposed to a lot of similar content.

The danger associated with these social media algorithms is that they create echo chambers that insulate us from different perspectives and feed us information that is already consistent with our existing beliefs (Bakshy et al. 2015), thereby strengthening the conviction of our existing beliefs and potentially inflating our perception of how many others share that belief. This does not encourage critical thinking. The more videos you see of people espousing similar beliefs to you, the more you come to believe that most people believe the same thing that you believe. You are less likely to be exposed to, and consider, alternative viewpoints, and are more likely to commit confirmation bias (the tendency to seek out, and eagerness to accept, information that is consistent with your preexisting beliefs). Imagine a person who is distrustful of science: when they see social media content that is critical of science or medicine, they "like" the post. The algorithms then feed them more content that is critical of medicine and soon much of the content they consume is stories about medical mistakes, negative experiences with doctors, and positive experiences with more holistic practices. They read the comments of others interacting with this content and most seem to agree that the medical establishment should not be trusted, so they conclude that doctors are dangerous and that most people share this belief. The rise in a distrust of science has been well documented (Tsipursky 2018), but it is certainly not the only domain in our lives impacted by these echo chambers. Echo chambers have been implicated for their role in the rise of partisan politics in the United States (Frenkel and Isaac 2018) and can contribute to the phenomenon known as *the group polarization effect* (the tendency for the views of like-minded people to become more extreme when they discuss their opinions on the topics they share similar beliefs about).

More recently, artificial intelligence (AI) has contributed to the spread of misinformation by generating fake images and videos. Creators of this content could technically be accused of spreading *dis*information, since the intent of the sharer of such information is to mislead consumers. The problem has become so widespread that *Rolling Stone* magazine published a story on the problem, urging readers to use their good judgement before sharing stories online (Klee and McCann Ramirez 2023). The article blamed AI technology for fanning political flames and spreading misinformation about the Israel–Hamas conflict. It is unfortunate that the rise of social media usage will likely result in less critical thinking about the information we consume online. The enormous benefits of the Internet are undeniable, but educators across the globe are encouraged to discuss with their students the damaging impact that echo chambers can have on our everyday lives by making critical thinking more difficult.

2. How Critical Thinking Impacts Everyday Life

The ability to think critically does not guarantee us a good life that is free from bias or errors, and it does not guarantee that we will not fall prey to bad advice given on social media, but it may protect us from experiencing certain negative life events. In a series of studies, researchers measured the extent to which critical thinking predicted the occurrence of certain everyday life outcomes (Butler 2012; Butler et al. 2012, 2017). Community adults from several countries took a well-established critical thinking assessment (the Halpern Critical Thinking Assessment) and completed an inventory of negative life events. The inventory of negative life events was adapted from a decision-making competence inventory (Bruine de Bruin et al. 2007). The inventory was unique in that it allowed the researchers to measure the *proportion* of negative life events experienced by the respondent by inventorying both the negative life event and the neutral life event that may have made the negative event possible. For instance, the respondents were asked whether they had driven a car (a neutral life event) and then whether they had ever been arrested for driving under the influence of drugs or alcohol (a negative life event also known as a DUI in the United States). If you only asked whether the respondent had received a DUI and the respondent reported that they did not get a DUI, you would not know whether they did not get a DUI because they made the good decision not to drive under the influence of drugs or alcohol or whether they did not drive a car at all because they do not have a license to drive. Thus, this unique inventory allowed researchers to measure the proportion of negative life events experienced by the respondents. The everyday life events ranged in severity from trivial (e.g., I ruined a load a laundry) to severe (e.g., I contracted a sexually transmitted disease by failing to use a condom when I had sex). They also measured experiences across various domains of life, such as health (e.g., I had or was responsible for an unplanned pregnancy), safety (e.g., I was arrested for driving under the influence of drugs or alcohol), finances (e.g., I was charged a late fee because I did not pay my bill on time), social/interpersonal (e.g., I cheated on my significant other of more than one year), and education (e.g., I forgot about a scheduled exam). The researchers found that those who scored higher on the critical thinking assessment experienced fewer negative life events, compared to those who scored lower on the critical thinking assessment. The authors concluded that thinking critically offers us some protection from making questionable life decisions. Another benefit of the inventory used in this research is that it captured self-reported behaviors, which offers some insight into the respondents' dispositions towards making good decisions and thinking critically.

3. Critical Thinking: Skills and Dispositions

The disposition to use one's critical thinking skills is as important as the skills themselves. If a person understands the skills involved in thinking critically but fails to deploy those skills when the situation warrants, they would not be classified as a critical thinker. Imagine a person who understands that causation should not be inferred from correlational research but accepts as truth medical advice based on correlation. This is what happened with a common vaccine given in childhood. Despite several large-scale studies confirming that the Measles, Mumps, and Rubella (MMR) vaccine was not responsible for causing autism (see Jain et al. 2015) parents in several countries elected not to give the vaccine to their children and this had severe consequences. Europe saw a 400% increase in measles from 2016–2017 (World Health Organization 2018). In 2015, 10% of children in the United States were not vaccinated for the disease, which had nearly been irradicated (National Center for Health Statistics 2015, tab. 67). In Romania, celebrities took to social media to warn parents not to vaccinate their children and to drink cabbage juice instead. Dozens of infants died due to a major outbreak (Gheorghia 2018). Correlational research found that autism was diagnosed around the same time a vaccine was given to children and incorrectly concluded that the vaccine was causing autism. Decades later, we still do not know what causes autism, but we do know that it is not the vaccine. Yet, hundreds of well-meaning parents question whether to give their child the vaccine each year.

Psychologists and philosophers have debated the exact definition of critical thinking for decades, as well as whether the construct is domain-specific or domain-general, but most definitions of critical thinking include thinking that is logical and free of bias. In her book, *Thought and Knowledge*, Halpern defined critical thinking as:

> "the use of those cognitive skills and abilities that increase the probability of a desirable outcome. It is used to describe thinking that is purposeful, reasoned, and goal directed—the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions" (Halpern 2014, p. 8).

Critical thinking also differs from intelligence, although both constructs refer to cognitive abilities. Stanovich and West (2008) and others have argued that our everyday definition of intelligence more accurately describes critical thinking than what most intelligence tests measure, which tends to be short-term memory, vocabulary, analogies, and spatial skills (Butler and Halpern 2020). In terms of predicting behavior, both critical thinking and intelligence can predict everyday behavior. Butler et al. (2017) compared the predictive power of an intelligence test to the predictive power of a critical thinking assessment. Participants took the INSBAT intelligence test (Arendasy et al. 2012), the Halpern Critical Thinking Assessment (HCTA; Halpern 2012), and the real-world outcomes inventory (the same inventory discussed previously; Butler 2012). Overall, both predicted negative life events, although the critical thinking assessment did a slightly better job at this than the intelligence test. That is, those who scored high on the intelligence test and those who scored high on the critical thinking assessment reported experiencing fewer negative life events. Interestingly, the critical thinking scores accounted for unique variance in the model beyond the variance intelligence scores accounted for. This implies that the constructs of intelligence and critical thinking are different, but more importantly that they are impacting our everyday lives in different ways.

One of the advantages of critical thinking over intelligence is that it is easier to teach someone to be a critical thinker than it is to improve their intelligence. Each year, thousands of college students enroll in critical thinking courses and nearly every university includes critical thinking as a university-wide student learning outcome. Despite this, there is evidence that the critical thinking abilities of over one-third of college students do not improve during their time in college. The book, *Academically Adrift* (Arum and Roksa 2010), discusses this finding in an analysis that is critical of higher education. The book has been criticized for being overly pessimistic and ignoring the lack of incentives offered to students who participated in the research. The publication was successful in prompting a thorough meta-analysis of the topic, which reached a different conclusion about whether the academy was successful in training critical thinkers. Huber and Kuncel (2015) analyzed 71 studies conducted over a 48 year period that measured changes in the critical thinking of college students during their time in the academy. The meta-analysis concluded that critical thinking skills and critical thinking dispositions improved over the college experience. That said, the gains in critical thinking became smaller as time passed, indicating that students are not learning thinking skills and developing a disposition towards critical thinking as much as they have in the past. The authors argue that the findings could be the result of changes to the college curriculum, changes in student behavior, and the increase in critical thinking instruction while students are still in high school, middle, or elementary school.

If we truly value critical thinking in education, then we should be measuring whether our students are learning to think critically in our classrooms. Colleges and universities would do well to provide resources for these important assessment efforts.

4. Measuring Critical Thinking

4.1. Practical Challenges

There are many practical challenges to the assessment of critical thinking, especially on college campuses. First, there is little incentive to do so. While many colleges and universities declare critical thinking as an important learning outcome of the education they provide, few require high-quality evidence that it is occurring. Much of the assessment work done at a university-wide level is done during accreditation by a few faculty members under the guise of service to the university. It is not embedded in normal university activities and is viewed as additional work, which makes it more likely that the easiest path of assessment is chosen over the most accurate. Furthermore, the details of assessment work are rarely shared broadly with the entire university or discussed as a responsibility of all faculty. Second, it takes time to assess critical thinking well. There are several different types of assessment to choose from. It takes time to select one (and knowledge of what to look for in a quality assessment). One of the most fundamental differences between these assessments is whether the questions are multiple-choice or forced-choice questions that rely on recognition memory or short-answer questions that rely on recall memory. The weakness of a forced-choice question is that respondents are being provided a memory cue that may make it easier to guess the correct answer, which is less of a concern with a short-answer question that does not provide any cues. A challenge of the short-answer question is that the answers will be more difficult to grade and may be more susceptible to biased grading. Third, most critical thinking assessments cost money. Colleges and universities must provide the financial resources to purchase the assessments and to have them graded. Despite the practical challenges of critical thinking assessment, we believe it to be an important endeavor that universities should prioritize. It should also be a recursive process, whereby the information gained from the assessment is shared with educators who can then use it to improve instruction, which is then visible in subsequent assessments.

Regardless of setting, the assessment of complex constructs is challenging, and it is especially difficult to measure a complex construct like critical thinking when the definition of critical thinking is still debated by scholars. How a test developer defines critical thinking plays a role in how it is measured and the factors that are included. As you will see from the review of several critical thinking assessments below, while each assessment provides an overall score for critical thinking skills or dispositions, the subscales used to create this overall score differ based on how the construct was defined by the test developer. Some test developers adopted a more conceptual approach (e.g., using the Delphi Report's definition of critical thinking to guide the test's development), while others were guided by the psychometric properties of their assessments. While differences exist both in the definition of critical thinking and the skills that developers choose to include, most critical thinking skill assessments measure some form of argument analysis, questioning assumptions, inductive and deductive reasoning, and quantitative reasoning.

One area where critical thinking assessment has done particularly well has been the emphasis on realistic assessment scenarios. Many of the assessments reviewed in this chapter ask respondents to respond to everyday scenarios, such as evaluating a letter to the editor of a newspaper, or a statement made by a politician. These scenarios are the very everyday life situations we hope respondents are using their critical thinking skills to evaluate. Unfortunately, many critical thinking assessments fail to confirm that performance on the assessment predicts everyday behavior. Most assessments of critical thinking use academic performance to demonstrate the predictive (criterion) validity of the assessment. If your goal is to assess whether learners are applying critical thinking skills in the classroom only, then perhaps this gap in predictive power may not seem particularly troublesome. If your goal is to assess whether the knowledge gained by learning thinking skills transfers to other domains of life for the betterment of the individual and society, then this is an area where many critical thinking assessments fall short. As you will see in the review that follows, only a few assessments have demonstrated that scores on their assessments predict everyday behavior.

4.2. Critical Thinking Assessments

This section will examine the psychometric qualities of eight critical thinking assessments: six assessments measure cognitive skills associated with critical thinking and two measure critical thinking dispositions. This is not an exhaustive list of critical thinking assessments. Six assessments utilize a multiple-choice (recognition memory) format only: the California Critical Thinking Dispositions Inventory (CCTDI), California Critical Thinking Skills Test (CCTST), Cornell Critical Thinking Test (CCTT), the California Measure of Mental Motivation (CM3), the Test of Everyday Reasoning (TER), and the Watson–Glaser™ II Critical Thinking Appraisal (W-GII). One assessment relies exclusively on a short-answer (recall memory) format, the Ennis–Weir Critical Thinking Essay. Only one assessment utilizes both multiple-choice and short-answer, the Halpern Critical Thinking Assessment (HCTA). For a concise list of assessment attributes, see Table 1.

Table 1. Critical thinking assessment characteristics.

	CCTDI [a]	**CCTST** [b]	**CCTT** [c]	**CM3** [d]	**E-W** [e]	**HCTA** [f]	**TER** [g]	**W-GII** [h]
Construct	Disposition	Skills	Skills	Disposition	Skills	Skills	Skills	Skills
Respondent Age	18+	18+	10+	5+	12+	18+	Late childhood to adulthood	18+
Format(s)	Digital and paper	Digital	Paper	Digital and paper	paper	Digital	Digital and paper	Digital
Length	75 items	40	52–76 items	25 items	1 problem	20–40 items	35 items	40 items
Administration Time	30 min	55 min	50 min	20 min	40 min	20–45 min	45 min	30 min
Response Format	Multiple-choice	Multiple-choice	Multiple-choice	Multiple-choice	Essay	Multiple-choice and short-answer	Dichotomous choice	Multiple-choice
Fee	yes	yes	yes	yes	no	yes	yes	yes
Evidence—Reliability	yes	yes	yes	yes	no	yes	yes	yes
Evidence—validity	no	yes	no	yes	yes	yes	None available	yes
Credential required for administration	yes	no	no	no	no	no	Developer scores	no

[a] CCTDI = California Critical Thinking Dispositions Inventory; [b] CCTST = California Critical Thinking Skills Test; [c] CCTT = Cornell Critical Thinking Test; [d] CM3 = California Measure of Mental Motivation; [e] E-W = Ennis–Weir Critical Thinking Essay Test; [f] HCTA = Halpern Critical Thinking Assessment; [g] TER = Test of Everyday Reasoning; [h] W-GII = Watson-Glaser Critical Thinking Appraisal II.

4.2.1. California Critical Thinking Dispositions Inventory (CCTDI; Insight Assessment, Inc. n.d.)

Insight Assessment is the developer of this assessment, which was originally authored by Facione (1990) to measure an individual's tendency to think critically. The assessment measures truth-seeking, open-mindedness, analyticity, systematicity, critical thinking confidence, inquisitiveness, and maturity of judgment. It is intended for use with undergraduate and graduate students. The assessment contains 75 items and takes 30 min to complete. The CCTDI asks respondents the extent to which they agree or disagree with a series of questions. For example, respondents might be asked whether "it is important to me to figure out what people really mean by what they say" or "changing your mind is a sign of weakness" (reverse scored). It is available in both digital and paper form in multiple languages, including English, French, Spanish, Chinese, Japanese, and 14 others. To administer this assessment, you must have the appropriate credentials and formal training in administering and scoring clinical assessments ethically.

The seven factors measured by this assessment are based on the Delphi Report's definition of critical thinking. Subsequent research conducted by Walsh et al. (2007) did not support the seven-factor structure and instead recommended a four-factor structure, but the test is still being advertised as measuring the seven original factors. The internal reliability of the CCTDI is good (Cronbach $\alpha = 0.91$) but varies based on the type of sample (e.g., nursing students, college students).

4.2.2. California Critical Thinking Skills Test (CCTST; Insight Assessment, Inc. n.d.)

The developers of this assessment state that it is the most widely used critical thinking assessment in the world. It measures problem analysis, interpretation, inference, evaluation of arguments, explanation (providing evidence, assumptions, and rational decision-making), induction, deduction, and numeracy (quantitative reasoning). It is intended for use with college undergraduate and graduate students. The assessment contains 40 scenarios that test-takers respond to by selecting a given response. It is available online in multiple languages including English, Arabic, Chinese Simplified, Chinese Traditional, Dutch, French, German, Indonesian-Bahasa, Italian, Japanese, Korean, Norwegian, Portuguese, Spanish, Swedish, Thai, Turkish, and Vietnamese. No specific license is required to administer this assessment, but it is only sold to educational institutions, educational consultations, or other educationally related organizations such as the Department of Education or the National Science Foundation.

The manual for this assessment cites publications that provide evidence of reliability and validity. It was validated with college students (community college, undergraduate, graduate, law, and MBA), employees, military personnel, children K-12, health professionals, and the general population. It was also tested against the influence of social desirability and culture bias. In terms of content validity, only face validity was provided; namely, that the factors measured by this assessment were based on the Delphi Report's definition of critical thinking. There is evidence supporting the construct validity of the assessment. The strongest evidence compared scores on the assessment to scores on the GRE (GRE Total Score $r = 0.719$, GRE Analytic $r = 0.708$, GRE Verbal $r = 0.716$, GRE Quantitative, $r = 0.582$). The relationship between academic performance and scores on the assessment was weak to moderate (ranging from 0.20 to 0.46), but the developers argue that more goes into grades than just a student's ability to think such as participation and content knowledge. In terms of criterion validity, the assessment has been used to evaluate training programs, learning outcomes in educational settings, and decision-making in employment settings. These evaluations occurred largely with medical and nursing students. The internal consistency of the measure is sufficient (e.g., most tests exceeded the minimum standard 0.70), as is the test–retest reliability (0.80). The factor loadings for the items ranged from 0.30 to 0.77, indicating a questionable factor structure, as was the case with the CCTDI.

4.2.3. Cornell Critical Thinking Test (CCTT; The Critical Thinking Company n.d.)

This assessment measures critical thinking skills and abilities. There are two versions of the assessment: level X was developed for use with students grades 5 to 12 and level Z was developed for use with students in grade 11 to adulthood. Level X advertises that it measures induction, deduction, credibility, and the identification of assumption. It consists of 71 items and takes 50 min to complete. Level Z advertises that it measures induction, deduction, credibility, semantics, definition, prediction and planning experiments, and the identification of assumption. It consists of 52 items and takes 50 min to complete. Both versions of the assessment rely on recognition memory (multiple-choice items). Neither assessment is available online; only a paper version is available. It is available in English. There is a fee for this assessment, but no credentials are required to administer it.

According to the publisher of the assessment (The Critical Thinking Company n.d.) evidence of the assessment's reliability and validity can be found in the manual, which was not available publicly at the time this chapter was written. There have been a few published and peer-reviewed studies of the assessment that provide weak evidence to support its reliability and validity. In terms of the factor structure, Michael et al. (1980) did not find evidence to support the measurement of the factors proposed by the test developer (only one factor corresponded to that of the developer) and French et al. (2012) found that 94% of the items were potentially biased and showed differential item functioning based on gender. In terms of reliability, the evidence varied, but none met the recommended standards for reliability. The internal consistency of the tests ranged from 0.52 to 0.77 and split-half reliability ranged from 0.55 to 0.76 (Bart 2010). In terms of validity, the relationship between scores on the assessment and student grades was rather weak ($r = 0.15$–0.17; Michael et al. 1980); the relationship with standardized language or quantitative reasoning was modest (0.51–0.62; Landis and Michael 1981); and the relationship with scholastic aptitude and intelligence measures were strong (approximately 0.50 for both). In 2005, following the publication of the research evaluating the psychometric qualities of this assessment, the assessment was refined. Unfortunately, the research establishing the measure as reliable and valid was not available publicly at the time of this chapter's publication. It is available in the manual provided upon purchase.

4.2.4. California Measure of Mental Motivation (CM3; Insight Assessment, Inc. n.d.)

Insight Assessment is the developer of this assessment, which measures cognitive engagement and motivation towards problem solving and learning in children and adolescents (K-12+). It is available in both digital and paper versions, and in multiple languages including English, Chinese, Spanish, Arabic, and Greek (Insight Assessment, Inc. n.d.). Several versions are available based on the age of the respondent. The assessment contains approximately 25 items (it varies based on the version) and takes approximately 20 min to complete. There is a fee for this assessment. Confirmatory factor analysis on the 25-item instrument found four distinct constructs that ranged in internal consistency from 0.73 to 0.87 (Giancarlo et al. 2004). The four constructs were learning orientation, creative problem solving, mental focus, and cognitive integrity. The criterion validity of the assessment was assessed by comparing scores on the assessment to scores on measures of self-efficacy ($r = 0.28$) and academic achievement, including scores on the SAT ($r = 0.10$ to 0.46) and GPA ($r = 0.19$ to 0.46).

4.2.5. Ennis–Weir Critical Thinking Essay Test (Ennis and Weir 2005)

This assessment measures critical thinking (primarily argumentation and evaluation) by asking respondents to evaluate fictitious letters to newspaper editors. It was intended as a teaching tool, to be used as a framework a short critical thinking course or to be embedded as an assessment tool within a full critical thinking course. The psychometric qualities of the assessment have been extensively studied in 24 studies (Ennis 2005; Ennis and Weir 2005). Bart (2010) found that both the external validity and the content validity of the assessment were good, but criterion validity has not been established. In terms of reliability, the interrater reliability of the assessment is acceptable ($r = 0.86$ to 0.99 for the college student sample), but the internal reliability of the assessment was not acceptable (Cronbach's $\alpha = 0.59$ for the college student sample). The lack of internal reliability and criterion validity associated with this assessment makes its use questionable. That said, it was the only assessment we reviewed that was free, which may appeal to resource-strained educators who intend to use it for its intended purpose as a tool in the classroom.

4.2.6. Halpern Critical Thinking Assessment (HCTA; Halpern 2012)

This assessment measures verbal reasoning, argument analysis, hypothesis testing, likelihoods, and decision-making/problem-solving. It was available for a fee through the Vienna Test System (www.schuhfried.com accessed on 1 May 2018) for a time but has since been retired. The target audience for the assessment was adults. Both versions of the assessment included 20 scenarios drawn from different aspects of everyday life. The short version of the assessment took 20 min to complete and included multiple-choice response options only, while the longer version of the assessment took 45 min to complete and included both the multiple-choice questions and short-answer questions. The assessment included computer-assisted grading of the written responses, which guided novice grades through grading the assessment.

There is research confirming the reliability and validity of this assessment (see Halpern 2012). In terms of reliability, both the internal consistency of the assessment (Cronbach's $\alpha = 0.88$) and the interrater reliability ($r = 0.93$) are strong. It should be noted that the interrater reliability was established with the computerized grading system, which guides graders through the processing of grading the short-answer responses. In terms of validity, construct and criterion validity have been established. The factor structure was confirmed in two studies. Numerous studies have evaluated the construct validity of the assessment with samples from different countries. The relationship between responses to the multiple-choice questions and responses to the short-answer questions were examined in four separate studies and indicate the two versions of the assessment measure separate, but related factors ($r = 0.39$ to 0.51). The criterion validity of the assessment was established by comparing scores on the assessment to students' GPA ($r = 0.35$) and standardized exam scores (SAT-Verbal $r = 0.58$, SAT-Math $r = 0.50$, GRE-Verbal $r = 0.12$, GRE-Quantitative $r = 0.20$). Scores on the assessment have also been compared to scores on a personality assessment measuring conscientiousness ($r = 0.02$), the Arlin Test of Formal Reasoning ($r = 0.32$), and scores on the Need for Cognition Scale ($r = 0.34$). And finally, as already discussed, scores on the assessment predicted real-world behaviors such that they were inversely related to the proportion of negative life events experienced by a group of community adults and college students who took the assessment online (Butler 2012; Butler et al. 2012, 2017). This relationship was found in numerous countries (e.g., the United States, Ireland, Portugal). Although this assessment is no longer available, we include it as an example of assessment with excellent psychometric qualities that predicts behavior in everyday life and encourage readers to consider developing similar measures.

4.2.7. Test of Everyday Reasoning (TER; Insight Assessment, Inc. n.d.)

This test is available from Insight Assessment. The developer states that it measures analysis, interpretation, inference, evaluation, explanation, numeracy, deduction, and induction. It is available in both digital and paper formats. The assessment contains 35 items that respondents respond to by selecting one of two options (dichotomous choice). The test is available in English, Greek, Russian, and Spanish. There is a fee for the assessment. In terms of reliability, the internal consistency of the assessment ranged from 0.71 to 0.86 (Facione et al. 2012). No evidence of validity was available for this assessment.

4.2.8. Watson–Glaser™ II Critical Thinking Appraisal (W-GII; NCS Pearson, Inc. 2009)

This assessment measures inference, assumptions, deduction, interpretation, and argument evaluation. The problem-based assessment uses multiple-choice questions with varying numbers of response options. It is marketed to employers but could be used in a variety of settings. It contains 40 questions and takes roughly 30 min to complete. There is a fee for the assessment, which is available in a digital/online format. The developer provides two practice tests, drills, and five interactive study guides on their website. One sample item that measures inference asks respondents to read the passage and "choose whether each of the statements that follow are true or false to varying degrees...". The scenario is as follows.

> "Virtual employees, or employees who work from home via a computer, are an increasing trend. In the US, the number of virtual employees has increased by 39% in the last two years and 74% in the last five years. Employing virtual workers reduces costs and makes it possible to use talented workers no matter where they are located globally. Yet, running a workplace with virtual employees might entail miscommunication and less camaraderie and can be more time-consuming than face-to-face interaction".

Respondents answer two questions about this passage. The first question is "The marked advantage of virtual employee hiring is the ability to benefit from the output of unsociable employees without involving them in face-to-face interactions" and the second question is "Today, a majority of the employees in the US are virtual employees". Respondents answer by selecting one option: true, probably true, insufficient data, probably false, or false.

There is research confirming the reliability and validity of this assessment (see NCS Pearson, Inc. 2009). In terms of reliability, research supports both the factor structure and internal consistency of the assessment. A factor analysis revealed three factors: recognizing assumptions, evaluating arguments, and drawing conclusions. The internal consistency of the assessment was good, it ranged from 0.81 to 0.89. Convergent and criterion validity have been established. Tests of convergent validity compared scores on the assessment to scores on several tests of intelligence, such as the WAIS-IV ($r = 0.52$), the Raven's APM ($r = 0.53$), and the Advanced Numerical Reasoning Appraisal ($r = 0.68$).

Tests of criterion validity compared scores on the assessment to both academic and job performance. The GPAs of nursing students ($r = 0.30$) and the exam scores from an educational psychology class ($r = 0.42$–0.57) were moderately related to scores on the assessment. Scores on the W-GII were also moderately related to supervisor ratings of job performance in numerous industries ($r = 0.28$) and a government agency ($r = 0.39$). This assessment was one of a few assessments that established a relationship between scores on the assessment and everyday behavior outside of a classroom (e.g., job performance).

5. Conclusions

It is clear from the review of these assessments that a test developer's definition of critical thinking impacts the skills or traits that are measured. Still, many of the critical thinking skills assessments measure the same skills (e.g., argument analysis, inductive and deductive reasoning, quantitative reasoning), so there appears to be some overlap in the subscales measured by these assessments. The same cannot be said of critical thinking disposition assessments, where the subscales measured by the assessments vary widely. As the disposition to use one's critical thinking skills is paramount, this may be a fruitful area for future research. Additionally, many of the critical thinking assessments use realistic scenarios from everyday life, but more work needs to be done to demonstrate scores on these assessments; both the skills and the disposition to use them predict actual behavior.

The previous section began by encouraging educators to overcome the practical challenges associated with critical thinking assessment and by asking colleges and universities to prioritize this important student learning outcome by allotting resources to its assessment and creating a space for educators to discuss ways to improve critical thinking in their classrooms. Educators might find Halpern's (1998) model for teaching critical thinking useful in this endeavor. The model urges educators to explicitly teach critical thinking skills in all classes (e.g., name the skill being taught), encourage and incentivize students to develop their critical thinking disposition, use real everyday examples to make knowledge transfer more likely to occur, and model metacognitive monitoring in class.

It is important that college students gain critical thinking skills and a disposition to use those skills during their time in the academy, but it is equally important that those who are not fortunate enough to receive a quality higher education learn critical thinking skills and dispositions. Beyond the ivory tower of higher education, there are few opportunities for people to learn and receive feedback about their critical thinking skills. Readers are encouraged to be creative and consider ways to remedy this (e.g., developing short online tutorials or a critical thinking pop-up that would appear on questionable webpages to remind readers to consider the evidence behind the claims). We built an educational game that taught students scientific reasoning (Forsyth et al. 2012; Halpern et al. 2012), why not build one to teach critical thinking and make it accessible to the masses for free?

Even if we were only successful at teaching one critical thinking skill, it could have a major impact on the world. Lilienfeld et al. (2009), argue that if we could overcome confirmation bias, we could have world peace by reducing ideological extremism and intergroup conflict. In a world that is experiencing a war in Israel and political extremism in the United States, that sounds great to me.

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Review

Critical Thinking, Intelligence, and Unsubstantiated Beliefs: An Integrative Review

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Abstract: A review of the research shows that critical thinking is a more inclusive construct than intelligence, going beyond what general cognitive ability can account for. For instance, critical thinking can more completely account for many everyday outcomes, such as how thinkers reject false conspiracy theories, paranormal and pseudoscientific claims, psychological misconceptions, and other unsubstantiated claims. Deficiencies in the components of critical thinking (in specific reasoning skills, dispositions, and relevant knowledge) contribute to unsubstantiated belief endorsement in ways that go beyond what standardized intelligence tests test. Specifically, people who endorse unsubstantiated claims less tend to show better critical thinking skills, possess more relevant knowledge, and are more disposed to think critically. They tend to be more scientifically skeptical and possess a more rational–analytic cognitive style, while those who accept unsubstantiated claims more tend to be more cynical and adopt a more intuitive–experiential cognitive style. These findings suggest that for a fuller understanding of unsubstantiated beliefs, researchers and instructors should also assess specific reasoning skills, relevant knowledge, and dispositions which go beyond what intelligence tests test.

Keywords: critical thinking; intelligence; cognitive ability; dispositions; unsubstantiated beliefs

1. Introduction

Why do some people believe implausible claims, such as the QAnon conspiracy theory, that a cabal of liberals is kidnapping and trafficking many thousands of children each year, despite the lack of any credible supporting evidence? Are believers less intelligent than non-believers? Do they lack knowledge of such matters? Are they more gullible or less skeptical than non-believers? Or, more generally, are they failing to think critically?

Understanding the factors contributing to acceptance of unsubstantiated claims is important, not only to the development of theories of intelligence and critical thinking but also because many unsubstantiated beliefs are false, and some are even dangerous. Endorsing them can have a negative impact on an individual and society at large. For example, false beliefs about the COVID-19 pandemic, such as believing that 5G cell towers induced the spread of the COVID-19 virus, led some British citizens to set fire to 5G towers (Jolley and Paterson 2020). Other believers in COVID-19 conspiracy theories endangered their own and their children's lives when they refused to socially distance and be vaccinated with highly effective vaccines, despite the admonitions of scientific experts (Bierwiaczonek et al. 2020). Further endangering the population at large, those who believe the false conspiracy theory that human-caused global warming is a hoax likely fail to respond adaptively to this serious global threat (van der Linden 2015). Parents, who uncritically accept pseudoscientific claims, such as the false belief that facilitated communication is an effective treatment for childhood autism, may forego more effective treatments (Lilienfeld 2007). Moreover, people in various parts of the world still persecute other people whom they believe are witches possessing supernatural powers. Likewise, many people still believe in demonic possession, which has been associated with mental disorders (Nie and Olson 2016). Compounding the problems created by these various unsubstantiated beliefs, numerous studies now show that when someone accepts one of these types of unfounded claims, they tend to accept others as well; see Bensley et al. (2022) for a review.

Studying the factors that contribute to unfounded beliefs is important not only because of their real-world consequences but also because this can facilitate a better understanding of unfounded beliefs and how they are related to critical thinking and intelligence. This article focuses on important ways in which critical thinking and intelligence differ, especially in terms of how a comprehensive model of CT differs from the view of intelligence as general cognitive ability. I argue that this model of CT more fully accounts for how people can accurately decide if a claim is unsubstantiated than can views of intelligence, emphasizing general cognitive ability. In addition to general cognitive ability, thinking critically about unsubstantiated claims involves deployment of specific reasoning skills, dispositions related to CT, and specific knowledge, which go beyond the contribution of general cognitive ability.

Accordingly, this article begins with an examination of the constructs of critical thinking and intelligence. Then, it discusses theories proposing that to understand thinking in the real world requires going beyond general cognitive ability. Specifically, the focus is on factors related to critical thinking, such as specific reasoning skills, dispositions, metacognition, and relevant knowledge. I review research showing that that this alternative multidimensional view of CT can better account for individual differences in the tendency to endorse multiple types of unsubstantiated claims than can general cognitive ability alone.

2. Defining Critical Thinking and Intelligence

Critical thinking is an almost universally valued educational objective in the US and in many other countries which seek to improve it. In contrast, intelligence, although much valued, has often been viewed as a more stable characteristic and less amenable to improvement through specific short-term interventions, such as traditional instruction or more recently through practice on computer-implemented training programs. According to Wechsler's influential definition, intelligence is a person's "aggregate or global capacity to act purposefully, to think rationally, and to deal effectively with his environment" (Wechsler 1944, p. 3).

Consistent with this definition, intelligence has long been associated with general cognitive or intellectual ability and the potential to learn and reason well. Intelligence (IQ) tests measure general cognitive abilities, such as knowledge of words, memory skills, analogical reasoning, speed of processing, and the ability to solve verbal and spatial problems. General intelligence or "g" is a composite of these abilities statistically derived from various cognitive subtests on IQ tests which are positively intercorrelated. There is considerable overlap between g and the concept of fluid intelligence (Gf) in the prominent Cattell–Horn–Carroll model (McGrew 2009), which refers to "the ability to solve novel problems, the solution of which does not depend on previously acquired skills and knowledge," and crystalized intelligence (Gc), which refers to experience, existing skills, and general knowledge (Conway and Kovacs 2018, pp. 50–51). Although g or general intelligence is based on a higher order factor, inclusive of fluid and crystallized intelligence, it is technically not the same as general cognitive ability, a commonly used, related term. However, in this article, I use "general cognitive ability" and "cognitive ability" because they are the imprecise terms frequently used in the research reviewed.

Although IQ scores have been found to predict performance in basic real-world domains, such as academic performance and job success (Gottfredson 2004), an enduring question for intelligence researchers has been whether g and intelligence tests predict the ability to adapt well in other real-world situations, which concerns the second part of Wechsler's definition. So, in addition to the search for the underlying structure of intelligence, researchers have been perennially concerned with how general abilities associated with intelligence can be applied to help a person adapt to real-world situations. The issue is largely a question of how cognitive ability and intelligence can help people solve real-world problems and cope adaptively and succeed in dealing with various environmental demands (Sternberg 2019).

Based on broad conceptual definitions of intelligence and critical thinking, both intelligence and CT should aid adaptive functioning in the real world, presumably because they both involve rational approaches. Their common association with rationality gives each term a positive connotation. However, complicating the definition of each of these is the fact that rationality also continues to have a variety of meanings. In this article, in agreement with Stanovich et al. (2018), rationality is defined in the normative sense, used in cognitive science, as the distance between a person's response and some normative standard of optimal behavior. As such, degree of rationality falls on a continuous scale, not a categorical one.

Despite disagreements surrounding the conceptual definitions of intelligence, critical thinking, and rationality, a commonality in these terms is they are value-laden and normative. In the case of intelligence, people are judged based on norms from standardized intelligence tests, especially in academic settings. Although scores on CT tests seldom are, nor could be, used to judge individuals in this way, the normative and value-laden basis of CT is apparent in people's informal judgements. They often judge others who have made poor decisions to be irrational or to have failed to think critically.

This value-laden aspect of CT is also apparent in formal definitions of CT. Halpern and Dunn (2021) defined critical thinking as "the use of those cognitive skills or strategies that increase the probability of a desirable outcome. It is used to describe thinking that is purposeful, reasoned, and goal-directed." The positive conception of CT as helping a person adapt well to one's environment is clearly implied in "desirable outcome".

Robert Ennis (1987) has offered a simpler, yet useful definition of critical thinking that also has normative implications. According to Ennis, "critical thinking is reasonable, reflective thinking focused on deciding what to believe or do" (Ennis 1987, p. 102). This definition implies that CT helps people know what to believe (a goal of epistemic rationality) and how to act (a goal of instrumental rationality). This is conveyed by associating "critical thinking" with the positive terms, "reasonable" and "reflective". Dictionaries commonly define "reasonable" as "rational", "logical", "intelligent", and "good", all terms with positive connotations.

For critical thinkers, being reasonable involves using logical rules, standards of evidence, and other criteria that must be met for a product of thinking to be considered good. Critical thinkers use these to evaluate how strongly reasons or evidence supports one claim versus another, drawing conclusions which are supported by the highest quality evidence (Bensley 2018). If no high-quality evidence is available for consideration, it would be unreasonable to draw a strong conclusion. Unfortunately, people's beliefs are too often based on acceptance of unsubstantiated claims. This is a failure of CT, but is it also a failure of intelligence?

3. Does Critical Thinking "Go Beyond" What Is Meant by Intelligence?

Despite the conceptual overlap in intelligence and CT at a general level, one way that CT can be distinguished from the common view of intelligence as general cognitive ability is in terms of what each can account for. Although intelligence tests, especially measures of general cognitive ability, have reliably predicted academic and job performance, they may not be sufficient to predict other everyday outcomes for which CT measures have made successful predictions and have added to the variance accounted for in performance. For instance, replicating a study by Butler (2012), Butler et al. (2017) obtained a negative correlation ($r = -0.33$) between scores on the Halpern Critical Thinking Appraisal (HCTA) and a measure of 134 negative, real-world outcomes, not expected to befall critical thinkers, such as engaging in unprotected sex or posting a message on social media which the person regretted. They found that higher HCTA scores not only predicted better life decisions, but also predicted better performance beyond a measure of general cognitive ability. These results suggest that CT can account for real-world outcomes and goes beyond general cognitive ability to account for additional variance.

Some theorists maintain that standardized intelligence tests do not capture the variety of abilities that people need to adapt well in the real world. For example, Gardner (1999), has proposed that additional forms of intelligence are needed, such as spatial, musical, and interpersonal intelligences in addition to linguistic and logical–mathematical intelligences, more typically associated with general cognitive ability and academic success. In other theorizing, Sternberg (1988) has proposed three additional types of intelligence: analytical, practical, and creative intelligence, to more fully capture the variety of intelligent abilities on which people differ. Critical thinking is considered part of analytical skills which involve evaluating the quality and applicability of ideas, products, and options (Sternberg 2022). Regarding adaptive intelligence, Sternberg (2019) has emphasized how adaptive aspects of intelligence are needed to solve real-world problems both at the individual and species levels. According to Sternberg, core components of intelligence have evolved in humans, but intelligence takes different forms in different cultures, with each culture valuing its own skills for adaptation. Thus, the construct of intelligence must go beyond core cognitive ability to encompass the specific abilities needed for adaptive behavior in specific cultures and settings.

Two other theories propose that other components be added to intelligent and rational thinking. Ackerman (2022) has emphasized the importance of acquiring domain-specific knowledge for engaging in intelligent functioning in the wide variety of tasks found in everyday life. Ackerman has argued that declarative, procedural, and tacit knowledge, as well as non-ability variables, are needed to better predict job performance and performance of other everyday activities. Taking another approach, Halpern and Dunn (2021) have proposed that critical thinking is essentially the adaptive application of intelligence for solving real-world problems. Elsewhere, Butler and Halpern (2019) have argued that dispositions such as open-mindedness are another aspect of CT and that domain-specific knowledge and specific CT skills are needed to solve real-world problems.

Examples are readily available for how CT goes beyond what IQ tests test to include specific rules for reasoning and relevant knowledge needed to execute real-world tasks. Take the example of scientific reasoning, which can be viewed as a specialized form of CT. Drawing a well-reasoned inductive conclusion about a theory or analyzing the quality of a research study both require that a thinker possess relevant specialized knowledge related to the question and specific reasoning skills for reasoning about scientific methodology. In contrast, IQ tests are deliberately designed to be nonspecialized in assessing Gc, broadly sampling vocabulary and general knowledge in order to be fair and unbiased (Stanovich 2009). Specialized knowledge and reasoning skills are also needed in non-academic domains. Jurors must possess specialized knowledge to understand expert, forensic testimony and specific reasoning skills to interpret the law and make well-reasoned judgments about a defendant's guilt or innocence.

Besides lacking specific reasoning skills and domain-relevant knowledge, people may fail to think critically because they are not disposed to use their reasoning skills to examine such claims and want to preserve their favored beliefs. Critical thinking dispositions are attitudes or traits that make it more likely that a person will think critically. Theorists have proposed numerous CT dispositions (e.g., Bensley 2018; Butler and Halpern 2019; Dwyer 2017; Ennis 1987). Some commonly identified CT dispositions especially relevant to this discussion are open-mindedness, skepticism, intellectual engagement, and the tendency to take a reflective, rational–analytic approach. Critical thinking dispositions are clearly value-laden and prescriptive. A good thinker should be open-minded, skeptical, reflective, intellectually engaged, and value a rational–analytic approach to inquiry. Conversely, corresponding negative dispositions, such as "close-mindedness" and "gullibility", could obstruct CT.

Without the appropriate disposition, individuals will not use their reasoning skills to think critically about questions. For example, the brilliant mystery writer, Sir Arthur

Conan Doyle, who was trained as a physician and created the hyper-reasonable detective Sherlock Holmes, was not disposed to think critically about some unsubstantiated claims. Conan Doyle was no doubt highly intelligent in cognitive ability terms, but he was not sufficiently skeptical (disposed to think critically) about spiritualism. He believed that he was talking to his dearly departed son though a medium, despite the warnings of his magician friend, Harry Houdini, who told him that mediums used trickery in their seances. Perhaps influenced by his Irish father's belief in the "wee folk", Conan Doyle also believed that fairies inhabited the English countryside, based on children's photos, despite the advice of experts who said the photos could be faked. Nevertheless, he was skeptical of a new theory of tuberculosis proposed by Koch when he reported on it, despite his wife suffering from the disease. So, in professional capacities, Conan Doyle used his CT skills, but in certain other domains for which he was motivated to accept unsubstantiated claims, he failed to think critically, insufficiently disposed to skeptically challenge certain implausible claims.

This example makes two important points. Conan Doyle's superior intelligence was not enough for him to reject implausible claims about the world. In general, motivated reasoning can lead people, even those considered highly intelligent, to accept claims with no good evidentiary support. The second important point is that we would not be able to adequately explain cases like this one, considering only the person's intelligence or even their reasoning skills, without also considering the person's disposition. General cognitive ability alone is not sufficient, and CT dispositions should also be considered.

Supporting this conclusion, Stanovich and West (1997) examined the influence of dispositions beyond the contribution of cognitive ability on a CT task. They gave college students an argument evaluation test in which participants first rated their agreement with several claims about real social and political issues made by a fictitious person. Then, they gave them evidence against each claim and finally asked them to rate the quality of a counterargument made by the same fictitious person. Participants' ratings of the counterarguments were compared to the median ratings of expert judges on the quality of the rebuttals. Stanovich and West also administered a new measure of rational disposition called the Actively Open-minded Thinking (AOT) scale and the SAT as a proxy for cognitive ability. The AOT was a composite of items from several other scales that would be expected to measure CT disposition. They found that both SAT and AOT scores were significant predictors of higher argument analysis scores. Even after partialing out cognitive ability, actively open-minded thinking was significant. These results suggest that general cognitive ability alone was not sufficient to account for thinking critically about real-world issues and that CT disposition was needed to go beyond it.

Further examining the roles of CT dispositions and cognitive ability on reasoning, Stanovich and West (2008) studied myside bias, a bias in reasoning closely related to one-sided thinking and confirmation bias. A critical thinker would be expected to not show myside bias and instead fairly evaluate evidence on all sides of a question. Stanovich and West (2007) found that college students often showed myside bias when asked their opinions about real-world policy issues, such as those concerning the health risks of smoking and drinking alcohol. For example, compared to non-smokers, smokers judged the health risks of smoking to be lower. When they divided participants into higher versus lower cognitive ability groups based on SAT scores, the two groups showed little difference on myside bias. Moreover, on the hazards of drinking issue, participants who drank less had higher scores on the CT disposition measure.

Other research supports the need for both reasoning ability and CT disposition in predicting outcomes in the real world. Ren et al. (2020) found that CT disposition, as measured by a Chinese critical thinking disposition inventory, and a CT skill measure together contributed a significant amount of the variance in predicting academic performance beyond the contribution of cognitive ability alone, as measured by a test of fluid intelligence. Further supporting the claim that CT requires both cognitive ability and CT disposition, Ku and Ho (2010) found that a CT disposition measure significantly predicted scores on a CT test beyond the significant contribution of verbal intelligence in high school and college students from Hong Kong.

The contribution of dispositions to thinking is related to another way that CT goes beyond the application of general cognitive ability, i.e., by way of the motivation for reasoning. Assuming that all reasoning is motivated (Kunda 1990), then CT is motivated, too, which is implicit within the Halpern and Dunn (2021) and Ennis (1987) definitions. Critical thinking is motivated in the sense of being purposeful and directed towards the goal of arriving at an accurate conclusion. For instance, corresponding to pursuit of the goal of accurate reasoning, the CT disposition of "truth-seeking" guides a person towards reaching the CT goal of arriving at an accurate conclusion.

Also, according to Kunda (1990), a second type of motivated reasoning can lead to faulty conclusions, often by directing a person towards the goal of maintaining favored beliefs and preconceptions, as in illusory correlation, belief perseverance, and confirmation bias. Corresponding to this second type, negative dispositions, such as close-mindedness and self-serving motives, can incline thinkers towards faulty conclusions. This is especially relevant in the present discussion because poorer reasoning, thinking errors, and the inappropriate use of heuristics are related to the endorsement of unsubstantiated claims, all of which are CT failures. The term "thinking errors" is a generic term referring to logical fallacies, informal reasoning fallacies, argumentation errors, and inappropriate uses of cognitive heuristics (Bensley 2018). Heuristics are cognitive shortcuts, commonly used to simplify judgment tasks and reduce mental effort. Yet, when used inappropriately, heuristics often result in biased judgments.

Stanovich (2009) has argued that IQ tests do not test people's use of heuristics, but heuristics have been found to be negatively correlated with CT performance (West et al. 2008). In this same study, they found that college students' cognitive ability, as measured by performance on the SAT, was not correlated with thinking biases associated with use of heuristics. Although Stanovich and West (2008) found that susceptibility to biases, such as the conjunction fallacy, framing effect, base-rate neglect, affect bias, and myside bias were all uncorrelated with cognitive ability (using SAT as a proxy), other types of thinking errors were correlated with SAT.

Likewise, two types of knowledge are related to the two forms of motivated reasoning. For instance, inaccurate knowledge, such as misconceptions, can derail reasoning from moving towards a correct conclusion, as in when a person reasons from false premises. In contrast, reasoning from accurate knowledge is more likely to produce an accurate conclusion. Taking into account inaccurate knowledge and thinking errors is important to understanding the endorsement of unsubstantiated claims because these are also related to negative dispositions, such as close-mindedness and cynicism, none of which are measured by intelligence tests.

Critical thinking questions are often situated in real-world examples or in simulations of them which are designed to detect thinking errors and bias. As described in Halpern and Butler (2018), an item like one on the "Halpern Critical Thinking Assessment" (HCTA) provides respondents with a mock newspaper story about research showing that first-graders who attended preschool were better able to learn how to read. Then the question asks if preschool should be made mandatory. A correct response to this item requires recognizing that correlation does not imply causation, that is, avoiding a common reasoning error people make in thinking about research implications in everyday life. Another CT skills test, "Analyzing Psychological Statements" (APS) assesses the ability to recognize thinking errors and apply argumentation skills and psychology to evaluate psychology-related examples and simulations of real-life situations (Bensley 2021). For instance, besides identifying thinking errors in brief samples of thinking, questions ask respondents to distinguish arguments from non-arguments, find assumptions in arguments, evaluate kinds of evidence, and draw a conclusion from a brief psychological argument. An important implication of the studies just reviewed is that efforts to understand CT can be further informed by assessing thinking errors and biases, which, as the next discussion shows, are related to individual differences in thinking dispositions and cognitive style.

4. Dual-Process Theory Measures and Unsubstantiated Beliefs

Dual-process theory (DPT) and measures associated with it have been widely used in the study of the endorsement of unsubstantiated beliefs, especially as they relate to cognitive style. According to a cognitive style version of DPT, people have two modes of processing, a fast intuitive–experiential (I-E) style of processing and a slower, reflective, rational–analytic (R-A) style of processing. The intuitive cognitive style is associated with reliance on hunches, feelings, personal experience, and cognitive heuristics which simplify processing, while the R-A cognitive style is a reflective, rational–analytic style associated with more elaborate and effortful processing (Bensley et al. 2022; Epstein 2008). As such, the rational–analytic cognitive style is consistent with CT dispositions, such as those promoting the effortful analysis of evidence, objective truth, and logical consistency. In fact, CT is sometimes referred to as "critical-analytic" thinking (Byrnes and Dunbar 2014) and has been associated with analytical intelligence Sternberg (1988) and with rational thinking, as discussed before.

People use both modes of processing, but they show individual differences in which mode they tend to rely upon, although the intuitive–experiential mode is the default (Bensley et al. 2022; Morgan 2016; Pacini and Epstein 1999), and they accept unsubstantiated claims differentially based on their predominate cognitive style (Bensley et al. 2022; Epstein 2008). Specifically, individuals who rely more on an I-E cognitive style tend to endorse unsubstantiated claims more strongly, while individuals who rely more on a R-A cognitive style tend to endorse those claims less. Note, however, that other theorists view the two processes and cognitive styles somewhat differently, (e.g., Kahneman 2011; Stanovich et al. 2018).

Researchers have often assessed the contribution of these two cognitive styles to endorsement of unsubstantiated claims, using variants of three measures: the Cognitive Reflection Test (CRT) of Frederick (2005), the Rational–Experiential Inventory of Epstein and his colleagues (Pacini and Epstein 1999), and the related Need for Cognition scale of Cacioppo and Petty (1982). The CRT is a performance-based test which asks participants to solve problems that appear to require simple mathematical calculations, but which actually require more reflection. People typically do poorly on the CRT, which is thought to indicate reliance on an intuitive cognitive style, while better performance is thought to indicate reliance on the slower, more deliberate, and reflective cognitive style. The positive correlation of the CRT with numeracy scores suggests it also has a cognitive skill component (Patel et al. 2019). The Rational–Experiential Inventory (REI) of Pacini and Epstein (1999) contains one scale designed to measure an intuitive–experiential cognitive style and a second scale intended to measure a rational–analytic (R-A) style. The R-A scale was adapted from the Need for Cognition (NFC) scale of Cacioppo and Petty (1982), another scale associated with rational–analytic thinking and expected to be negatively correlated with unsubstantiated beliefs. The NFC was found to be related to open-mindedness and intellectual engagement, two CT dispositions (Cacioppo et al. 1996).

The cognitive styles associated with DPT also relate to CT dispositions. Thinking critically requires that individuals be disposed to use their reasoning skills to reject unsubstantiated claims (Bensley 2018) and that they be inclined to take a rational–analytic approach rather than relying on their intuitions and feelings. For instance, Bensley et al. (2014) found that students who endorsed more psychological misconceptions adopted a more intuitive cognitive style, were less disposed to take a rational–scientific approach to psychology, and scored lower on a psychological critical thinking skills test. Further supporting this connection, West et al. (2008) found that participants who tended to use cognitive heuristics more, thought to be related to intuitive processing and bias, scored lower on a critical thinking measure. As the Bensley et al. (2014) results suggest, in addition to assessing reasoning skills and dispositions, comprehensive CT assessment research should assess knowledge and unsubstantiated beliefs because these are related to failures of critical thinking.

5. Assessing Critical Thinking and Unsubstantiated Beliefs

Assessing endorsement of unsubstantiated claims provides another way to assess CT outcomes related to everyday thinking, which goes beyond what intelligence tests test (Bensley and Lilienfeld 2020). From the perspective of the multi-dimensional model of CT, endorsement of unsubstantiated claims could result from deficiencies in a person's CT reasoning skills, a lack of relevant knowledge, and in the engagement of inappropriate dispositions. Suppose an individual endorses an unsubstantiated claim, such as believing the conspiracy theory that human-caused global warming is a hoax. The person may lack the specific reasoning skills needed to critically evaluate the conspiracy. Lantian et al. (2020) found that scores on a CT skills test were negatively correlated with conspiracy theory beliefs. The person also must possess relevant scientific knowledge, such as knowing the facts that each year humans pump about 40 billion metric tons of carbon dioxide into the atmosphere and that carbon dioxide is a greenhouse gas which traps heat in the atmosphere. Or, the person may not be scientifically skeptical or too cynical or mistrustful of scientists or governmental officials.

Although endorsing unsubstantiated beliefs is clearly a failure of CT, problems arise in deciding which ones are unsubstantiated, especially when considering conspiracy theories. Typically, the claims which critical thinkers should reject as unsubstantiated are those which are not supported by objective evidence. But of the many conspiracies proposed, few are vigorously examined. Moreover, some conspiracy theories which authorities might initially deny turn out to be real, such as the MK-Ultra theory that the CIA was secretly conducting mind-control research on American citizens.

A way out of this quagmire is to define unsubstantiated beliefs on a continuum which depends on the quality of evidence. This has led to the definition of unsubstantiated claims as assertions which have not been supported by high-quality evidence (Bensley 2023). Those which are supported have the kind of evidentiary support that critical thinkers are expected to value in drawing reasonable conclusions. Instead of insisting that a claim must be demonstrably false to be rejected, we adopt a more tentative acceptance or rejection of claims, based on how much good evidence supports them. Many claims are unsubstantiated because they have not yet been carefully examined and so totally lack support or they may be supported only by low quality evidence such as personal experience, anecdotes, or non-scientific authority. Other claims are more clearly unsubstantiated because they contradict the findings of high-quality research. A critical thinker should be highly skeptical of these.

Psychological misconceptions are one type of claim that can be more clearly unsubstantiated. Psychological misconceptions are commonsense psychological claims (folk theories) about the mind, brain, and behavior that are contradicted by the bulk of high-quality scientific research. Author developed the Test of Psychological Knowledge and Misconceptions (TOPKAM), a 40-item, forced-choice measure with each item posing a statement of a psychological misconception and the other response option stating the evidence-based alternative (Bensley et al. 2014). They found that higher scores on the APS, the argument analysis test applying psychological concepts to analyze real-world examples, were associated with more correct answers on the TOPKAM. Other studies have found positive correlations between CT skills tests and other measures of psychological misconceptions (McCutcheon et al. 1992; Kowalski and Taylor 2004). Bensley et al. (2014) also found that higher correct TOPKAM scores were positively correlated with scores on the Inventory of Thinking Dispositions in Psychology (ITDP) of Bensley (2021), a measure of the disposition to take a rational and scientific approach to psychology but were negatively correlated with an intuitive cognitive style.

Bensley et al. (2021) conducted a multidimensional study, assessing beginner psychology students starting a CT course on their endorsement of psychological misconceptions, recognition of thinking errors, CT dispositions, and metacognition, before and after CT instruction. Two classes received explicit instruction involving considerable practice in argument analysis and scientific reasoning skills, with one class receiving CT instruction focused more on recognizing psychological misconceptions and a second class focused more on recognizing various thinking errors. Bensley et al. assessed both classes before and after instruction on the TOPKAM and on the Test of Thinking Errors, a test of the ability to recognize in real-world examples 17 different types of thinking errors, such as confirmation bias, inappropriate use of the availability and representativeness heuristics, reasoning from ignorance/possibility, gambler's fallacy, and hasty generalization (Bensley et al. 2021). Correct TOPKAM and TOTE scores were positively correlated, and after CT instruction both were positively correlated with the APS, the CT test of argument analysis skills.

Bensley et al. found that after explicit instruction of CT skills, students improved significantly on both the TOPKAM and TOTE, but those focusing on recognizing misconceptions improved the most. Also, those students who improved the most on the TOTE scored higher on the REI rational–analytic scale and on the ITDP, while those improving the most on the TOTE scored higher on the ITDP. The students receiving explicit CT skill instruction in recognizing misconceptions also significantly improved the accuracy of their metacognitive monitoring in estimating their TOPKAM scores after instruction.

Given that before instruction neither class differed in GPA nor on the SAT, a proxy for general cognitive ability, CT instruction provided a good accounting for the improvement in recognition of thinking errors and misconceptions without recourse to intelligence. However, SAT scores were positively correlated with both TOTE scores and APS scores, suggesting that cognitive ability contributed to CT skill performance. These results replicated the earlier findings of Bensley and Spero (2014) showing that explicit CT instruction improved performance on both CT skills tests and metacognitive monitoring accuracy while controlling for SAT, which was positively correlated with the CT skills test performance.

Taken together, these findings suggest that cognitive ability contributes to performance on CT tasks but that CT instruction goes beyond it to further improve performance. As the results of Bensley et al. (2021) show, and as discussed next, thinking errors and bias from heuristics are CT failures that should also be assessed because they are related to endorsement of unsubstantiated beliefs and cognitive style.

6. Dual-Processing Theory and Research on Unsubstantiated Beliefs

Consistent with DPT, numerous other studies have obtained significant positive correlations between intuitive cognitive style and paranormal belief, often using the REI intuitive–experiential scale and the Revised Paranormal Belief Scale (RPBS) of Tobacyk (2004) (e.g., Genovese 2005; Irwin and Young 2002; Lindeman and Aarnio 2006; Pennycook et al. 2015; Rogers et al. 2018; Saher and Lindeman 2005). Studies have also found positive correlations between superstitious belief and intuitive cognitive style (e.g., Lindeman and Aarnio 2006; Maqsood et al. 2018). REI intuitive–experiential thinking style was also positively correlated with belief in complementary and alternative medicine (Lindeman 2011), conspiracy theory belief (Alper et al. 2020), and with endorsement of psychological misconceptions (Bensley et al. 2014; Bensley et al. 2022).

Additional evidence for DPT has been found when REI R-A and NFC scores were negatively correlated with scores on measures of unsubstantiated beliefs, but studies correlating them with measures of paranormal belief and conspiracy theory belief have shown mixed results. Supporting a relationship, REI rational–analytic and NFC scores significantly and negatively predicted paranormal belief (Lobato et al. 2014; Pennycook et al. 2012). Other studies have also obtained a negative correlation between NFC and paranormal belief (Lindeman and Aarnio 2006; Rogers et al. 2018; Stahl and van Prooijen 2018), but both Genovese (2005) and Pennycook et al. (2015) found that NFC was not significantly correlated with paranormal belief. Swami et al. (2014) found that although REI R-A scores were negatively correlated with conspiracy theory belief, NFC scores were not.

Researchers often refer to people who are doubtful of paranormal and other unfounded claims as "skeptics" and so have tested whether measures related to skepticism are associated with less endorsement of unsubstantiated claims. They typically view skepticism as a stance towards unsubstantiated claims taken by rational people who reject them, (e.g., Lindeman and Aarnio 2006; Stahl and van Prooijen 2018), rather than as a disposition inclining a person to think critically about unsubstantiated beliefs (Bensley 2018).

Fasce and Pico (2019) conducted one of the few studies using a measure related to skeptical disposition, the Critical Thinking Disposition Scale (CTDS) of Sosu (2013), in relation to endorsement of unsubstantiated claims. They found that scores on the CTDS were negatively correlated with scores on the RPBS but not significantly correlated with either a measure of pseudoscience or of conspiracy theory belief. However, the CRT was negatively correlated with both RPBS and the pseudoscience measure. Because Fasce and Pico (2019) did not examine correlations with the Reflective Skepticism subscale of the CTDS, its contribution apart from full-scale CTDS was not found.

To more directly test skepticism as a disposition, we recently assessed college students on how well three new measures predicted endorsement of psychological misconceptions, paranormal claims, and conspiracy theories (Bensley et al. 2022). The dispositional measures included a measure of general skeptical attitude; a second measure, the Scientific Skepticism Scale (SSS), which focused more on waiting to accept claims until high-quality scientific evidence supported them; and a third measure, the Cynicism Scale (CS), which focused on doubting the sincerity of the motives of scientists and people in general. We found that although the general skepticism scale did not predict any of the unsubstantiated belief measures, SSS scores were a significant negative predictor of both paranormal belief and conspiracy theory belief. REI R-A scores were a less consistent negative predictor, while REI I-E scores were more consistent positive predictors, and surprisingly CS scores were the most consistent positive predictors of the unsubstantiated beliefs.

Researchers commonly assume that people who accept implausible, unsubstantiated claims are gullible or not sufficiently skeptical. For instance, van Prooijen (2019) has argued that conspiracy theory believers are more gullible (less skeptical) than non-believers and tend to accept unsubstantiated claims more than less gullible people. van Prooijen (2019) reviewed several studies supporting the claim that people who are more gullible tend to endorse conspiracy theories more. However, he did not report any studies in which a gullible disposition was directly measured.

Recently, we directly tested the gullibility hypothesis in relation to scientific skepticism (Bensley et al. 2023) using the Gullibility Scale of Teunisse et al. (2019) on which people skeptical of the paranormal had been shown to have lower scores. We found that Gullibility Scale and the Cynicism Scale scores were positively correlated, and both were significant positive predictors of unsubstantiated beliefs, in general, consistent with an intuitive–experiential cognitive style. In contrast, we found that scores on the Cognitive Reflection Test, the Scientific Skepticism Scale, and the REI rational–analytic scale were all positively intercorrelated and significant negative predictors of unsubstantiated beliefs, in general, consistent with a rational–analytic/reflective cognitive style. Scientific skepticism scores negatively predicted general endorsement of unsubstantiated claims beyond the REI R-A scale, but neither the CTDS nor the CTDS Reflective Skepticism subscale were significant. These results replicated findings from the Bensley et al. (2023) study and supported an elaborated dual-process model of unsubstantiated belief. The SSS was not only a substantial negative predictor, it was also negatively correlated with the Gullibility Scale, as expected.

These results suggest that both CT-related dispositions and CT skills are related to endorsement of unsubstantiated beliefs. However, a measure of general cognitive ability or intelligence must be examined along with measures of CT and unsubstantiated beliefs to determine if CT goes beyond intelligence to predict unsubstantiated beliefs. In one of the few studies that also included a measure of cognitive ability, Stahl and van Prooijen (2018) found that dispositional characteristics helped account for acceptance of conspiracies and paranormal belief beyond cognitive ability. Using the Importance of Rationality Scale

(IRS), a rational–analytic scale designed to measure skepticism towards unsubstantiated beliefs, Stahl and van Prooijen (2018) found that the IRS was negatively correlated with paranormal belief and belief in conspiracy theories. In separate hierarchical regressions, cognitive ability was the strongest negative predictor of both paranormal belief and of conspiracy belief, but IRS scores in combination with cognitive ability negatively predicted endorsement of paranormal belief but did not significantly predict conspiracy theory belief. These results provided partial support that that a measure of rational–analytic cognitive style related to skeptical disposition added to the variance accounted for beyond cognitive ability in negatively predicting unsubstantiated belief.

In another study that included a measure of cognitive ability, Cavojova et al. (2019) examined how CT-related dispositions and the Scientific Reasoning Scale (SRS) were related to a measure of paranormal, pseudoscientific, and conspiracy theory beliefs. The SRS of Drummond and Fischhoff (2017) likely measures CT skill in that it measures the ability to evaluate scientific research and evidence. As expected, the unsubstantiated belief measure was negatively correlated with the SRS and a cognitive ability measure, similar to Raven's Progressive Matrices. Unsubstantiated beliefs were positively correlated with dogmatism (the opposite of open-mindedness) but not with REI rational–analytic cognitive style. The SRS was a significant negative predictor of both unsubstantiated belief and susceptibility to bias beyond the contribution of cognitive ability, but neither dogmatism nor analytic thinking were significant predictors. Nevertheless, this study provides some support that a measure related to CT reasoning skill accounts for variance in unsubstantiated belief beyond cognitive ability.

The failure of this study to show a correlation between rational–analytic cognitive style and unsubstantiated beliefs, when some other studies have found significant correlations with it and related measures, has implications for the multidimensional assessment of unsubstantiated beliefs. One implication is that the REI rational–analytic scale may not be a strong predictor of unsubstantiated beliefs. In fact, we have recently found that the Scientific Skepticism Scale was a stronger negative predictor (Bensley et al. 2022; Bensley et al. 2023), which also suggests that other measures related to rational–analytic thinking styles should be examined. This could help triangulate the contribution of self-report cognitive style measures to endorsement of unsubstantiated claims, recognizing that the use of self-report measures has a checkered history in psychological research. A second implication is that once again, measures of critical thinking skill and cognitive ability were negative predictors of unsubstantiated belief and so they, too, should be included in future assessments of unsubstantiated beliefs.

7. Discussion

This review provided different lines of evidence supporting the claim that CT goes beyond cognitive ability in accounting for certain real-world outcomes. Participants who think critically reported fewer problems in everyday functioning, not expected to befall critical thinkers. People who endorsed unsubstantiated claims less showed better CT skills, more accurate domain-specific knowledge, less susceptibility to thinking errors and bias, and were more disposed to think critically. More specifically, they tended to be more scientifically skeptical and adopt a more rational–analytic cognitive style. In contrast, those who endorsed them more tended to be more cynical and adopt an intuitive–experiential cognitive style. These characteristics go beyond what standardized intelligence tests test. In some studies, the CT measures accounted for additional variance beyond the variance contributed by general cognitive ability.

That is not to say that measures of general cognitive ability are not useful. As noted by Gottfredson (2004), "g" is a highly successful predictor of academic and job performance. More is known about g and Gf than about many other psychological constructs. On average, g is closely related to Gf, which is highly correlated with working memory ($r = 0.70$) and can be as high as $r = 0.77$ ($r^2 = 0.60$) based on a correlated two-factor model (Gignac 2014). Because modern working memory theory is, itself, a powerful theory (Chai et al.

2018), this lends construct validity to the fluid intelligence construct. Although cognitive scientists have clearly made progress in understanding the executive processes underlying intelligence, they have not yet identified the specific cognitive components of intelligence (Sternberg 2022). Moreover, theorists have acknowledged that intelligence must also include components beyond g, including domain-specific knowledge (Ackerman 2022; Conway and Kovacs 2018) which are not yet clearly understood,

This review also pointed to limitations in the research that should be addressed. So far, not only have few studies of unsubstantiated beliefs included measures of intelligence, but they have also often used proxies for intelligence test scores, such as SAT scores. Future studies, besides using more and better measures of intelligence, could benefit from inclusion of more specifically focused measures, such as measures of Gf and Gc. Also, more research should be carried out to develop additional high-quality measures of CT, including ones that assess specific reasoning skills and knowledge relevant to thinking about a subject, which could help resolve perennial questions about the domain-general versus domain-specific nature of intelligence and CT. Overall, the results of this review encourage taking a multidimensional approach to investigating the complex constructs of intelligence, CT, and unsubstantiated belief. Supporting these recommendations were results of studies in which the improvement accrued from explicit CT skill instruction could be more fully understood when CT skills, relevant knowledge, CT dispositions, metacognitive monitoring accuracy, and a proxy for intelligence were used.

8. Conclusions

Critical thinking, broadly conceived, offers ways to understand real-world outcomes of thinking beyond what general cognitive ability can provide and intelligence tests test. A multi-dimensional view of CT which includes specific reasoning and metacognitive skills, CT dispositions, and relevant knowledge can add to our understanding of why some people endorse unsubstantiated claims more than others do, going beyond what intelligence tests test. Although general cognitive ability and domain-general knowledge often contribute to performance on CT tasks, thinking critically about real-world questions also involves applying rules, criteria, and knowledge which are specific to the question under consideration, as well as the appropriate dispositions and cognitive styles for deploying these.

Despite the advantages of taking this multidimensional approach to CT in helping us to more fully understand everyday thinking and irrationality, it presents challenges for researchers and instructors. It implies the need to assess and instruct multidimensionally, including not only measures of reasoning skills but also addressing thinking errors and biases, dispositions, the knowledge relevant to a task, and the accuracy of metacognitive judgments. As noted by Dwyer (2023), adopting a more complex conceptualization of CT beyond just skills is needed, but it presents challenges for those seeking to improve students' CT. Nevertheless, the research reviewed suggests that taking this multidimensional approach to CT can enhance our understanding of the endorsement of unsubstantiated claims beyond what standardized intelligence tests contribute. More research is needed to resolve remaining controversies and to develop evidence-based applications of the findings.

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Essay

Critical Thinking: Creating Job-Proof Skills for the Future of Work

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Abstract: In this study, we explore the transformative impact of artificial intelligence (AI) on the job market and argue for the growing importance of critical thinking skills in the face of job automation and changing work dynamics. Advancements in AI have the potential to disrupt various professions, including, for example, programming, legal work, and radiology. However, solely relying on AI systems can lead to errors and misjudgments, emphasizing the need for human oversight. The concept of "job-proof skills" is introduced, highlighting the importance of critical thinking, problem-solving, empathy, ethics, and other human attributes that machines cannot replicate with the same standards and agility. We maintain that critical thinking can be taught and learned through appropriate classroom instruction and transfer-focused approaches. The need for critical thinking skills is further reinforced by the influx of information and the spread of misinformation in the age of social media. Moreover, employers increasingly value critical thinking skills in their workforce, yet there exists a gap between the demand for these skills and the preparedness of college graduates. Critical thinking is not only essential for the future of work, but also for informed citizenship in an increasingly complex world. The potential impact of AI on job disruption, wages, and employment polarization is discussed, highlighting the correlation between jobs requiring critical thinking skills and their resistance to automation. We conclude by discussing collaborative efforts between universities and labor market organizations to adapt curricula and promote the development of critical thinking skills, drawing on examples from European initiatives. The need to prioritize critical thinking skills in education and address the evolving demands of the labor market is emphasized as a crucial step for navigating the future of work and opportunities for workers.

Keywords: critical thinking; artificial intelligence; job market; job disruption

1. Introduction: Critical Thinking: Creating Job-Proof Skills for the Future of Work

The rapid evolution of online technologies has ushered in a paradigm shift in employment, redefining the nature of work and the skills required to succeed in the digital age. This transformative landscape, characterized by the ubiquitous presence of the Internet, social media platforms, and advanced artificial intelligence systems, has created a plethora of new opportunities and challenges in the labor market. As we navigate this digital frontier, it is becoming increasingly clear that traditional employment paradigms are undergoing a profound transformation. The convergence of online technologies with the demands of a networked world has not only created new job opportunities, but it has also disrupted established industries, rendering some job roles obsolete while creating demand for previously unforeseen skills. In this era of unprecedented connectivity and innovation, examining the intricate interplay between online technologies and jobs is paramount as it holds the key to understanding the dynamics of our rapidly evolving workforce.

Artificial intelligence (AI) is disrupting many jobs and promises "to change the way the world works" (adminGPT 2023, para. 13). The number and range of AI programs are increasing at a rapid pace, and they are likely to continually improve to meet user demands. Consider, for example, ChatGPT, which can respond to questions and requests in a way that seems to come from a human rather than a computer program. GPT stands for "generative pretrained transformer". It is generative in that it can provide responses that it never "learned"; it is pretrained with a large language model (Bushwick et al. 2023). Newer versions can describe visual images, although thus far, they cannot create visual images. Its uses are seemingly endless. It is easy to imagine how such programs can change the lives of blind individuals. In fact, it can and will change the lives of all of us.

In this paper, we argue that these advances in online technologies will make critical thinking (CT) more important than ever before. Many who are preparing to enter the job market, and many who are already employed, will need to adapt to new forms of job automation and different ways of working.

Consider, for example, that an early achievement of ChatGPT was its generation of Python code (a computer language) to compute various tasks, such as data analysis. Apparently, getting ChatGPT to generate code is so easy that several YouTube videos have popped up claiming that they can teach novice users to use ChatGPT to generate code in 90 s. (Data Professor 2023). The benefits are obvious, but so are the potential job losses for people who work in Python. Python coders will need to upgrade their skills, perhaps first becoming experts in the use of ChatGPT and similar programs, but this also has a positive side--they can spend more time working on larger questions such as which analyses are needed, and, of course, carefully reviewing the work produced by AI to ensure that it is accurate and understandable. Early versions of ChatGPT responses often contained errors. A New York lawyer learned the hard way: Steven A. Schwartz, a lawyer for 30 years, used ChatGPT to create a legal document (Weiser and Schweber 2023). It was filled with fake citations and bogus judicial opinions. Sadly, Mr. Schwartz never checked the accuracy of the document he filed in court. The judge was not amused. This highly public and embarrassing event should be a lesson for all of us. Current AI programs cannot be trusted to take over our work, though they may be able to aid or supplement it. However, other AI programs can "read" radiographs more accurately than human radiologists, which provides a benefit to both radiologists and patients. There is an immediate positive effect for this advancement: Radiologists will have more time to directly work with patients, and yes, they must also check the accuracy of the outputs from their programs when presenting diagnoses.

For the rest of us, whether we are students or early or late in our careers, we need to focus on the development of "job-proof skills" in the face of AI advances. A report from the United Nations defines job-proof skills as "conceptual and strategic thinking, problem-solving, empathy, optimism, ethics, emotional intelligence, and judgments are the future-proof skills and attributes that machines will not be able to replicate with the same standards and agility as qualified human beings" (Elkeiy 2022, para. 5). In other words, critical thinking skills will always be needed.

2. What Is Critical Thinking?

Although some scholars in the field of critical thinking have emphasized differences among various definitions, we believe that the commonalities are evident (c.f., Dwyer 2017; Nisbett 2015; Lipman 1991; Fisher 2001). There are some differences in the use of terms and several skills might be more important, but all of the definitions (more or less) conform to our preferred definition: "Critical thinking is the use of those cognitive skills and abilities that increase the probability of a desirable outcome. It is purposeful, reasoned, and goal directed. It is the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions. Critical thinkers use these skills appropriately, without prompting, and usually with conscious intent, in a variety of settings. That is, they are predisposed to think critically. When we think critically, we are evaluating the outcomes of our thought processes--how good a decision is or how well a problem is solved. Critical thinking also involves evaluating the thinking process--the reasoning that went into the conclusion we've arrived at, or the kinds of factors considered in making a decision" (Halpern and Dunn 2023, pp. 6–7). The reason we need a common definition of critical thinking is that, without it, instructors can and have passed almost anything off as instruction in critical thinking. However, common ground is to be found concerning CT definitions. In a European project, which we shall refer to in Section 4.3, the critical thinking definition is based on the works of Halpern and Dunn (2023), Facione (1990), Paul and Elder (2008), and Kuhn (1999). During two debate sessions, 33 international participants from higher education and the labor market defined critical thinking as a deliberate cognitive process guided by conscious, dynamic, self-directed, self-monitored, and self-correcting thought (Rebelo et al. 2023). It relies on both disciplinary and procedural knowledge, along with metacognitive aspects (including metacognitive, meta-strategic, and epistemological dimensions). Critical thinking can be cultivated and enhanced through the development of competencies, and it is facilitated by various attitudes, such as systematic thinking, open-mindedness, empathy, flexibility, and cognitive maturity. Additionally, it encompasses intellectual skills such as reflection, self-regulation, analysis, inference, explanation, synthesis, and systematic thought. Critical thinking not only stimulates problem-solving capabilities but also facilitates effective communication, fosters independent and holistic thinking, and bolsters decision-making and active citizenship (Pnevmatikos et al. 2021).

2.1. Can Critical Thinking Be Learned?

We teach writing, oral communication, and mathematics with the (often implicit) belief that these skills will be learned and transferred to multiple settings both inside and outside of the classroom. There is a large and growing research literature showing that, with appropriate classroom instruction in critical thinking, including specific instruction designed for transfer, the skills will spontaneously transfer and in uncued (i.e., there are no reminders to use the critical thinking skill that was learned in class) situations (Dumitru 2012; Heijltjes et al. 2014; Tiruneh 2019). Several such studies were presented by Dwyer (2017) and Halpern and Dunn (2023). For the sake of brevity, we review just one recent study. The study was designed to counteract the effects of conspiracy theories. When people believe conspiracy theories, they often act in harmful ways–such as refusing to get the COVID-19 vaccine, which resulted in the death of large numbers of people around the world, or attacking the United State Capitol Building on 6 January 2021 in the belief that there was a conspiracy afoot designed to steal the United States 2020 presidential election from Donald Trump. In a review of the research literature on the efficacy of interventions, the researchers found "there was one intervention which was characteristically different to the rest" (O'Mahony et al. 2023, para. 23). It was a semester-long university course in critical thinking that was designed to teach students the difference between good scientific practices and pseudoscience. These courses require effort and commitment, but they are effective. The same conclusion applies to all interventions designed to enhance critical thinking. There are no fast and easy "once and done" strategies that work. This is why we recommend continuous and pervasive coursework to make sure that the learning of CT skills "sticks."

2.2. The Need for Critical Thinking Skills

Online technologies-related (including AI) job loss and redesign are not the only reasons why we need to concentrate on teaching and learning the skills of critical thinking. COVID-19 left 140 million people out of work, and many of their jobs will never return (Roslansky 2021). We are drowning in a tsunami of information, confronted with advertisements online, in news reports, social media, podcasts, and more. The need to be able to distinguish good information from bad is critical. In addition, employers want to hire people with critical thinking skills. In a recent report by Hart Research Associated (2018), they found that in an employer survey of 501 business executives, 78% said that critical thinking/analytic reasoning is the most important skill they want in their employees, but they also added that only 34% of college graduates arrive well prepared in critical thinking. This gap between what employers want and their perception of the preparedness of the workforce was larger for critical thinking than for any other area. In fact, every report on the future of work made this same point. Consider this quote from The World Economic Forum (2020) on the future of jobs: "Skills gaps continue to be high as in-demand skills across jobs change in the next five years. The top skills and skill groups which employers see as rising in prominence in the lead up to 2025 include groups such as critical thinking and analysis as well as problem-solving." (p. 5). In a report from the Office of the European Union: Key Competences for Lifelong Learning, the commissioner wrote "Critical thinking, media literacy, and communication skills are some of the requirements to navigate our increasingly complex world" (Navracsics 2019, p. 3). Of course, critical thinking is not just needed in the world of work. A true democracy requires an educated citizenry with citizens who can think critically about world social issues, such as the use/threat of AI, war, poverty, climate change, and so much more. Irrational voters are a threat to all of us—and to themselves.

The need to think critically is not new, but it has taken on a new urgency as social media and other forms of communication have made the deliberate spread of misinformation move at the speed of light. There is nothing new about the use of lies, half-truths, and innuendos to get people to believe something that is not true. Anyone can post anything on popular media sites, and this "fake news" is often copied and shared thousands of times. Sometimes the information is spread with a deliberate attempt to mislead; other times, it is copied and spread by people who believe it is true. These messages are often used to discredit political adversaries, create social unrest, and incite fear. It can be a difficult task to determine what to believe and what to discard. Vosoughi et al. (2018) analyzed data from 126,000 tweets that were spread by approximately 3 million people. How did the researchers discriminate true data from false data? The same way we all should. They used several different fact-checking sites and found 95% to 98% agreement regarding the truth or falsehood of information. They found that false data spread more quickly and more widely than true data because the false data tended to be novel and sensational, rendering it salient and seductive.

In today's landscape, the imperative to foster critical thinking skills is becoming increasingly apparent as we grapple with the rapid rise of social media and artificial intelligence technologies and their profound impact on the future of work. The confluence of these transformative forces has ushered in a new era characterized by the potential for significant job disruption. As online technologies advance and automation becomes more widespread, certain traditional job roles may become obsolete, requiring the development of innovative skills and adaptability in the workforce. In this context, critical thinking emerges as a central element in preparing individuals to navigate the evolving job market. It equips individuals with the ability to analyze complex information, discern credible sources from the proliferation of social media information, and make informed decisions in an era of blurring boundaries between human and machine contributions to the workforce. Cultivating critical thinking skills will be essential to ensuring that individuals can take advantage of the opportunities presented by new technologies while mitigating the challenges of job disruption in this AI-driven future.

3. Critical Thinking Skills and Job Disruption and Replacement

Eloundou et al. in 2023 estimated that about 15% of all U.S. workers' jobs could be accomplished much faster and at the same level of quality with currently available AI. There are large differences in the extent to which various occupations and industries will be affected by advancements in AI. For example, tasks that require a high degree of human interaction, highly specialized domain knowledge, or creating innovative technologies will be minimally affected; whereas, other occupations such as providing captions for images or answering questions about a text or document are more likely to be affected. Routine-based jobs in general are more likely to be dislodged by advanced technologies (Acemoglu 2002). Using the basic definitions of skills that are standard in O*Net, Eloundou et al. (2023) found a clear negative correlation between jobs requiring knowledge of science and critical thinking skills and the likelihood that AI will "take over" the job. These findings reinforce our main point—the best way to gain job-proof skills is with critical thinking.

The effect of online technologies on wages is complicated because of the large number of factors that come together to determine earnings. Acemoglu and Autor (2011) advocated for a model that simultaneously considers the level of the tasks required for any job (low, medium, and high), where a high level of skill is defined as one that allows employees to perform a variety of tasks, the demand for the tasks, and technological changes that can complement a task or replace it. They assert that employment has become increasingly polarized with the growth in both high education, high wage occupations and low education, and low wage occupations in the United States and the European Union. To understand and predict which occupations will be most disrupted by AI (and other developing technologies), an investigator will need to simultaneously consider all of these variables. Technological advancements can generate shifts in demand, favoring either high- or low-skilled workers. According to Acemoglu and Autor (2011), we can expect some of the largest disruptive effects at the middle level of skills, where some of the tasks performed at this level can be more easily replaced by new technologies, with widespread employment growth in high- and low-skilled occupations.

4. Business-University Collaborations

The pursuit of promoting high standards of critical thinking in university students across various academic disciplines is a challenging endeavor that should be leveraged through collaboration with stakeholders. In such collaborations, stakeholders can contribute to refining the skills required by learners and bring their own perspectives to academic instruction. This close partnership between universities and stakeholders helps minimize gaps and mismatches in the transition to the labor market, facilitates research collaboration, and increases student motivation.

Collaborations between businesses and universities have gained increasing importance in today's rapidly evolving educational and economic landscape. These partnerships are instrumental in bridging the gap between academic learning and the real-world skills demanded by the job market. One key aspect of business-university collaboration (BUC) is the alignment of curricula with the dynamic needs of industries. This entails the joint effort of higher education institutions (HEIs) and industry experts to design, develop, and deliver educational programs that equip students with practical, job-ready skills. The curriculum design phase involves tailoring study programs, courses, and modules to address skills gaps and align with the specific requirements of employers.

Moreover, BUC extends beyond the classroom. Collaborations often involve business engagement in educational activities, including guest lectures, internships, co-op programs, and research projects. These interactions provide students with invaluable exposure to real-world scenarios, allowing them to apply theoretical knowledge in practical settings.

In essence, BUC is a multifaceted partnership that benefits both students and businesses. It ensures that educational programs remain relevant, fostering a seamless transition from academia to the workforce. This collaborative approach not only enhances students' employability but also contributes to the overall growth and innovation of industries.

Operationalizing the collaboration implicates a particular focus on curriculum design, development, and delivery. These involve the collaboration between higher education institutions and labor market partners to create or enhance undergraduate or postgraduate study programs, courses, or modules. This collaborative effort aims to address skills gaps, align curricula with employers' needs, integrate training initiatives, and improve graduates' employability. Additionally, curriculum delivery includes various forms of business involvement, such as guest lectures, placements, supervision, mentoring, and work-based learning activities.

While the existing literature often discusses the barriers and motivations for university-business collaboration (Healy et al. 2014; Orazbayeva et al. 2020), there is a need for more empirical insights into the roles and responsibilities of each party engaged in joint curriculum design, development, and delivery, as well as lessons learned from these collaborations (Rebelo et al. 2023).

4.1. Why Do We Need Higher Education's Help?

In the preceding sections of this paper, we delved into the disruptive forces of artificial intelligence (AI) on the job market and the critical need for individuals to adapt to these changes by developing "job-proof skills". The rise of online technologies such as ChatGPT presents both opportunities and challenges, particularly in fields where middle-level skills are required. To effectively tackle these challenges, we must turn our attention to the pivotal role of education and the cultivation of essential skills such as critical thinking.

We highlighted how AI is rapidly transforming various industries and the need for individuals to adapt to these changes. Moreover, we explored the question of whether critical thinking can be learned, showcasing research evidence that supports the teachability of this skill. Now, we shall explore practical strategies for fostering critical thinking skills through collaborations between universities and businesses. The idea here is to create an educational framework that equips students with the capabilities needed to thrive in the evolving workforce.

Building upon the success of two European projects, "Critical thinking across higher education curricula—CRITHINKEDU" and "Critical thinking for successful jobs—THINK4JOBS", we argue that incorporating practical experience and CT development through apprenticeships is a possible action for better higher education classes. This collaborative approach between HEI and LMO designed to address the differing perspectives and terminologies used by these two entities regarding critical thinking could be an important curriculum design for the better adaptation of job market technology disruptions.

Research conducted by Eloundou et al. (2023), which shows that critical thinking skills and science skills are less likely to be taken by AI, compels us to sustain the THINK4JOBS apprenticeship curricula as a possible teaching protocol for critical thinking enhancement to face challenges posed by AI at work.

The results from these projects demonstrate significant progress in students' critical thinking skills and dispositions. These improvements, as highlighted below in Section 4.3, underscore the effectiveness of embedding critical thinking in the curriculum. The guidelines formulated for implementing Critical Thinking Blended Apprenticeship Curricula provide a roadmap for educators to follow when effectively integrating critical thinking into their courses.

As we ponder the possibility of a world where critical thinking is widespread, we can envision a future where individuals are equipped to confront the ideological fanaticism that threatens global stability. Critical thinking, as both a cognitive skill and a disposition, has the potential to shape a workforce capable of adapting to the ever-changing landscape of work, making informed decisions, and contributing to a more rational and democratic world. The THINK4JOBS project emphasizes the practical steps taken to prepare students for the future job market and sets the stage for further exploration of the role of critical thinking in addressing global challenges, including AI presence in the job market.

4.2. CRITHINKEDU Proctocol for Critical Thinking Education across Curricula

Given that the best education for the future of work is the acquisition of critical thinking skills, how can we facilitate this sort of education? One way to obtain a job-proof education is to create classes with the help of labor market organizations. Two projects funded by the European Union were designed to bring to life the idea that better communication and collaboration between universities and employers result in a better adaptation of the curriculum, especially a curriculum involving critical thinking skill development.

Between 2016 and 2019, the project "Critical thinking across the European higher education curriculum—CRITHINKEDU" focused on how CT is taught in various academic domains. The CRITHINKEDU project, involving universities across Europe, exemplifies how academia and industry can join forces to bridge the gap between classroom learning and real-world job demands. This initiative aimed to enhance the curriculum by explicitly emphasizing critical thinking skill development. It revealed that employers across various fields value critical thinking, and they perceive it as essential for recent graduates entering the workforce.

The participants were eleven universities from nine European countries (Belgium, Czech Republic, Greece, Italy, Spain, Portugal, Romania, Lithuania, and Ireland; Dominguez 2018). Qualitative research was conducted with 32 focus groups comprised of professionals from various European countries and fields. The findings align with previous studies: "CT is a set of interconnected skills (interpretation, inference, analysis, explanation, evaluation, self-regulation", see Payan-Carreira et al. (2023, p. 16), and dispositions (open-mindedness, refection, attentiveness, organization, perseverance, intrinsic goal motivation (Payan-Carreira et al. 2023), essential for recent graduates in response to labor market demands. However, an important consideration is that the practical application of CT varies across professional fields. The participants in this study defined the ideal critical thinker as someone with a cultivated mindset, motivated to learn and improve, and equipped with cognitive and behavioral tools to anticipate, regulate, and monitor their thinking. CT is associated with problem-solving and decision-making and is intertwined with other skills such as proactivity, adaptability, creativity, emotional intelligence, communication, and teamwork. The report from this project also introduced "a European collection of the Critical Thinking skills and dispositions needed in different professional fields for the 21st century" (Dominguez 2018), which categorizes CT skills and dispositions based on professional fields and offers a basis for defining learning objectives and adapting university curricula. This study provides valuable insights from 189 European employers into CT needs in the labor market for new graduates. The interviewed professionals had an obvious preference for CT skills in STEM fields and an obvious preference for dispositions in the Humanities. Social Sciences and bio-medical sciences professionals were equally interested in CT skills and dispositions, with a slight preference for dispositions (Dominguez 2018, p. 28).

4.3. Next Steps: THINK4JOBS Blended Appreticeship Curricula

After the termination of the CRITHINKEDU project, partners from Romania, Greece, Lithuania, and Portugal, with the addition of a new partner from Germany, proposed a new research application: "Critical Thinking for Successful Jobs—THINK4JOBS" (www.think4jobs.uowm.gr). The idea was to utilize the results from the previous project and, together with labor market organizations, create new courses that are more adapted to the reality of the future of work. The core element of the classes was explicit teaching of critical thinking, using real-life cases and methods. In an apprenticeship model, critical thinking skills are embedded in a relevant context. The value of realistic contexts is that students can see the need for the skills being taught in a workplace scenario. Relevant contexts enhance student engagement and motivation to learn. Dumitru et al. (2021) focused on improving students' critical thinking skills and dispositions through collaboration between Higher Education Institutions (HEIs) and Labor Market Organizations (LMOs). The aim was to bridge the gap between HEI curricula and the expectations of the labor market by incorporating apprenticeships that provide practical experience and CT development.

The process of mapping responses from those in the labor market organizations onto college curricula involved the use of research methods such as observation, focus groups, and documentary analysis, with stakeholders from HEIs and LMOs participating. The findings indicated that while there were no definitive "gaps" between HEIs and LMOs, there were contextual differences in the approach to CT. HEIs focus on long-term career preparation, while LMOs emphasize short-term learning strategies. The terminology and expression of CT also differed between the two contexts. Based on the findings, ten work-based scenarios were created, with one from each discipline involved in the project. Overall, the report (Dumitru et al. 2021) highlighted the different goals and perspectives of HEIs and LMOs regarding CT, emphasizing the need for collaboration and a common understanding of which skills should be included in the college curriculum.

There is a different context in the approach to CT, since HEIs usually use different learning activities, focusing more on career preparation with long-term goals, while LMOs follow compact and short-term learning and teaching strategies. Furthermore, the findings suggest that CT is a new workplace requirement and that HEIs and LMOs do not choose the same terminology when referring to the concept, with HEIs usually choosing scientific terms. Another element that emerged is that CT is generally expressed in a declarative way in higher education institutions, while in LMOs the application to specific cases follows a more procedural approach. Put another way, LMOs are focused on making a profit, while HEI is focused on being socially responsible.

In the second phase of the project, partners (Pnevmatikos et al. 2021) focused on the development of a collaborative training curriculum for Higher Education Instructors and LMO tutors. The purpose of the training was to enhance comprehension and knowledge of critical thinking for both sides of this collaboration, since previous research indicated a potential lack of conceptual and procedural understanding between these two entities. Additionally, the training aimed to facilitate the promotion, support, and evaluation of students' CT skills within apprenticeship curricula, as well as the creation of blended curricula utilizing an open-source learning platform. The training course encompassed workshops that delved into various aspects of CT, including analyzing and reassembling ideas about CT, formulating a working definition of CT, instructional methodologies, blended learning techniques, usage of a learning platform, CT assessment, and the development of a Memorandum of Understanding (MoU) between higher education institutions and LMOs. The participants' knowledge about these topics was assessed through pre- and post-training online questionnaires. Although data analysis showed various predicted trends, only perceived self-confidence in the topics covered during the training obtained statistical significance (Pnevmatikos et al. 2021).

In the final report from this project, Payan-Carreira et al. (2023) presented the results of the implementation of the critical thinking Blended Apprenticeships Curricula (CTBAC) and discussed the improvements in critical thinking skills and dispositions observed in students. The study involved cross-disciplinary analysis and assessed changes before and after the piloting activities. A total of 609 students participated, and their critical thinking skills and dispositions were evaluated.

The consortium chose the Critical Thinking Self-Assessment Scale (CTSAS) developed by Nair (2011) as an instrument to assess CT skills based on an earlier conceptualization (Facione 1990). The questionnaire has been tested in various geographic and cultural contexts, demonstrating good reliability, internal consistency, and confirmatory factor analysis results. However, the original CTSAS was considered too long to complete, consisting of 115 items, so a shorter version was specifically developed for this project. The short form of the questionnaire (CTSAS-SF) was created through a two-step process. Items with loading weights below .500 were eliminated, resulting in 84 remaining items. Redundant and non-cognitive-focused items were marked for elimination, leaving 60 items. The short form maintained the original scale's framework and utilized a seven-point Likert scale ranging from 0 (Never) to 6 (Always) for students to respond to items assessing various dimensions and subdimensions of CT skills.

The CTSAS-SF validation process, with confirmatory factor analysis, resulted in two models with equivalent satisfactory goodness-of-fit indices. Model 4, the second-order factor model (RMSEA = .051; TLI = .924; CFI = .927), had a chi-square/df ratio of 2.33. The

Cronbach alpha of the overall instrument was excellent (α = .969). Sample items are shown in Table 1.

Table 1. Sample items forming Critical Thinking Self-Assessment Scale (CTSAS), Nair (2011).

NO. of Item	Item	Skill
1	*I try to figure out the content of the problem.*	Interpretation
10	*I examine the similarities and differences among the opinions posed for a given problem.*	Analysis
22	*I seek the accuracy of the evidence supporting a given judgment.*	Evaluation
31	*I figure out alternate hypotheses/questions, when I need to solve a problem.*	Inference

Compared to instruments for assessing CT skills, the availability of instruments for measuring critical thinking (CT) dispositions is limited. However, one of the instruments adopted by the consortium to assess CT dispositions is the Student-Educator Negotiated Critical Thinking Dispositions Scale (SENCTDS), which was developed by Quinn et al. (2020). The scale was validated with a mixed population of Irish and American undergraduate students. The scale considers a variety of CT dispositions that the authors consider important for the labor market and real-world decision-making. Some of the items in the scale combine Facione's (1990) original CT dispositions into new dimensions that are relevant to academic and labor market success, such as organization, perseverance, and intrinsic goal motivation. The scale consists of six dimensions (Reflection, Attentiveness, Open-mindedness, Organization, Perseverance, and Intrinsic Goal Motivation) and presents statements for students to respond to using a 7-point Likert scale. The Likert scale ranges from 1 (strongly disagree) to 7 (strongly agree). The original version of the SENCTDS contains 21 items. The validation process, with confirmatory factor analysis, identified only one model presenting a satisfactory goodness-of-fit index—model 3, comprised of six correlated factors (RMSEA = .054; TLI = .974; CFI = .969) with a chi-square/df ratio of 2.57. The instrument presented a high Cronbach alpha (α = .842), suggesting a strong internal consistency of the instrument. Sample items are presented in Table 2.

Table 2. Sample items from Student-Educator Negotiated Critical Thinking Dispositions Scale (SENCTDS), developed by Quinn et al. (2020).

No. of Item	Item	Disposition
2	*When faced with a decision, I seek as much information as possible.*	Reflection
6	*I often miss out on important information because I'm thinking of other things.*	Attentiveness
11	*I know what I think and believe so it's not important to dwell on it any further.*	Open-mindedness
13	*I take notes so I can organize my thoughts.*	Organization
21	*Even if material is difficult to comprehend, I enjoy dealing with information that arouses my curiosity.*	Intrinsic goal motivation

The analysis showed gains in critical thinking skills and indicated that changes were more prominent in skills than dispositions. All skills (interpretation, analysis, inference, explanation, self-regulation, and evaluation) obtained significant differences between the pretest and posttest, with $p \leq .0001$ to all skills, plus the integrated critical thinking skills score was t = 9.705 and $p \leq .0001$, which demonstrates strong significant difference between pre- and the posttest. Dispositions displayed no significant differences regarding the integrated score, but showed significant differences in reflection (t = 1.766, p = .079), open-mindedness (t = 2.636, p = .009), organization (t = 2.568, p = .011), and intrinsic goal motivation (t = 1.712, p = .088).

Based on the findings from the implementation of the blended apprenticeship curricula, the following guidelines were formulated for implementing Critical Thinking Blended Apprenticeship Curricula (Payan-Carreira et al. 2023):

- Provide an explanation of the importance of critical thinking—Clearly communicate to students why critical thinking is a vital skill in today's workforce and how it is valued in specific professions. Explicitly incorporate the development of critical thinking as an outcome of the course.
- Emphasize continuous and pervasive CT training—To achieve success, there should be a concerted effort across disciplinary curricula to foster students' critical thinking skills and dispositions. Skills require training, and dispositions necessitate the internalization of desired attitudes. Therefore, sufficient time and a collaborative approach at the disciplinary level are necessary for consistent and significant progress.
- Allocate dedicated time—Building on the previous point, it is essential to allocate specific time within the course to work on the proposed critical thinking goals. Students and educators need to schedule activities and create opportunities for preparation, development, and feedback exchange. This ensures that the intervention leads to meaningful, lasting learning.
- Establish connections with real-world scenarios—Foster student engagement and improve their perception of learning experiences by incorporating case studies that reflect situations professionals encounter in their daily work. By grounding the learning content in reality, students are more likely to be motivated and actively participate in the educational process.

Foster reflection on CT skills and dispositions—Offer students the chance to reflect on their reasoning processes and the attitudes they have developed throughout their learning experiences. Encouraging reflective thinking enhances the effectiveness of learning interventions and helps cultivate a deeper understanding of one's experiences.

These steps aim to guide educators in effectively implementing the critical thinking blended apprenticeship curricula while also maximizing the impact of critical thinking development in students.

The two European projects made a great start in integrating the skills that employers want employees to learn from university curricula, but the results are nonetheless provisional. There is not a clear agreement among participating universities regarding how best to teach critical thinking, nor any regarding its importance for future jobs. We urge that more work should be done to nurture critical thinking within university curricula in order to provide our current students—who represent the future of the workforce—the much-wanted job-proof skills they need.

5. European Recommendations and Good Practices

Critical thinking stands as a pivotal goal for European Higher Education Institutions. To facilitate the attainment of this objective, we present an educational protocol that draws from comprehensive research and practical experiences, including insights from the CRITHINKEDU project. This protocol amalgamates insights from both theoretical and empirical studies on critical thinking with practical strategies for its cultivation.

Recommendations go toward signing memorandums of understanding between universities and labor market organizations to cultivate strong partnerships (Rebelo et al. 2023). Effective collaboration between universities and businesses is crucial in fostering critical thinking. This partnership thrives on the synergy that results when academic institutions and businesses combine their expertise, resources, and perspectives. Strategies such as aligning goals, fostering long-term commitment, and promoting a culture of collaboration can strengthen these partnerships and ensure that academic research is harmoniously aligned with real-world needs.

Another recommendation relates to the *formulation of compelling goals*. Accurate and transparent goals are fundamental to the successful implementation of university-industry collaborations to promote critical thinking. These goals must be clearly defined and easily understood at multiple levels, from the institutional to the program and course levels. Recognition of critical thinking as an overarching goal implies its integration into assessment and evaluation processes.

Another recommendation is to *develop flexible curricula*. To effectively foster critical thinking, curricula must demonstrate adaptability and responsiveness to emerging trends and market demands. The use of agile curriculum design methodologies and the involvement of business partners in curriculum development is of great value. Approaches such as problem-based and case-based learning facilitate rapid adaptation to evolving market needs, such as the use of AI-powered software to solve work tasks better and faster. Regular feedback mechanisms and ongoing collaboration with business partners ensure that curricula remain relevant and flexible.

Incorporating real-world challenges and case studies into curricula bridges the gap between academia and the business world, creating an environment that encourages experiential learning. The active involvement of business stakeholders in providing relevant challenges plays a key role. Students' problem-solving skills are enhanced by shifting from traditional teaching methods to project-based, problem-based, or case-based learning. Engaging students through apprenticeships, internships, guest lectures, and seminars immerses them in authentic work environments and fosters their professional development.

Ongoing, multi-faceted evaluation is a cornerstone of the collaboration between higher education and the business community to cultivate critical thinking. Assessment includes measuring learners' progress in critical thinking, the effectiveness of curricula, and the impact of partnerships through the use of key performance indicators.

Regarding how to implement a critical thinking curriculum, pedagogical research (Elen et al. 2019) suggests that in the development of critical thinking, whether it is regarded as a skill, disposition, or a combination of both, three categories of supportive measures can be identified: modeling, induction, and declaration.

Modeling: Support the development of critical thinking skills by demonstrating what it means to think critically at the institutional, programmatic, and course levels, considering multiple perspectives and alternative viewpoints.

Induction: Support critical thinking development by provoking critical thinking through the presentation of open-ended questions, unstructured tasks, complex problems, and real-world issues. The exact nature of "induction" and how it is implemented may vary across fields and disciplines. Induction can be carried out in a variety of ways; for example, presenting unstructured problems, providing authentic tasks, encouraging constructive controversy, asking "why" questions, or encouraging student autonomy.

Explanation: Promote the development of critical thinking by articulating or explicitly stating what is at stake, what strategies can be used, and what criteria must be met. This explanation can take the form of oral or written communication and should always be explicit and specific. Declaring and making things explicit can be accomplished in a variety of ways, including using critical thinking rubrics, developing elaborate concept maps, providing feedback on critical thinking, and engaging in discussion and reflection on critical issues.

This integrated approach, encompassing university-business collaboration and an educational protocol, underscores the significance of critical thinking in higher education. It provides a structured framework for nurturing this essential skill by aligning objectives, fostering partnerships, adapting curricula, and implementing ongoing evaluation practices. In doing so, educational institutions are better poised to equip students with the critical thinking skills needed to thrive in a rapidly evolving world.

6. Concluding Remarks or Can Critical THINKING Save the World?

In summary, the dynamic interaction between universities, businesses, and the evolving technology landscape, including the rise of artificial intelligence (AI) and online technologies, underscore the critical need to nurture and develop students' critical thinking skills. As we navigate the challenges posed by AI and the ever-expanding digital realm, collaborative efforts between academia and industry have proven to be instrumental in preparing students for the future job market.

Incorporating real-world experiences, such as apprenticeships, into the curriculum is an important step toward improving students' critical thinking skills in real-world contexts. Projects such as "Critical thinking across higher education curricula—CRITHINKEDU" and "Critical thinking for successful jobs—THINK4JOBS" have demonstrated the potential of these collaborations to bridge the gap between classroom learning and industry needs. In addition, the development of flexible curricula that can adapt to the evolving needs of the job market, especially considering online technologies, is essential. By integrating real-world challenges and case studies into the curriculum, students gain valuable problem-solving skills and are better prepared to navigate the complexities of the digital age.

Ongoing assessment and evaluation are critical components of this collaborative effort, ensuring that critical thinking remains a central focus and that students are making meaningful progress in acquiring this essential skill.

With the disruption of AI and the ubiquity of online technologies, the integration of critical thinking into higher education curricula is more important than ever. It enables students not only to thrive in a technology-driven world, but also to contribute to a rational, democratic, and globally interconnected society. The partnerships forged between universities and businesses, along with a well-defined educational protocol, provide a roadmap for cultivating these essential skills and preparing students for the challenges and opportunities of the future job market. The imperative to foster critical thinking in university curricula remains a fundamental step in equipping tomorrow's workforce to navigate the complexities of an AI-influenced job market and a rapidly changing world.

Lilienfeld (2007, para. 3) said it well: "The greatest threat to the world is ideological fanaticism, by ideological fanaticism I mean the unshakeable conviction that one's belief system and that of other in-group members is always right and righteous and that others' belief systems are always wrong and wrong-headed". Imagine a world where (most or even many) people use the skills of critical thinking. Just maybe, CT could save the world.

The job market will require a psychologically adaptable toolkit, and we propose that critical thinking is an essential component therein. The disruptions imposed by new technological advances such as AI will require students to learn new employable skills because we will need not just an engineer, but a critical thinking engineer; not just a programmer, but a critical thinking programmer; and not just a journalist, but a critical thinking journalist. The dignity of workers—their humanity and our collective survival—may well depend on CT, a very human creation.

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Essay

Mindware: Critical Thinking in Everyday Life

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Abstract: Humans make many decisions in everyday life, some of which require careful use of evidence. Because emotional and heuristic mental processes dominate human cognition, it is common to suggest that there is little hope that critical thinking tools will be widely used. However, the concept of "mindware" gives hope to the idea that critical thinking skills may be more widely deployed than they currently are. This article reflects on some impediments to critical thinking, assesses some future challenges to critical thinking being more widely used, and suggests that "mindware" modules can be used widely both in and out of educational settings to significantly enhance critical thinking in everyday life.

Keywords: mindware; critical thinking; artificial intelligence

1. Introduction

Humans make thousands of decisions daily, ranging in importance from innocuous to life changing. Many of them involve somewhat automated, habitual, or quotidian matters that require little cognition; however, some of them require deep thought, proper use of evidence, and methods that are generally categorized under the rubric of "critical thinking". Unfortunately, humans frequently fail to recognize the conditions under which deeper thought, proper evidence, counterfactual thinking, and rules of logic are required for proper decisions. Instead, we over-rely on personal experience, intuition, social cues, and other cognitive shortcuts (Dwyer 2023). Indeed, many of these means are automated. Considerable scholarship acknowledges that automated responses such as these arise outside conscious awareness (Johnson-Laird 2006). For example, Antonio Damasio posits that "we gradually categorize the situations we experience" and that "when a situation that fits the profile of a certain category" is recognized, emotions attached to that category of experiences allow us to "intuit a decision and enact it, speedily and efficiently, without any knowledge of the intermediate steps" (Damasio 2003). And Leonard Mlodinow has documented dozens of experiments in which the unconscious mind strongly influences decision making, ranging from our preference to marry people with our same last name at a much higher rate than would be predicted by probability to the universal ability to recognize human emotion through facial expression (Mlodinow 2012).

The automated nature of human decision making is commonly attributed to the functional efficiency of associative thinking and resource conservation. This fast-processing mode, which has come to be called "System One" processing, allows us to conserve resources through patterned, conditioned replies, often called "heuristics", that allow us to make decisions, solve problems, and predict outcomes very quickly, without deploying higher-level cognitive systems (Kahneman 2011). Researchers often attribute this "cognitive miserliness" to neurological processes that economize resources (glucose levels or attention span, for example) (Stanovich 2009; Stanovich 2011; Stanovich et al. 2016). In addition, we may take shortcuts from environmental cues, such as cultural or social prompts. Culturally biased responses can manifest as habitual responses to intellectual tasks. And emotions can undermine rational thinking when deeply held personal beliefs, such as political and religious views, are challenged (Wexler 2006; Nisbett 2003; Stanovich 2011). Likewise, humans can bow to social pressure, acting or adopting views in response to perceived or real pressure to conform (Asch 1956; Chen et al. 2022; Schultz 2022).

These automated, System One responses do not involve careful thinking, proper use of evidence, or precise logic and therefore can lead to decisions that are less than optimal or even harmful (Herbranson et al. 2022; Sin et al. 2022). Because these responses are so common, laments about the lack of critical thinking in everyday life are legion. We are accustomed to wondering where commonsense has gone, asking why smart people can do dumb things, and decrying the state of human abilities to make "intelligent" decisions. Those who study this world of thinking know full well that the path to consistent critical thinking is obstructed with seemingly intractable problems like human biases, kneejerk emotional responses, and tribalism (Dwyer 2023). The ubiquity of these responses and the solid science behind them often leads us to conclude that there is no hope that humans will use critical thinking consistently. However, it is possible to reframe this despair into a more sanguine model. In this article, I want to show that one particularly hopeful path to enhancing and broadening critical thinking in everyday life is through the relatively unfamiliar concept of mindware.

2. The Concept of Mindware

Keith Stanovich writes that "Mindware is a generic label for the rules, knowledge, procedures, and strategies that a person can retrieve from memory in order to aid decision making and problem solving" (Stanovich 2009). This simple definition, I believe, has the potential to reshape the world of critical thinking instruction and improve critical thinking skills in everyday life. Through this definition, Stanovich suggests that the difficulties of complex decisions and problems can be overcome through acquired modular knowledge and its application using appropriate "rules, knowledge, procedures, and strategies". In other words, if people could learn these "rules, knowledge, procedures, and strategies", they would be more successful in recognizing endeavors that require critical thinking and make better decisions in those endeavors. This implies that the seemingly insurmountable roadblocks of social conformity, tribalism, biases, and unthinking emotional replies are merely default techniques for navigating a complex world without the proper thinking tools and that, therefore, with better thinking tools, they could be overcome more consistently.

Reframing critical thinking in this way allows us to see the apparent intractability of heuristic thinking as our way of dealing with complex issues in the absence of more effective tools and not merely as a flaw in its nature—the result of evolutionary development that prioritizes limbic responses. Even though the brain does prioritize limbic responses (Mackeracher 2004), framing the solution to heuristic and emotional responses as "mindware", that is, as easily learned modules of cognitive strategies, makes possible a graduated approach to critical thinking, emphasizing incremental mastery that begins with easily learnable tools that are applicable to situations that people find useful in the moment. It is unusual that individuals would feel the need to "learn how to think critically"; however, one could see that goals, such as wealth acquisition, weight loss, success at work, or general self-improvement, can all be reached more effectively by using proven rules based on sound evidence and the basic principles of critical thinking.

3. Mindware Gaps

Before delving more deeply into mindware, we need to look at one of the most important—and least recognized—principles of human cognition: "unavoidable reality constraints" (Dunning and Kruger 1999). Most people unfamiliar with college mathematics would acknowledge that they do not know how to find the area under a curve using integral calculus, nor would those who never played college football claim that they could compete in the National Football League. That occurs because there is an unavoidable reality constraint to each. The reality of systematic knowledge required to do a calculus problem or the reality of needing world class speed and strength are obvious to everyone. Nonetheless, many people who would acknowledge being unable to do calculus have very strong opinions on how to put the economy right, who would best govern a country, or which belief system guarantees heaven in the afterlife. In a now-famous cartoon from the New Yorker, a man stands up in a plane and declares, “These smug pilots have lost touch with regular passengers like us. Who thinks I should fly the plane?” It is funny because there is an easily recognizable reality constraint to flying an airplane that has escaped the passenger because he has confused expertise with privilege.

Mindware refers to the presence of “rules, knowledge, procedures, and strategies” that allow for success in many endeavors, such as flying a plane. When we are missing these intellectual skills, we have a “mindware gap”. Mindware gaps are most common in arenas where there are no unavoidable reality constraints. Stanovich introduced the concept of “mindware gaps” to refer to knowledge acquisition and verification procedures that could be used if available but which are not (Stanovich 2009). Notice that Stanovich does not refer to lack of dispositions toward critical thinking or overreliance on default cognitive mechanisms but to procedures that are “not available”. In other words, often what keeps people from using critical thinking—this will sound tautological—is their lack of critical thinking tools. But despite sounding tautological, it is actually a profound shift away from a view that sees critical thinking as a unique skill that few people master toward a view that treats critical thinking modularly. In the same way that we treat learning accounting, mastering a language, or acquiring expertise in nursing, we can treat individual critical thinking skills as discrete and learnable (Maknun 2022; Rarita 2022). If we view critical thinking not as a general inclination, nor as a skill that one possesses or does not, but in a modular way, improvements in critical thinking skills become manageable pedagogically and extendible to people on a broad social scale. Conceptualizing critical thinking modularly would allow people to frame cognitive achievement realistically, in the same way that we acknowledge that there are levels of expertise in wealth management, weight training, or calligraphy. We can begin to see critical thinking as the product of mastering individual skills through concentrated effort rather than a mysterious gift bestowed on the super-rational.

4. “Installing” Mindware: Filling in the Gaps

Let us take the simple idea of probabilistic reasoning. Many thinking errors can be attributed to the failure to think probabilistically: what might be unfortunately labeled the “inability” to think probabilistically (Benjamin et al. 2019). One common error in this arena is the failure to consider base rates (Stanovich 2009). For example, suppose we saw a person in Los Angeles wearing what we considered to be typically French attire—whatever we imagine that to be. Perhaps the person is sporting a beret, wearing a black-and-white striped shirt, and carrying a baguette. What is the likelihood that this person is French? One might use the stereotype to guess that the probability is very high, given the clues, perhaps more than fifty percent. If we guess that that person is French, we would almost certainly be wrong. Why? Because there are 10 million people in Los Angeles and only about 11,000 of them are French: a 99.9% chance of not being French. This tendency to rely on stereotypes and heuristics without reference to statistics is known as “base rate neglect”. In this reasoning error, people over-rely on present experience and individual examples without considering prevalence in a population (Pennycook and Thompson 2022). Most of the mathematical examples used to exemplify this error involve working with probabilities that would intimidate the majority of people. However, the simple rule of remembering to take into account prevalence in a population rather than a very small sample or a stereotype is easy to deploy and very helpful in decision making. For example, very few people who want to be professional actors, social media influencers, or YouTube stars recognize that only an extremely small percentage of people who hope to succeed in those fields attain even a small degree of success. Teaching probabilities and base rates may seem like a daunting task. However, there are games that teach its fundamental principles, such as BeatTheOdds, Probability Fair, TinyTap Probability, and The Vile Vendor. Each game enhances probabilistic thinking mindware.

Humans are also generally ill-disposed to seek answers to questions once an adequate answer has been found. This tendency has been described in various ways in the literature from cognitive science. For example, in radiology, "satisfaction of search" occurs when the physician "fails to continue to search for subsequent abnormalities after identifying an initial one" (Knipe et al. 2021; Ashman et al. 2000). Similar tendencies have been noted in airport security workers, leading to the inference that this may be a general cognitive tendency. As Mirtoff, Biggs, and Cain write, "Over 50 years of research has shown that when searchers successfully find a visual target, they become less likely to find another target in the same" (Mitroff et al. 2015). Clearly, this research has implications not only for radiology and security checks but for crime scene investigation, loss prevention, logistics, drug interventions, psychological diagnoses, psychological treatments, instructional methodologies, business growth, and many other fields. The particular mindware would be the simple rule that when one finds an answer, a malfunction, a sought object, or a piece of evidence, one should continue searching to find additional answers, problems, objects, or evidence. "Installing" the mindware in the minds of students, employees, or citizens would be a simple matter of raising awareness regarding the cognitive tendency to cease searching and the necessity to continue the search even after an initial target is acquired.

Closely related to this tendency of satisficing (Caplin et al. 2011) is the idea of a "makes-sense epistemology". The term, coined by David Perkins, describes the tendency to accept as true any explanation that has an adequate feel of plausibility (Perkins et al. 1991). Our brains have not evolved to be constant truth-seeking machines; instead, they rely on good-enough explanations—approximations that allow us to move forward with decisions based on incomplete knowledge. Most of the time, such decisions are not dangerous and can, indeed, be trusted to lead us down a path that will provide some degree of happiness, success, pleasure, or correctness. However, in more-important matters, such as decisions that inform public policy, responses that rely on personal experience, associative thinking, and heuristics are nearly always inadequate. However, a simple piece of mindware allows us to circumvent the mistakes that follow from satisfactory explanations generated by System One. This is the habit of considering alternative explanations. For example, during the height of the COVID-19 pandemic in the United States, hospitals filled up at highly variable rates. It was important to know why this was happening because the differences might have supplied clues as to how to improve hospitalization rates or allow local areas to respond more effectively. Rather than reducing the issue to a bipartisan political problem (as it was sometimes presented), it was important to recognize that numerous factors might have influenced occupation rates. The following are only some: local vaccination rates; the number of available ICU beds; the general health of the local population; underlying health conditions in the population; prevalence of smoking; age of the local population; distance to hospitals; and the concurrence of other disasters, such as weather events. This simple skill could easily become habituated among students, for example, through simple and consistent assignments in considering alternative explanations. Asking students to formulate a variety of hypotheses about what might explain recidivism, wealth acquisition, or athletic prowess would cultivate habits of mind that could be consistently deployed in a variety of fields and significantly enhance critical thinking (Alsaleh 2020). One can even imagine a game show called "Alternative Explanations" along the lines of the format of the famous "Family Feud".

5. Taking Mindware Public

However, only a small percentage of the population has access to direct instruction in critical thinking. Therefore, the question remains about how a society might leverage the concept of mindware to enhance critical thinking in broader sectors of the population. Mindware's modularity helps solve this problem. Moreover, our knowledge of how difficult it is to induce belief change can be used to an advantage. For example, learning that one needs to learn to think critically can be threatening, especially since such comments are commonly made in reaction to the perception that one is not doing so. This issue is even more intractable in highly personalized realms, such as politics and religious discourse. Other areas are more approachable. For example, many people are interested in retirement planning, often making significant errors on the road to retirement or over-relying on the wrong professionals. However, retirement planning is a piece of mindware whose principles are readily “installed”: begin saving money early, use compound interest, avoid debt, and scrutinize luxury purchases. At the risk of promoting a particular brand of retirement planning, Dave Ramsey’s work promotes these basic steps toward wealth accumulation (Ramsey 2013). They are not, however, the unique ideas of an investment guru—they are fundamental economic principles that Ramsey has successfully condensed into a format that anyone can follow. He popularized a piece of mindware. In essence, he reduced a seemingly difficult problem—retirement planning—to a set of “rules, knowledge, procedures, and strategies” that could be easily learned, remembered, and practiced.

In order for people to recognize that this is a practice of critical thinking in everyday life, methods such as Ramsey’s need to be labeled as such. If Mr. Ramsey were to refer to his program as a piece of “mindware” that promoted wealth acquisition and critical thinking (defined here as following known rules for a positive benefit while eliminating errors caused by emotion and reliance on heuristics), the practical and beneficial aspects of following logical rules to reach a desired end would be more obvious to the population at large.

6. Contaminated Mindware

Despite the relative ease of learning/installing mindware, it can be offset by contaminated mindware. Just as mindware is a set of knowledge, skills, and procedures that lead to more rational, beneficial, or epistemically sound decisions and conclusions, contaminated mindware leads to the opposite. While there are many varieties of contaminated mindware, such as superstition and anti-scientific beliefs, Stanovich cites “mindware that contains evaluation-disabling procedures” as particularly pernicious. These include “the promise of punishment if the mindware is questioned; the promise of rewards for unquestioning faith in the mindware; or the thwarting of evaluation attempts by rendering the mindware unfalsifiable” (Stanovich 2011). Any faulty thought processes may be considered to be contaminated mindware as well: racism, xenophobia, radical skepticism, human sacrifice, or even public policy in a democracy that fails to consider data, demographics, or current scientific knowledge. These “evaluation-disabling procedures” map to activities that disallow critical thinking. Indeed, anything that proscribes evidence, questioning, and logic in the name of the sacredness of the ideology falls into the category of “contaminated mindware”.

The fact that mindware can not only be contaminated but spread easily once contaminated presents one of the greatest challenges to the dissemination of critical thinking skills to society at large. The intractability of utter conviction has been recognized for thousands of years (Beck 2017), and the absolute fact of belief enhancement in the face of contrary evidence has been firmly established by cognitive scientists (Susmann and Wegener 2023), social psychologists (Gold and Gold 2014), and philosophers. Writers have puzzled over how to convince others of their obviously erroneous ideas, sometimes despairing of the hopelessness of logical argumentation and the inefficacy of evidence to change minds (Staats et al. 2017). The psychologist Lou Cozolino explains this tendency humorously by pointing out the difference between rats and humans. Rats, he says, will find cheese in a maze and return to the spot where they found it; when it is no longer there, they look elsewhere. “Humans, on the other hand”, he says, will return to the original spot “forever because they come to believe that’s where the cheese should be. Within a few generations, humans will develop rituals, philosophies, and religions focused on” the cheese’s original place, and “invent gods to rule over it” (Cozolino and Davis 2017).

7. Critical Thinking, Mindware, and Artificial Intelligence

Possibly the greatest threat to critical thinking in everyday life, however, lies in the near future: artificial intelligence—especially knowledge generators such as ChatGPT. Starting in the 1980s, authors such as Neil Postman began raising the cry against the potential negative effects of automated technologies that infringed upon thinking processes. Postman warned that beginning in the early twentieth century, "workers were relieved of any responsibility to think at all. The system would do their thinking for them", with the disastrous consequence of technology moving into the realm of the "moral, social, and political". This led to the "idea that society is best served when human beings are placed at the disposal of their techniques and technology" (Postman 1993). With the rise of the Internet, others began recognizing that many human thought processes could be delegated to software and intelligent machines, just as manual labor had been automated through machinery and robotics. Nicholas Carr, among others, warned of the deleterious effects of human overreliance on computational devices (Carr 2010, 2014; Lanier 2013). Studies such as "Google Effects on Memory" (Sparrow et al. 2011) and Dahmani and Bohbot's (2020) study revealing the negative effects of habitual GPS use demonstrate the cognitive and neurological tradeoff between the efficiency of increased computational capacity and the slower cultivation of organic brain power. But artificial intelligence presents to us the possibility of not needing to think, weigh evidence, make decisions, and perform many cognitive tasks that make us human. It presents the very real possibility of providing an automated substitute for critical thinking in everyday life in the same way that GPS provides an automated substitute for navigating, search engines for laborious research, and, at times, social media for real-life interactions.

An important artificial intelligence manifesto is Marko Rodriguez' 2009 article (Rodriguez and Watkins 2009) titled "Faith in the Algorithm, Part 2: Computational Eudaemonics". In it, he argues that as a matter of social responsibility and in order to maximize happiness for humanity, we should turn our decision making over to machines—to the algorithm. He writes that once a certain computational capacity is reached and combined with massive data, we can have

> "a society of individuals where the vocation one takes, the person one dates, the books one reads, the restaurants one frequents, and so on are chosen not through the advice of one's family, friends, and community, but through a deep computational understanding of what is required for that individual to live an optimal life. . .. In other words, the individual would choose options that they do not perceive as necessary. Without the perception of need, the individual would take on faith that the algorithm knows what is best for them in a resource complex world. Thus, the perfect life is not an aspiration, but a well-computed path".

Written fourteen years before the release of ChatGPT, the article nicely summarizes the true potential of AI in the realm of human life, thinking, and decision making. Artificial intelligence ("algorithms" in Rodriguez' parlance) is the computational mindware whose function it is to bypass the inefficiency of human cognition. By using AI, humans subcontract the knowledge acquisition and verification procedures of critical thinking, creativity, and decision making (Marszalek-Kotzur 2022). Reliance on AI for these processes may circumvent the need for critical thinking in the same way that faith in any given ideology circumvents the need for analysis, evaluation, and evidence. In other words, AI has the potential to create the ultimate mindware gap by eliminating the need for mindware. The knowledge, skills, procedures, and protocols that make up human mindware could be transferred to the black box of artificial intelligence. In the same way that people do not remember facts so much as remember where they can find the fact when Internet access is available to them, people may not remember and utilize the mindware necessary for proper thinking and decision making so much as remember where the mindware resides: in the AI.

Many comparisons are being drawn between technologies that replaced human labor and AI. Those who decry the intrusion of AI into human thought and creativity are sometimes labeled “Luddites”. Long before, Plato wanted to ban writing because it might supplant human memory; the case of AI could be qualitatively different. We now have the possibility to use AI to write papers (Terry 2023), thereby eliminating the need for research and effortful thinking. AI is already used as a “truth generator” despite its embarrassing failures (Neumeister 2023), which could be seen as the technological equivalent of an ideology generator. The mindware at the heart of critical thinking—questioning the truth of claims and evaluating the viability, motivation, and evidence behind ideologies—could be rendered inoperable by trusting AI to generate answers. Like ideologies, AI qualifies as having “evaluation-disabling procedures” implied in its apparent infallibility.

8. Ideologies and Artificial Intelligence

Since AI may infringe upon independent human thinking and circumvent gathering and evaluating evidence, it appears to function as do ideologies. Leor Zmigrod has suggested that ideological thinking is “a style of thinking that is rigid in its adherence to a doctrine and resistance to evidence-based belief-updating” (Zmigrod 2022). Seeking to understand the nature of “ideological cognition” rather than the supposedly convincing nature of “the content of ideological beliefs”, Zmigrod concludes that ideological thinking is “a meaningful psychological phenomenon”. While there are no studies about the psychology of reliance on AI for answers, other studies on our reliance on search engines, GPS, and other technologies, combined with our knowledge of default modes of thought (System One thinking, usage of heuristics, cognitive miserliness), offer viable reasons to believe that AI will quickly take its place alongside these other technologies in diminishing the perceived need for effortful thought. As such, AI use—especially as a knowledge generator—could soon be considered “a meaningful psychological phenomenon”. In other words, they will be using “evaluation-disabling procedures” as easily and frequently as they use search engines and GPS. This may be best understood by recognizing that GPS is a “navigation-disabling procedure” to the degree that it is used as a “navigation-facilitation” tool. In an age of increased nationalism (Brown 2022), ideological influence in healthcare decisions (Ruisch et al. 2021), ideological divides surrounding climate change (Ballew et al. 2020), moral and ethical issues (Voelkel and Brandt 2019; Waytz et al. 2019), and, of course, religion (Perry 2022), if humans turn to knowledge generators such as ChatGPT to help formulate beliefs in unfamiliar areas, regaining control over our own ideas is all the more necessary.

9. Mindware to Promote System Two Thinking

One of the greatest advances in cognitive science in the twenty-first century has been the recognition that the human brain’s default mode uses heuristics, social cues, cultural norms, and resource conservation when positing answers, reaching conclusions, and making decisions. This research has enabled increasingly precise insights into tribalistic thinking, myside bias, cultural divisiveness, and a broad array of thinking errors. Conceptualizing critical thinking in everyday life as consisting in part as “mindware modules” holds great promise to help people circumvent the problems created by reliance System One thinking when more effortful thinking is required. Once people learn the concept of mindware and the accompanying concepts of mindware gaps and contaminated mindware, awareness can motivate people to use the rules, knowledge, procedures, and strategies of rationality and succeed in implementing critical thinking as mindware. Once the vocabulary is adopted, school courses could be developed titled “mindware for retirement”, “mindware for public policy”, “mindware for crime scene investigation”, “mindware for healthcare professionals”, and the like. Thus, the terms “mindware for retirement”, “mindware for public policy”, and the like could be recognized as the “rules and strategies” that anyone can learn to increase the likelihood of success in these fields. In the same way that people can learn to use accounting software to help with a small business, they could learn the rules and strategies for college success, retirement planning, or environmental responsibility. Thus, the vocabulary of mindware could be spread outside academia as well.

10. Conclusions

The concept of mindware as learnable "rules, knowledge, procedures, and strategies" has the potential to enhance awareness about the need for critical thinking and to provide individuals with easily learnable tools to make better decisions, be better thinkers, and use evidence more consistently and virtuously. Mindware's individual modules (retirement planning, weight loss, relationship enhancement, college success) then become manageable units of decision enhancement that lead to better critical thinking abilities. As AI makes inroads into everyday life, offering people solutions to decisions without the customary cognitive effort, the concept of mindware and the implementation of mindware modules may help us maintain and enhance individual CT abilities.

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Essay

Why Critical Thinking Can and Often Does Fail Us in Solving Serious Real-World Problems: A Three-Track Model of Critical Thinking

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Abstract: This article deals with how love and hatred of ideas can influence, and often distort or suppress, critical thinking. Love and hate can serve adaptive intellectual functions, but in practice, they often manifest in maladaptive ways. The article reviews the role of critical thinking in adaptation, then discusses how love and hate can influence critical thinking. The article suggests that teaching critical thinking needs to take into account that real-world critical thinking often bears little resemblance to that shown in tests or in school. We need to teach critical thinking as it exists in the world, not in rarefied settings.

Keywords: critical thinking; analytical intelligence; love of ideas; hatred of ideas; intimacy; passion; commitment; triangular theory of love

1. Introduction

If you are like the authors of this article, you know someone intelligent who seems, in their everyday thinking about one important problem or another, to have abandoned critical thinking entirely. The someone may be a loved one, a friend, an acquaintance, a colleague, or even oneself. They may have a decent IQ, even a notably elevated one, and yet, when it comes to one serious everyday problem or another, or perhaps several problems, you seemingly cannot get a coherent thought out of them.

Examples of failures of critical thinking by highly intelligent people are legion. Robert McNamara, who was often called the "architect of the Vietnam War," was a graduate of the University of California, Berkeley and Harvard, and generally considered to be of staggering intellect. But even after the Vietnam War was failing badly, he committed the sunk-cost fallacy, a failure of critical thinking, and continued to advocate for the war (Murse 2018). More extreme was Ted Kaczynski, a Harvard-educated mathematics professor at the University of California, Berkeley, who became the Unabomber and destroyed other people's lives as well as his own. William James Sidis is perhaps the most famous example of a failed individual with a prodigious IQ who ended up living an unhappy life, writing under pennames on topics such as Native American streetcar tokens (Mahony 2016). Bill Clinton, a Yale Law School graduate, was impeached during his term as the U.S. president in part because, when questioned about his relationship with Monica Lewinsky, a White House intern, he resorted to saying "it depends on what the meaning of the word 'is' is," a statement that gained him no credibility with the members of the U.S. Senate who would be judging him (Noah 1998).

There are many reasons that IQ and related skills might be inadequate to the challenges of real-world problems. In the case of Sidis, he appeared to have personality and emotional issues that hindered his adjustment. Some theorists have suggested that the kind of intelligence measured by IQ tests and their proxies, which may be of substantial importance in school tasks, may not be the same kinds of intelligence that are most needed for successful real-world critical thinking (Wagner and Sternberg 1984). Examples of kinds of intelligence needed for real-world adaptation are contextual intelligence (Ceci and Roazzi 1994); interpersonal and intrapersonal intelligence (Gardner 2011); practical intelligence (Hedlund 2020); social intelligence (Kihlstrom and Cantor 2020); emotional intelligence (Rivers et al. 2020); rational thinking (Stanovich 2009); intuitive intelligence (Gigerenzer 2023); and adaptive intelligence (Sternberg 2021a, 2025a).

One might have hoped that, with rising IQs in the 20th century (Flynn 1984, 1987, 2011, 2020), people who do not exhibit critical thinking would have become scarcer. Even if IQs have been falling in some places (Bratsberg and Rogeberg 2018; Pietschnig and Gittler 2015), the fall would not seem to account for the situation in which many of us find ourselves—wondering whether a major proportion of one's own country, perhaps as much as half the country—has gone off the deep edge. And all the time, one has been aware that this seemingly unthinking half of the country, and their friends or acquaintances, are thinking the same thing about oneself that one is thinking about them. Are they losing it? Are you losing it? Is everyone losing it?

This article argues that critical thinking as a competence is often at a level entirely different from, and often substantially higher than, its manifestation in performance. People have evolved to detect and protect themselves from threats, and two ways in which they do so is through love and hate. However, although love and hate can help one detect and counteract threats, they also can lead one to imagine threats and counteract them in ways that are irrational, regardless of one's level of intelligence.

Threats can be either positive or negative in how they affect critical thinking. If they lead to greater vigilance and attention and prompt the individual to realize that clear thinking is needed to counter a particular threat, they will improve critical thinking. But if the threats lead to high levels of anxiety or confusion, or to avoidance behavior, they will impede the quality of critical thinking.

What Is Critical Thinking?

Before discussing the argument of the article and the assumptions underlying this argument, it is important to get a sense of how various scholars have understood *critical thinking*, and what the similarities and differences are. According to Richard Paul, the essence of critical thinking is the study and evaluation of one's thoughts (Elder and Paul 2008; Paul 2005; Paul and Elder 2008). Such analysis in turn improves one's critical thinking.

According to Paul and Elder, critical thinking occurs in processing stages. The first stage is an analysis stage. People deconstruct their thinking—including its assumptions and its implications. The second stage is the assessment of critical thinking (Elder and Paul 2008; Foundation for Critical Thinking 2009). In this stage, critical thinkers assess their thinking based on its accuracy, internal consistency, clarity, precision, fairness, consistency, etc. Elder and Paul also have argued that critical thinking develops over time in chronological stages: (1) unreflective thinker; (2) challenged thinker; (3) beginning thinker; (4) practicing thinker; (5) advanced thinker; and (6) advanced thinker (see also Leon 2020).

Swartz et al. (2008) analyzed the metacognitive processes in critical thinking through the metaphor of climbing a ladder. Each rung of the metaphorical ladder brings one further into critical thinking: (1) an awareness of *what* kind of thinking is being done; (2) describing, in procedural terms, *how* the thinking is being done; (3) becoming more evaluative—is the critical thinking effective?; and (4) planning how to engage in this same type of thinking in future situations, utilizing the previous rungs. Such thinking becomes self-correcting, so that one is always improving in one's thinking (see also Swartz 1987).

Perhaps the most complete taxonomy of critical thinking dispositions was provided by Ennis (1987, 1991, 2011). These dispositions of the individual include the following: (a) care that their beliefs are true and that the decisions that are based on these beliefs are reasonable; (b) seek alternative hypotheses, explanations, conclusions, etc.; (c) consider in a serious manner points of view other than one's own; (d) do your best to be well informed before making decisions; (e) endorse a position only to the extent that it is supported by whatever credible information is available; and (f) be concerned about the welfare of others. The emphasis on dispositions is also found in the theoretical and empirical work of Nieto and Valenzuela (2012). Ennis also proposed critical-thinking abilities, including (a) focusing on the relevant question; (b) analyzing arguments; (c) asking questions; (d) judging the credibility of sources; (e) making material inferences.

Another major framework for understanding critical thinking is that of Lipman (1995, 1998, 2003), as exemplified by his program, *Philosophy for Children.* The program teaches young children to engage in deliberative inquiry and logical reasoning. The program provides a K–12 curriculum that sets up "communities of inquiry." These communities are designed to foster and encourage critical, creative, and caring thinking. The results are better reasoning, comprehension, and evaluation. Lipman's approach emphasizes how important children's metacognitive processes are, a point underscored by the theoretical and empirical work of Rivas et al. (2022).

A major thinker in the field of critical thinking is Diane Halpern, whose book with Dana Dunn, *Thought and Knowledge: An Introduction to Critical Thinking* (Halpern and Dunn 2022), is a classic in the field and puts together in a masterful fashion much of the work that has been done in psychology over a period of many years.

What can critical thinking provide that IQ does not provide? IQ, and the related General Mental Ability (GMA) (Sackett et al. 2020) measure, among other things, crystallized intelligence, which, as measured, is largely based upon accumulation of declarative knowledge; and fluid intelligence, which, as measured, is largely based on reasoning about matters remote from everyday life, in terms of both content and the situations in which the content is encountered. The reasoning measured is usually inductive rather than deductive (Guyote and Sternberg 1981): There are no logically certain conclusions. Critical thinking has certain particularly important aspects for real-world problem solving.

First, critical thinking explicitly encompasses attitudes as well as abilities. Although one view of intelligence encompasses attitudes (Sternberg 2022; Sternberg et al. 2024a), most other views of intelligence do not. And a major problem in real-world problem solving is that people often simply do not want to think reflectively or at all deeply about problems. Rather, they accept what their religious, political, or ideological leadership, or their friends and colleagues, tell them (see Sternberg and Niu 2025a, 2025b). Their problem is not in their ability, but rather in their attitude toward thinking critically. They do not want to be bothered to think critically; often, they seem to just want to be entertained.

Second, the literature on critical thinking, historically, has focused on application to the everyday world (e.g., Ennis 2011; Lipman 1995, 1998, 2003; Sternberg and Niu 2025b). Although there are some accounts of intelligence that are oriented toward action in the everyday world (Sternberg 2025a), most of the literature has focused on performance on intelligence tests administered in settings that provide an extremely limited representation of real-world environmental contexts.

Third, the literature on critical thinking emphasizes solving deep, concrete, complex, often not fully soluble real-world problems (see, e.g., Lipman 1995; Sternberg and Niu

2025b). Thinking about intelligence, on the other hand, has emphasized psychometric tests with problems that are rather shallow, abstract, and soluble with a unique answer (see, e.g., any major existing intelligence test).

Finally, critical thinking is a matter of judgment and reflection (Sternberg and Niu 2025a). In this respect, it is in some ways closer to wisdom (Sternberg 2004) than intelligence is. Understanding critical thinking as related to, but distinct from intelligence, therefore, is important.

Before making the main argument of the article, it will be useful to lay out three assumptions that underlie the present analysis.

2. Assumptions Underlying the Present Analysis

Three assumptions underlie the analysis presented in the current article.

1. **The operations of critical thinking and analytical intelligence can be understood only in light of the tasks people need to solve and the environmental contexts in which they need to solve them** (Sternberg 2021a, 2025a). Critical thinking occurs as a person x task x environmental context interaction. How intelligently people operate depends greatly on task: If your adaptation and life depended on your ability to hunt wild animals and forage for edible plants, how well would you do? And how intelligently people operate also depends on the environmental context: Your ability to hunt a wild animal might depend on whether the animal was fearfully running away from you or menacingly running toward you. But the importance of task and situation is not limited to hunting/gathering cultures. In life-threatening situations—such as natural disasters or human-created disasters such as war—whether one can rise to using one's intelligence and critical thinking maximally under stress becomes a matter of life or death.
2. **Real-world problems are qualitatively different from test problems.** The real tasks and problems we face in life look little like the problems we face on standardized tests. In particular, real problems:
    - are for high and sometimes life-changing (or, in extreme cases, potentially life-ending) stakes,
    - are emotionally complex and arousing, sometimes to the level that emotions cloud or utterly befuddle people's better judgment, leading people to think in suboptimal ways,
    - are highly driven by environmental context, requiring people to balance many conflicting interests, and sometimes forcing people to decide whether they will respond in suboptimal ways because their fellow humans want suboptimal solutions,
    - do not typically have a single "correct" answer, but rather multiple answers, each of which is better in some ways and worse in other ways,
    - are lacking a third party to tell us that we even have a problem in need of solution,
    - often are unclear in their parameters, so that it is not certain what the problem is,
    - are often in need of a collective solution, usually by people with different backgrounds, interests, and stakes in the solution,
    - typically provide, at best, only vague paths to a solution, or seemingly no good paths at all, so that we have to create our own new path,
    - often unfold over long periods of time, and sometimes, change as we are in the midst of solving them so that the course we have taken stops working, even if it worked before,

- often make it hard to figure out what information is needed for problem solution or where that needed information is to be located,
- are often riddled with numerous and diverse bits of false or misleading information, with the information deliberately inserted to lead the problem solver down a garden path (Sternberg 2025a).

3. **The rewarded solution to a problem often is not the best answer in any objective sense, but rather, the solution that those in power want to reach, even if it is wrong, pernicious, immoral, or the product of corrupted thinking.** We live in a time when authorities are often driven by the demand for more power, more financial or other resources, more fame, or more revenge against those they view as having betrayed them. Human nature being what it is, many people succumb to authority, whatever its demands (Milgram 2009; Zimbardo 2008). In a world where there are so many strong and often contrary agendas, the idea that there are real-world problems to be solved that depend just on being given the problem explicitly, with a clear path to solution, and with a single "correct" solution that everyone accepts, seems almost quaint.

We now apply these assumptions in an analysis of adaptive intelligence and critical thinking as, in part, a response to threats.

3. The Costs and Benefits of Adaptive Behavior—Threats

Humans have evolved, in part, to be rapid threat detectors. If a wild beast, a human enemy, or a freak natural occurrence (earthquake, hurricane, tornado, volcanic eruption, avalanche, etc.) is about to assail one, one has little or no time to think. One must act. Or one is severely injured or dies and may fail to pass on one's genes to the next generation. Evolutionary pressures aside, one learns in one's life that threats can be anywhere and, sometimes, everywhere, and that if one does not react, often instinctively, one may forfeit one's well-being or life. The time to react may not be immediate, but in general, with threats, to wait may be to risk one's survival.

Adaptivity requires one to be self-protective or to risk one's capacity to carry on and, ultimately, to reproduce. It also requires one to have mechanisms by which one will want to reproduce. That is, of course, where love and sex come into the picture (Buss 2016; Byrne and Whiten 1998; Geher et al. 2013; Miller 2001).

To produce a new generation, therefore, requires at least two things: adaptive intelligence to survive (Sternberg 2021b) and mating intelligence (Geher et al. 2013). It also requires other things, of course, such as advanced expertise in threat detection and related skills (Sternberg 2000), creativity (Sternberg 2025b), and wisdom (Sternberg 2004). All these skills can be taught (Grigorenko et al. 2002), but schools do not often purposely teach them. And, we argue in this essay, they can work against each other.

Adaptive intelligence leads one to recognize threats. Mating intelligence leads one to recognize good mating matches. In contemporary society, that often means choice of a long-term partner, perhaps of a marital partner. But a notable amount of mating is not intelligence-driven, but rather, driven by instinctive drives that take over, often despite one's adaptive intelligence. Sex and love toward another individual often emerge not because of any intelligence, but rather, despite it.

Adaptive intelligence involves changing oneself to fit an environment, changing an environment to fit oneself, or selecting a new environment instead of one in which the individual does not fit, or no longer fits. It is a reflective process that often involves critical thinking. It requires one to have beliefs that are internally consistent and that are consistent with what is out there in the environment (Sternberg 2021b). It requires one carefully to seek out alternative views and arguments, to comparatively assess them, and to choose the best ones (Sternberg and Niu 2025a, 2025b). What is there to go wrong?

A major thing that can go wrong is that just as people fall in love with other people, or even with pets, they also fall in love with ideas; and just as people can hate other people, so can they hate ideas (Hayes 2025; Sternberg 2025c). Both love and hate are adaptive mechanisms to deal with threats. Through love, one has the protection of one or more others who will be there when one needs aid and support. Through hate, one can flee from or retaliate against threats as they arise, to conquer them before they conquer oneself. Suppose, for example, that one is threatened by an enemy. Love may lead those you love to try to protect you from the enemy. Hate may lead you to retaliate against the enemy so that they can never threaten you again. In times of a natural disaster, the first ones we may try to save are those we love. Those we hate, we may make no effort to save. Love and hate are thus part of a full repertoire of adaptive intelligence. Consider an elaboration on this idea.

Sternberg and Sternberg (2024) have proposed what they call a RELIC (Real Love in Context) theory of love, which is drawn upon here for understanding, in part, why it is that critical thinking and intelligence do not fare well when it comes to many real-world problems.

Part of the theory—called a triangular theory of love—has been cross-culturally validated in 25 countries and 37 languages (Kowal et al. 2023; Sorokowski et al. 2020; Sternberg 1997). The theory has also been found to apply very well to love of musical instruments (Sternberg et al. 2022), love of political figures (Goldberg and Sternberg 2024), love of food (Goldberg and Sternberg 2025); and love of academic and other disciplines (Hayes 2025). It is the most widely validated extant theory of love, at least in terms of empirical operations. Love and hate of ideas, like love and hate of people, can be protective. Good ideas help one adapt to the environment, whereas bad ideas can undermine one's adaptation. Thus, love and hate can, under some circumstance, be adaptive as protective forces. But sometimes they lead one astray, and that is a theme of this article.

What do love and hate of an idea look like? And how do they connect to critical thinking?

4. Love and Hatred of Ideas Can Deflect or Even Utterly Decimate Critical Thinking

Critical thinking depends on thinking "straight" (Stanovich 2018). Love, however, often involves almost anything except thinking straight. There are exceptions. Sternberg and colleagues construct-validated (Sternberg et al. 2001) 26 different stories about love, one of which was a story that tried to analyze one's love scientifically. But even that story is often subject to the distortion of the emotions and motivations of the person in love. The other stories, such as fairy-tale stories, business stories, and travel stories, were all based on imposed structures that define love according to how one chooses to define it, based on one's personality, upbringing, and environment. Thus, love can be protective, but, for better or worse, we do not always choose the right form of protection.

According to the triangular theory of love, part of the RELIC theory (Sternberg and Sternberg 2024), love has three components: intimacy, passion, and commitment. Each has different characteristics. Here, it is argued that love applies not only to people, but also to ideas (Hayes 2025; Sternberg 2025c).

Intimacy is primarily emotional. It is characterized by emotional support, care, concern, communication, closeness, attachment, and trust. Intimate partners are very good friends—they are there for each other when they are needed.

How does the concept of intimacy apply to love for ideas? We can become highly attached to ideas, much as we can to people. Such ideas might be equality for our (or another's) persecuted group, communism, capitalism, racial superiority (of one group over another or others), democracy, personal superiority in one or more respects, professional success, and financial success, among many others. We may feel comfortable with those ideas, supportive of and supported by those ideas, close to the ideas, attached to the ideas, and so forth.

Consider as an example just one of these ideas: communism. The idea of communism (as opposed to the practice) was a society that no longer distinguished between classes—no upper class, no middle class, no lower class—just a uniform "class" of workers whose resources would be owned collectively and to whom resources would be allocated based on need rather than societally valued contribution—to each according to their needs. Communism seemed to some a road to equality and an end to manifest differences in ownership of private property and injustices through social inequality. All citizens would own resources equally and experience equal ownership of the means of production, as well as equal sharing of the benefits of production (Marx and Engels [1848] 2008).

The idea of communism was (and, to some, still is) very attractive. It was especially attractive to many intellectuals, at least in the mid-20th century, especially but not exclusively in France (Aron 2001). Intellectuals and others found the idea of enforced equality attractive. They had seen how capitalism seemed to grind down many workers while enriching capitalists, and communism seemed to provide an antidote. It could be trusted, they felt, to take care of people according to their needs, not according to their ability to exploit others to meet one's own desires and wants. It felt like a comfortable friend, because no one would be betrayed. Who would not want a partner whom one can trust to provide for one, good times or bad? As we know, the implementation was a far cry from the conceptualization (e.g., Zubok 2009).

Whether an idea provokes feelings of intimacy depends upon the person and their needs, much as is the case with human partners. Intimacy-provoking ideas have in common that they meet some kind of emotional need that is not being adequately met by one's current set of ideas. Cults are one way of providing this kind of intimacy. Like the very best of friends, they have the apparent answers to one's problems in life. Those answers may not be compelling to others, but then, human partners are not always compelling to others either. One finds ideas that meet one's needs, and cult leaders specialize in convincing people that they, the cult leaders, have what only they and no one else can provide (Sternberg et al. 2024b). Even if the ideas they promote are somewhat ridiculous, with familiarity and repetition, those ideas may come to seem quite reasonable (Zajonc 2001). Autocrats know, for example, that repetition establishes credibility (Orwell 1950).

Passion is characterized by an intense need, longing, and overwhelming desire (Sternberg and Sternberg 2024). People who are passionate for others may obsess over them, may find themselves thinking about those others much of the time, and may feel that they cannot live without those others. They may even become addicted to those persons. For an idea to provoke passion, the individual affected—or afflicted—must feel a desperate need for the idea. For example, someone may feel passionately about communism, and indeed, the Russian Revolution, starting in 1917, was instigated in the name of communism. Some scientists who betrayed the United States, such as Klaus Fuchs, were passionate about communism and what it offered. In the United States of 2025, some ideologues, such as Steve Bannon, appear to be passionate about the idea of populism, or perhaps, what they believe populism to be (see Douthat 2025). They may believe, or say they believe, that government has served people with entrenched privilege in society, and that it is past time for those who have been ignored to rise up and demand their full rights.

Commitment to a partner represents the decision to stay with that partner over the long term, come what may. The individual plans to be with the other regardless of changing life circumstances, including challenges to the relationship, whether from the outside (e.g., discouragement of the relationship by others) or the inside (e.g., disagreements or illnesses). Commitment is cognitive in nature; it is a decision that, no matter what happens, one is in the relationship for good. Commitment to an idea is cognitive as well. It represents a reflective, often long-developed decision that an idea is one in which one can believe, come what may. Many revolutionaries develop a commitment to an idea and decide that if that idea is not realized, they will fight for it until it is. When governments become autocratic, one of the first things they do is take over the press and the schools (Free Press Unlimited 2024; Rippenberger et al. 2025). Thus, the 2025 lawsuits against the press in the United States and the concerted attacks on the most prestigious universities basically follow the autocratic playbook, however they may be intended. This is not a matter of left- or right-wing politics, but rather of government capture.

With ideas, as with persons, greater love is represented by greater amounts of intimacy, passion, and commitment (Sternberg and Sternberg 2024). The greater the love, the more one will fight for an idea, just as one will become more likely to fight for a person. All of this is well and good, if the idea is actually a good one. Sometimes, it is a great one.

Consider an example. The love that Marie Curie, the first woman to receive a Nobel Prize, felt toward her discoveries with portable X-ray machinery, radioactivity, radium, and polonium was palpable. In 1903, Curie became the first woman to receive a Doctor of Science degree in France, an achievement made possible by her continued passion and commitment to the field (Coppes-Zantinga and Coppes 1998; Rockwell 2003). Before attending university, Curie worked as a governess in Poland. She tutored other women in secret after advanced education was outlawed for women in Poland under Russian occupation (Langevin-Joliot 1998; Rockwell 2003). While at the university, Curie's thesis on radiation led her and her husband Pierre to coin the term "radioactivity." Her research ultimately contributed to her earning her two Nobel Prizes (Langevin-Joliot 1998; Rockwell 2003; The Nobel Prize 2018). But as a result of radiation exposure, Curie's fight and love for her idea came at the cost of her life, a sacrifice of a kind that many romance novels idealize. To love an idea to its fullest potential is not always without its caveats.

Curie's idea shifted society's understanding of both chemistry and physics for the better. However, physicist J. Robert Oppenheimer, the "father of the atomic bomb," also loved his idea of fission creating a weapons of mass destruction, but he and his colleagues appear to have changed the landscape of society for the worse. Despite three Nobel Prize nominations in physics and being hailed as one of the most powerful scientists in the American government during the 1940s, J. Robert Oppenheimer never won the coveted award (Bernstein 1982; Bethe 1968). Throughout this professional career, Oppenheimer was questioned about his loyalty to the United States (Bernstein 1982). Did he love his country more than he cared for the ethical considerations of the weapon he was tasked with creating?

Some may argue that, during his time as the chairman of the General Advisory Committee of the Atomic Energy Commission (AEC), his outward opposition to the hydrogen bomb may have hinted that his love of the field was greater than his love for the powers that sought to use his knowledge to cause destruction (Bethe 1968; Bernstein 1982). While witnessing the first atomic bomb explosion, he stated, "Now I am become Death, the destroyer of worlds" (NBC 1965). Can love and death exist simultaneously?

The creation of the atomic bomb was not merely a scientific breakthrough; it was also the "destroyer of worlds." The love of scientific discovery can exist alongside the potential regret and even later hatred of the invention. In addressing and understanding how our love of an idea can be seen through different contextual lenses, we are better equipped to navigate the pluses but also the minuses of our ideas.

As most people learn through hard experience, love is not always directed toward others who are a good match or even deserving of the love. The same challenges apply to love of ideas. For example, some of the individuals who originally loved communism later turned from the extreme left to the extreme right, such as Whittaker Chambers (Tanenhaus 1997). As can be true with love of persons, love can turn to dislike and even hate. And when this conversion happens, hate, like love, can impair critical thinking.

One's love of one's ideas is not always a stable relationship. Like that of individuals, love for an idea can begin fruitfully but turn sour in a matter of seconds. Love of an idea is not merely constructed and impacted by one's personal experience and relationship to it, but also by unifying and/or opposing ecosystems (Bronfenbrenner 2000; Sternberg and Sternberg 2024). These ecosystems, as defined by Bronfenbrenner, consist of five levels: (1) the microsystem (one's immediate environment); (2) the mesosystem (the connections between different microsystems); (3) the exosystem (the environment one is not immediately apart of, but still impacts their life); (4) the macrosystem (the broader sociocultural context); and (5) the chronosystem (the change in environment over one's lifetime). Just as love between individuals can falter and waver under external pressures, so can the love one feels toward an idea. As easily an ecosystem can nourish the idea, it can just as easily inhibit or potentially completely dismantle how one feels about one's idea. One's critical thinking can be facilitated or impaired by these factors in the environment. If, for example, one voted for a politician because one loved the politician and their ideas but then found out that what the politician said before being elected and what they do after election have little in common, one may feel betrayed; one can find oneself thinking only in negative and even hateful terms of the politician. If the betrayal is severe enough—for example, if one's spouse is about to be deported—it becomes hard to think critically or at all objectively about the politician.

Hatred of ideas, and often of the people who cling to those ideas, can distort thinking at least as much as love of ideas can, and possibly more. Hatred, like love, can be understood in terms of three components, namely, negation of intimacy, passion, and commitment (Sternberg 2003). Hate-mongers try to cultivate all three components when they turn people into haters.

Negation of intimacy refers to feelings of aversion, repulsion, and extreme distaste. Someone who experiences the negation of intimacy toward another is repelled by them. They want to have as little as possible to do with them and to avoid any physical contact. They often find these others to arouse disgust and loathing and seek to distance themselves to the greatest extent possible. Negation of intimacy in terms of an idea involves finding the idea vile, disgusting, repulsive, or inhuman. Examples, for some people, might be eugenics, lab-grown meat, communism, capitalism, or miscegenation. The same ideas that one person hates and reviles, another might love and find to be precious.

Passion in hate represents much the same arousal as in love, but with a negative valence. Instead of feeling passionate about connecting with the loved one, one feels passionate about one's aversion to them. Often, one sees them as a threat or as a source of dark energy of some kind; one passionately wants to either avoid them or fight against them. Revolutionary movements can be fomented and encouraged by hatred toward a governmental entity and the idea or ideas it represents, such as hatred of King George III, or taxation without representation, during the American Revolutionary War.

Commitment in hate represents the result of a cognitive investment to produce what seems like sound reasons for one's extreme negative feelings toward another. With hatred of ideas, commitment represents a process whereby one comes to believe that one's negative feelings are well thought out, justified, and worth retaining, even when those ideas are challenged or disconfirmed, including by a governmental system with the power to imprison or even execute one.

For example, cult leaders and their affiliated members operate under the assumption that all ideas that contradict the teachings they are trying to disseminate to their followers are both incorrect and harmful. Through the systematic erosion of critical thinking, cult members come to love their ideas so much that their hate for outsiders may become an emotion equally contributing to their decision-making (Langone 1993). The 1997 mass suicides of 39 members of the Heaven's Gate cult illustrate how far our love of an idea and our eventual hate of others' ideas can lead the critical thinking of the citizens of a society to become warped beyond repair (Balch and Taylor 2002). As a reminder, Heaven's gate was a UFO cult that began during the 1970s and resurfaced during the 1990s; followers believed that the comet Hale-Bopp was used as a disguise for an alien spacecraft. In March 1997, when the comet was at its closest to Earth, members of the group drank a lethal elixir of drugs. Their hope was to leave their bodies, enter the alien spacecraft, and exit into Heaven's Gate (the celestial plane). Before taking the action that he hoped would lead himself and his followers into the celestial plane, the leader of Heaven's Gate, Do, said, "We are returning to life and we do in all honesty *hate* this world" (Balch and Taylor 2002).

In the case of the members of Heaven's Gate, their love of their ideas was not just a means of existence; they were also the fruits that would lead to their ultimate end. The power of love and hate cannot be underestimated in their contribution to how we digest information and later act on what we have received. Do and his followers believed that they had exhausted all human options to escape the inevitable end of the world (Balch and Taylor 2002). Their disdain for outsiders was, in their belief, a well-thought-out and justified reaction to non-members' lack of belief in their cause. When love and hate fuel one another to neglect reality, our decisions no longer feel as though they are our own, but rather, exist to promote the idea. Unfortunately, people in cults generally do not see themselves as being in cults, so they do not perceive the impairment in their critical thinking. The cult members may come to think that they (those in the cult) are the only ones who think critically.

Love and hate of ideas can be every bit as powerful as love and hate of persons. People die in the service of ideas, just as they die in the service of other people. Nathan Hale's reputed famous last words, before he was hanged by the British—"I only regret, *that I* have but one life to lose for my country," represented love of country and the ideals upon which it was founded. In his case, one might believe that his love of country was well thought through and justified.

In recent times, North Korean soldiers have been fighting and dying in Ukraine, having been recruited by their government to serve the Russian one in a genocide against Ukraine. During World War II, German and other soldiers died in the service of Germany and the Nazi movement it spawned. It is perhaps harder to justify service to one of the most reviled governments in the world (North Korea—Pianin 2017) or one of the most reviled ideological movements in history (Nazism). People can be indoctrinated, it appears, to serve and even love almost any cause, no matter how horrific, and then to act in a self-justificatory way (Bandura 2015; Milgram 2009; Zimbardo 2008). Indoctrination can serve as a defense against criminal charges (Robinson and Holcomb 2020), but the strong whiff of immorality for the actions undertaken never goes away. People fall in love with ideas or countries that embody immoral ideas, no matter how attractive or unattractive they may be to others and to posterity.

A problem is that people develop myside biases—biases in favor of whatever their current ideas may be—and intelligence and rational thinking not only appear to be largely powerless to combat them but even can serve those biases by giving people elaborate rationalizations for the beliefs they favor (Baron 2023; Stanovich 2021), or, as discussed here, love. So can develop, as Stanovich has noted, the biases that divide us. Many highly intelligent people, including *Communist Manifesto* authors Vladimir Lenin and Friedrich Engels, have fomented and served causes that have proven to be toxic.

Love and hatred of ideas can be found even in the most mundane circumstances. Although we used high-stakes and historically prominent examples to illustrate these phenomena, it is equally important to recognize that passion for an idea can develop from the simplest and most common experiences. For many academics, medical professionals, writers, historians, etc., their love for their profession began with what others would consider an ordinary event. Whether that be a subject in school that fueled their imagination, a book that sparked their curiosity, or an invention they imagined could change the world, that love began with an interest. This initial interest could come to fuel a love toward the idea, or, in some cases, it might lead to hate. Even the later disdain Dr. Oppenheimer felt toward his (partial) creation, the atomic bomb, began with a passion for physics. One's affective response to one's idea(s) can begin anytime, anywhere, and with any subject. As one comes to love an idea more and more, or to hate it more and more, one's critical thinking may suffer, as would be the case for love of, or hatred toward, a person.

5. A Three-Track Model of Critical Thinking

Based on the considerations presented in this article, we propose a three-track model of critical thinking. The model is summarized in Figure 1. The three tracks in the model are a cognitive track (which is the primary track), attitudinal track, and affective. This model is not intended as a wholly new perspective on critical thinking, but rather as a model that integrates many existing strands of thought about critical thinking, as discussed earlier.

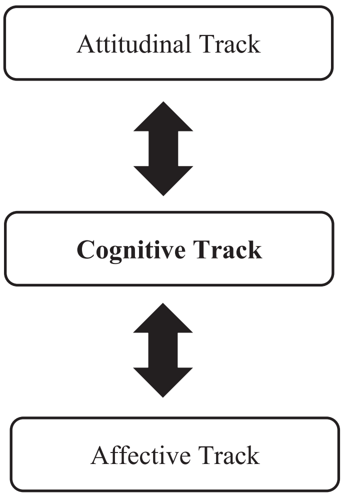

Figure 1. Three tracks of critical thinking.

The model suggests that critical thinking is primarily cognitive (bolded print in Figure 1), but it is also continually interacting with the attitudinal track and the affective track (which also includes personality states and traits). The attitudinal and affective tracks can either facilitate or impede the quality of critical thinking. For example, an attitude of cognitive inertia or of myside bias will impede critical thinking, the former by preventing one from instigating critical thinking, the latter by allowing critical thinking but then by biasing it once it occurs. An affect of love for one's work may increase one's engagement in critical thinking, whereas hate for the work one does may decrease one's engagement. Love may increase engagement but also lead to biased thinking.

Table 1 presents the model in somewhat more detail. There is no attempt to be exhaustive with respect to all the attitudinal, cognitive, and affective states and processes that can influence critical thinking. Rather, the table presents a sample of the kinds of states and processes that can influence the outcomes of critical thinking. As the table shows, attitudes and affects can influence critical thinking in either a positive or a negative way.

Table 1. A three–track model of critical thinking.

I. Cognitive Track (Metacomponents)			
Recognition of Problem Definition/Analysis of Problem Acceptance of Problem Mental Representation of Problem Allocation of Resources for Problem Solution Formulation of Strategy for Problem Solution Monitoring of Solution Strategy Evaluation of Solution			
II. Attitudinal/Dispositional Track			
		Positive Effects	*Negative Effects*
Information Seeking		Adequate Information	Inadequate Information
Desire to Think Analytically/Critically		Deep Analysis	Superficial Analysis
Willingness to Adopt Multiple/Alternative Perspective		Multi-Perspective Analysis	Uni-Perspective Analysis
Willingness to Question One's Own or Others' Solutions		Questioning of Solution	Uncritical Acceptance of Solution
Caring If Solution Is Optimal		Optimizing	Satisficing
Willingness to Think "Outside the Box"		Creative Solution	Pedestrian Solution
Asking: Optimality for Whom?		Common-Good Solution	Egocentric-Good Solution
III. Affective Track			
		Positive Effects	*Negative Effects*
Love			
	Intimacy	Familiarity with Problem and Requirements	Entrenchment in Solving Problem
	Passion	Burning Desire for a Solution	Positively Motivated Distortion
	Commitment	Will See Problem through to the End	Cognitive Commitment to Positive Distortion
Hate			
	Negation of Intimacy		Desire to Distance/Separate from Agents
	Passion		Negatively Distorted Motivations
	Commitment		Cognitive Commitment to Negative Distortion

6. Implications for Education

The proposed model of critical thinking has some implications for education that we hope schools might take into account in that so many students seem to lack adequate critical thinking in these times.

1. **Critical thinking does not come naturally.** Critical thinking involves complex metacognitive and cognitive processes integrated with attitudinal and affective variables that can facilitate or impede it. Teachers cannot assume that students will just learn how to do it by being in school or by being on their own. Many students graduate from school and are nevertheless deficient critical thinkers.
2. **Critical thinking taught in the abstract as a set of metacognitive and cognitive processes is inadequate to meeting the demands of the everyday world.** As soon as people have a vested interest in an outcome or a feeling of personal or ideological alignment with a certain viewpoint, their critical thinking will begin to be affected by the alignment. Part of instruction needs to be teaching students to be aware of their own biases and counteract them.
3. **Much of critical thinking is determined, just as the critical thinking gets seriously started, by what problems one recognizes and how one defines those problems.** So much of problem solving is a matter of how one defines problems. That is why, say, Vladimir Putin refers to the invasion of Ukraine as a "special military operation" instead of, say, a genocide aimed at wiping out a separate Ukrainian identity. Or why people who view abortion as a matter of "right to life" usually come to conclusions different from those who define abortion as a matter of "women's choice with their own bodies."
4. **People often use their analytical (IQ-based) intelligence not to improve their critical thinking but rather to garner support for their own prior position.** High IQ can help critical thinking by improving metacognitive (metacomponential) functioning, but it is at least as likely merely to serve as a means for people to figure out ever more clever reasons to support their own position—much as in debate contests.
5. **Standardized testing could, but generally does not, help support critical thinking.** Students growing up in a testing culture learn, very often, not how to think critically but rather how to provide authorities with the answers that the test-taker thinks the authorities want to hear. Thus, standardized testing may discourage critical thinking in favor of learning how to produce ingratiating responses.
6. **Critical thinking has both domain-general and domain-specific aspects.** Because abilities, attitudes, and affects all influence critical thinking, the quality of critical thinking may vary greatly across domains as a function of one's interests, ideologies, abilities, and efforts. At the same time, the metacomponential executive processes are largely the same across domains, so there is some domain-generality as well.
7. **One cannot improve critical thinking if one requires it of others but does not show it oneself.** Students and everyone else acquire much of their tacit knowledge base by observational learning (Bandura 1986). Ultimately, as Bandura showed, people will model the behavior they observe far more than they will base their behavior on what they are told.
8. **Critical thinking is desperately needed in today's world, but the current emphasis on knowledge acquisition often generates students who lack the critical thinking skills they need to succeed in the world and also to make the world a better place.** Teaching for facts may lead to success on achievement tests that superficially measure school achievement, but it will not lead to success when students need to confront real problems in real-world contexts.

9. **Love can either fuel or detract from critical thinking.** As educators, we need to ensure that students are aware of how an emotion such as love can yield critical thinking. Love, especially passionate love of an idea, can lead to great advances in creativity and knowledge. But it also can lead to the same kind of distorted or even obsessive thinking that people in love sometimes feel toward people with whom they fall in love, especially in the early stages of a romantic relationship.
10. **Recognizing the connection between the affective and attitudinal tracks of critical thinking is imperative to helping students understand that their ideas may not always remain unchanged**. Critical thinking is a process that takes time, practice, patience, and care. One's ideas may take on new meanings and evolve year to year or perhaps even day to day. Teaching students to understand that their critical thinking is impacted by the positive but also the negative effects of the attitudinal and affective tracks may fundamentally reshape their understanding of the idea at hand. This reshaping is not a phenomenon to fear but rather a testament to the continued pursuit of engaging in critical thinking.

7. Conclusions

When we talk about measuring and teaching for "critical thinking," we are often talking about critical thinking in the abstract—as reflected in performance on tests and in school. The problem is that such critical thinking can be and often is bypassed by the vagaries of real life—our ideology, our religious or political beliefs, and our vested interests in particular ideas. We love others through stories (Sternberg and Sternberg 2024). We do not actually know the other, only the story through which we filter our knowledge of the other. Sometimes, the stories we create change very rapidly, as when we discover a betrayal or a piece of what we consider to be compromising history that the other failed to disclose. In an instant, love can turn to hate, or at least, intense dislike. The turning may feel as though it is rational, but as likely as not it is a result of one story replacing another—a story we do not like with one we liked.

Critical thinking, in the present view, is not merely a matter of cognitive abilities (see Figure 1 and Table 1). It also involves, inevitably, dispositions and attitudes. Moreover, its execution is influenced by affective states as well as personality traits. If one does not want to think critically—if one experiences too much cognitive inertia—one will not think critically, no matter the level of one's abilities. Furthermore, critical thinking is very much influenced by affective variables, such as love and hate. To our knowledge, this is the first account of critical thinking that draws on theories of love (Sternberg and Sternberg 2024) and hate (Sternberg 2003) to show that critical thinking in practice cannot be separated from the affective components that influence it. When you love or hate ideas—or people or things about which you think—your critical thinking most likely will be affected, often for the worse.

Every theory of critical thinking is different. If we were to characterize what distinguishes ours from many other models, we would point to three highlights: (a) the specification in the model (as depicted in Figure 1 and Table 1) of the interaction between cognition, on the one hand, and attitudes and affect, on the other; (b) the particular specification of the metacomponents of critical thinking, which derive from the theory of adaptive intelligence; and (c) the use of a particular theory of love—the triangular theory (and also of hate)—to understand how affect can influence critical thinking.

Schools do not seem to teach development of critical thinking, or at least, not as much as some might wish. PISA scores in reading, mathematics, and science have shown a generally declining pattern in the Western world (Colombatto 2024), suggesting that knowledge and the ability to reason with it are moving in the wrong direction in the student body of the Western world. Teaching critical thinking would be a valuable first step in improving the critical thinking and analytical intelligence of students. Students can be taught these skills (Grigorenko et al. 2002), but teaching in ways that ignore the importance of real-world forces that lead students to love ideas, hate ideas, or anything in-between, is not likely to result in meaningful improvement in critical thinking.

Authoritarian governments in the world are progressing full speed ahead, both in getting elected and in staying in power (Repucci and Slipowitz 2022). In 2025, the United States, a country with a long history of democracy, is heading toward authoritarianism at a dizzying pace, literally day by day, according to hundreds of government scholars (Langfitt 2025). Such a government works in favor of collaborators who benefit from it but limits the rights of many others. In a country where many individuals seem to have reduced or suspended critical thinking (Well 2023), the results may not be particularly concerning, but the long-term result is the decline of democracy and its gradual replacement with autocracy (Albright 2018; Mounk 2018, 2023; Ziblatt and Levitsky 2018). This is not a matter of preference for one political party or another, or for right- or left-wing governments. Autocracy can originate on the right or the left, and with any political party. It is a matter of change of a form of government, democracy, that has been in existence, however imperfectly, since 1787. Autocracy, and toxic leaders in general, can be very attractive, especially to people who feel victimized (Lipman-Blumen 2006; Sternberg et al. 2024b) or who see ways to use the autocracy for personal enrichment or other gain. Countries can decide to change their form of government, but often, when they elect toxic leaders, the people do not realize that they will be electing not only a new leader but inadvertently ushering in a new form of government. And this is why critical thinking is so important in real life, not just in the taking of standardized or other tests. High IQ will provide no protection against lapses in critical thinking due to myside bias, and may actually encourage such lapses when people of high IQ think they are immune to failures in critical thinking (Stanovich 2021).

Although critical thinking and intelligence (as tested) are related, they are not the same, as noted throughout this article. A question arises as to whether higher measured intelligence might lead to *more* use of critical thinking, because intelligent people should recognize the importance of critical thinking, or whether those with higher measured intelligence might use *less* critical thinking because smart people trust their intuitions and do not believe that they need to think things through carefully. We believe that whether higher intelligence leads to more or less critical thinking depends not on intelligence or even on critical thinking, but rather, on a central aspect of wisdom, namely, epistemic humility (Grossmann et al. 2020; Sternberg 2024). Epistemic humility, as we conceive of it, is understanding what one knows, what one does not know, what one can know, and what one cannot know (Sternberg 2024). In this case, an intelligent person might believe they know what they do not know—that they are generalized experts—and thus not use critical thinking when it is needed; or they might recognize how much they do not know but that they could know and then use critical thinking. As a result, an intelligent person lacking epistemic humility can be dangerous, because they act in ways that fail to reflect their understanding of their own ignorance.

Students need to learn not only how to think critically, but how their attitudes and personal likings, loving, and hatreds can inadvertently alter their critical thinking. They need to understand that no matter what ability they have to think critically, in real life, there is a gap, often a huge gap, between competence and performance (Sternberg 2025a). No matter how intelligent we are, we are often unaware of the competence/performance gap. We feel that we are operating at a level of full competence, even when we are not because of the influence of attitudes and affects. This is scarcely a new observation. Plato and Aristotle both wrote about how the passions can influence our thinking. Perhaps, after all these centuries, it is time to take their message seriously.

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An Evaluative Review of Barriers to Critical Thinking in Educational and Real-World Settings

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Abstract: Though a wide array of definitions and conceptualisations of critical thinking have been offered in the past, further elaboration on some concepts is required, particularly with respect to various factors that may impede an individual's application of critical thinking, such as in the case of reflective judgment. These barriers include varying levels of epistemological engagement or understanding, issues pertaining to heuristic-based thinking and intuitive judgment, as well as emotional and biased thinking. The aim of this review is to discuss such barriers and evaluate their impact on critical thinking in light of perspectives from research in an effort to reinforce the 'completeness' of extant critical thinking frameworks and to enhance the potential benefits of implementation in real-world settings. Recommendations and implications for overcoming such barriers are also discussed and evaluated.

Keywords: critical thinking; reflective judgment; epistemology; emotion; bias

1. Introduction

Critical thinking (CT) is a metacognitive process—consisting of a number of skills and dispositions—that, through purposeful, self-regulatory reflective judgment, increases the chances of producing a logical solution to a problem or a valid conclusion to an argument (Dwyer 2017, 2020; Dwyer et al. 2012, 2014, 2015, 2016; Dwyer and Walsh 2019; Quinn et al. 2020).

CT has long been identified as a desired outcome of education (Bezanilla et al. 2019; Butler et al. 2012; Dwyer 2017; Ennis 2018), given that it facilitates a more complex understanding of information (Dwyer et al. 2012; Halpern 2014), better judgment and decision-making (Gambrill 2006) and less dependence on cognitive bias and heuristic thinking (Facione and Facione 2001; McGuinness 2013). A vast body of research (e.g., Dwyer et al. 2012; Gadzella 1996; Hitchcock 2004; Reed and Kromrey 2001; Rimiene 2002; Solon 2007), including various meta-analyses (e.g., Abrami et al. 2008, 2015; Niu et al. 2013; Ortiz 2007), indicates that CT can be enhanced through targeted, explicit instruction. Though CT can be taught in domain-specific areas, its domain-generality means that it can be taught across disciplines and in relation to real-world scenarios (Dwyer 2011, 2017; Dwyer and Eigenauer 2017; Dwyer et al. 2015; Gabennesch 2006; Halpern 2014). Indeed, the positive outcomes associated with CT transcend educational settings into real-world, everyday situations, which is important because CT is necessary for a variety of social and interpersonal contexts where good decision-making and problem-solving are needed on a daily basis (Ku 2009). However, regardless of domain-specificity or domain-generality of instruction, the transferability of CT application has been an issue in CT research (e.g., see Dumitru 2012). This is an important consideration because issues with transferability—for example, in real-world settings—may imply something lacking in CT instruction.

In light of the large, aforementioned body of research focusing on enhancing CT through instruction, a growing body of research has also evaluated the manner in which CT instruction is delivered (e.g., Abrami et al. 2008, 2015; Ahern et al. 2019; Cáceres et al.

2020; Byerly 2019; Dwyer and Eigenauer 2017), along with additional considerations for and the barriers to such education, faced by teachers and students alike (e.g., Aliakbari and Sadeghdaghighi 2013; Cáceres et al. 2020; Cornell et al. 2011; Lloyd and Bahr 2010; Ma and Liu 2022; Ma and Luo 2021; Rear 2019; Saleh 2019); for example, those regarding conceptualisation, beliefs about CT, having feasible time for CT application and CT's aforementioned transferability. However, there is a significant lack of research investigating barriers to CT application by individuals in real-world settings, even by those who have enjoyed benefits from previous CT instruction. Thus, perhaps the previously conjectured 'something lacking in CT instruction' refers to, in conjunction with the teaching of what CT consists of, making clear to students what barriers to CT application we face.

Simply, CT instruction is designed in such a way as to enhance the likelihood of positive decision-making outcomes. However, there are a variety of barriers that can impede an individual's application of CT, regardless of past instruction with respect to 'how to conduct CT'. For example, an individual might be regarded as a 'critical thinker' because they apply it in a vast majority of appropriate scenarios, but that does not ensure that they apply CT in *all* such appropriate scenarios. What keeps them from applying CT in those scenarios might well be one of a number of barriers to CT that often go unaddressed in CT instruction, particularly if such instruction is exclusively focused on skills and dispositions. Perhaps too much focus is placed on what educators are teaching their students *to do* in their CT courses as opposed to what educators should be recommending their students to look out for or advising what they *should not* be doing. That is, perhaps just as important for understanding what CT is and how it is conducted (i.e., knowing what to do) is a genuine awareness of the various factors and processes that can *impede* CT; and so, for an individual to think critically, they must know what to look out for and be able to monitor for such barriers to CT application.

To clarify, thought has not changed regarding what CT is or the cognitive/metacognitive processes at its foundation (e.g., see Dwyer 2017; Dwyer et al. 2014; Ennis 1987, 1996, 1998; Facione 1990; Halpern 2014; Paul 1993; Paul and Elder 2008); rather, additional consideration of issues that have potential to negatively impact CT is required, such as those pertaining to epistemological engagement; intuitive judgment; as well as emotional and biased thinking. This notion has been made clear through what might be perceived of as a 'loud shout' for CT over at least the past 10–15 years in light of growing political, economic, social, and health-related concerns (e.g., 'fake news', gaps between political views in the general population, various social movements and the COVID-19 pandemic). Indeed, there is a dearth of research on *barriers* to CT (Haynes et al. 2016; Lloyd and Bahr 2010; Mangena and Chabeli 2005; Rowe et al. 2015). As a result, this evaluative perspective review aims to provide an impetus for updating the manner in which CT education is approached and, perhaps most importantly, applied in real-world settings—through further identifying and elaborating on specific barriers of concern in order to reinforce the 'completeness' of extant CT frameworks and to enhance the potential benefits of their implementation[1].

2. Barriers to Critical Thinking

2.1. Inadequate Skills and Dispositions

In order to better understand the various barriers to CT that will be discussed, the manner in which CT is conceptualised must first be revisited. Though debate over its definition and what components are necessary to think critically has existed over the 80-plus years since the term's coining (i.e., Glaser 1941), it is generally accepted that CT consists of two main components: skills and dispositions (Dwyer 2017; Dwyer et al. 2012, 2014; Ennis 1996, 1998; Facione 1990; Facione et al. 2002; Halpern 2014; Ku and Ho 2010a; Perkins and Ritchhart 2004; Quinn et al. 2020). CT skills—analysis, evaluation, and inference—refer to the higher-order, cognitive, 'task-based' processes necessary to conduct CT (e.g., see Dwyer et al. 2014; Facione 1990). CT dispositions have been described as inclinations, tendencies, or willingness to perform a given thinking skill (e.g., see

Dwyer et al. 2016; Siegel 1999; Valenzuela et al. 2011), which may relate to attitudinal and intellectual habits of thinking, as well as motivational processes (Ennis 1996; Norris 1994; Paul and Elder 2008; Perkins et al. 1993; Valenzuela et al. 2011). The relationship between CT skills and dispositions has been argued to be mutually dependent. As a result, overemphasising or encouraging the development of one over the other is a barrier to CT as a whole. Though this may seem obvious, it remains the case that CT instruction often places added emphasis on skills simply because they can be taught (though that does not ensure that everyone has or will be taught such skills), whereas dispositions are 'trickier' (e.g., see Dwyer 2017; Ku and Ho 2010a). That is, it is unlikely that simply 'teaching' students to be motivated towards CT or to value it over short-instructional periods will actually meaningfully enhance it. Moreover, debate exists over how best to train disposition or even measure it. With that, some individuals might be more 'inherently' disposed to CT in light of their truth-seeking, open-minded, or inquisitive natures (Facione and Facione 1992; Quinn et al. 2020). The barrier, in this context, is how we can enhance the disposition of those who are not 'inherently' inclined. For example, though an individual may possess the requisite skills to conduct CT, it does not ensure the tendency or willingness to apply them; and conversely, having the disposition to apply CT does not mean that one has the ability to do so (Valenzuela et al. 2011). Given the pertinence of CT skills and dispositions to the application of CT in a broader sense, inadequacies in either create a barrier to application.

2.2. Epistemological (Mis)Understanding

To reiterate, most extant conceptualisations of CT focus on the tandem working of skills and dispositions, though significantly fewer emphasise the *reflective judgment* aspect of CT that might govern various associated processes (Dawson 2008; Dwyer 2017; Dwyer et al. 2014, 2015; King and Kitchener 1994, 2004; Stanovich and Stanovich 2010). Reflective judgment (RJ) refers to a self-regulatory process of decision-making, with respect to taking time to engage one's understanding of the nature, limits, and certainty of knowing and how this can affect the defense of their reasoning (Dwyer 2017; King and Kitchener 1994; Ku and Ho 2010b). The ability to metacognitively 'think about thinking' (Flavell 1976; Ku and Ho 2010b) in the application of critical thinking skills implies a reflective sensibility consistent with epistemological understanding and the capacity for reflective judgement (Dwyer et al. 2015; King and Kitchener 1994). Acknowledging levels of (un)certainty is important in CT because the information a person is presented with (along with that person's pre-existing knowledge) often provides only a limited source of information from which to draw a conclusion. Thus, RJ is considered a component of CT (Baril et al. 1998; Dwyer et al. 2015; Huffman et al. 1991) because it allows one to acknowledge that epistemological understanding is necessary for recognising and judging a situation in which CT may be required (King and Kitchener 1994). For example, the interdependence between RJ and CT can be seen in the way that RJ influences the manner in which CT skills like analysis and evaluation are conducted or the balance and perspective within the subsequent inferences drawn (Dwyer et al. 2015; King et al. 1990). Moreover, research suggests that RJ development is not a simple function of age or time but more so a function of the amount of active engagement an individual has working in problem spaces that require CT (Brabeck 1981; Dawson 2008; Dwyer et al. 2015). The more developed one's RJ, the better able one is to present "a more complex and effective form of justification, providing more inclusive and better integrated assumptions for evaluating and defending a point of view" (King and Kitchener 1994, p. 13).

Despite a lesser focus on RJ, research indicates a positive relationship between it and CT (Baril et al. 1998; Brabeck 1981; Dawson 2008; Dwyer et al. 2015; Huffman et al. 1991; King et al. 1990)—the understanding of which is pertinent to better understanding the foundation to CT barriers. For example, when considering one's proficiency in CT skills, there might come a time when the individual becomes so good at using them that their application becomes something akin to 'second nature' or even 'automatic'. However, this creates a contradiction: automatic thinking is largely the antithesis of reflective judgment (even though judgment is never fully intuitive or reflective; see Cader et al. 2005; Dunwoody et al. 2000; Hamm 1988; Hammond 1981, 1996, 2000)—those who think critically take their time and reflect on their decision-making; even if the solution/conclusion drawn from the automatic thinking is 'correct' or yields a positive outcome, it is not a critically thought out answer, per se. Thus, no matter how skilled one is at applying CT skills, once the application becomes primarily 'automatic', the thinking ceases to be *critical* (Dwyer 2017)—a perspective consistent with Dual Process Theory (e.g., Stanovich and West 2000). Indeed, RJ acts as System 2 thinking (Stanovich and West 2000): it is slow, careful, conscious, and consistent (Kahneman 2011; Hamm 1988); it is associated with high cognitive control, attention, awareness, concentration, and complex computation (Cader et al. 2005; Kahneman 2011; Hamm 1988); and accounts for epistemological concerns—consistent not only with King and Kitchener's (1994) conceptualisation but also Kuhn's (1999, 2000) perspective on metacognition and *epistemological knowing*. This is where RJ comes into play as an important component of CT—interdependent among the requisite skills and dispositions (Baril et al. 1998; Dwyer et al. 2015)—it allows one to acknowledge that epistemological understanding is vital to recognising and judging a situation in which CT is required (King and Kitchener 1994). With respect to the importance of epistemological understanding, consider the following examples for elaboration.

The primary goal of CT is to enhance the likelihood of generating reasonable conclusions and/or solutions. Truth-seeking is a CT disposition fundamental to the attainment of this goal (Dwyer et al. 2016; Facione 1990; Facione and Facione 1992) because if we just applied any old nonsense as justification for our arguments or solutions, they would fail in the application and yield undesirable consequences. Despite what may seem like truth-seeking's obvious importance in this context, all thinkers succumb to unwarranted assumptions on occasion (i.e., beliefs presumed to be true without adequate justification). It may also seem obvious, in context, that it is important to be able to distinguish facts from beliefs. However, the concepts of 'fact' or 'truth', with respect to how much empirical support they have to validate them, also require consideration. For example, some might conceptualise truth as factual information or information that has been or can be 'proven' true. Likewise, 'proof' is often described as evidence establishing a fact or the truth of a statement—indicating a level of absolutism. However, the reality is that we cannot 'prove' things—as scientists and researchers well know—we can only disprove them, such as in experimental settings where we observe a significant difference between groups on some measure—we do not prove the hypothesis correct, rather, we disprove the null hypothesis. This is why, in large part, researchers and scientists use cautious language in reporting their results. We know the best our findings can do is reinforce a theory—another concept often misconstrued in the wider population as something like a hypothesis, as opposed to what it actually entails: a robust model for how and/or why a given phenomenon might occur (e.g., gravity). Thus, theories will hold 'true' until they are falsified—that is, disproven (e.g., Popper [1934] 1959, 1999).

Unfortunately, 'proof', 'prove', and 'proven'—words that ensure certainty to large populations—actually disservice the public in subtle ways that can hinder CT. For example, a company that produces toothpaste might claim its product to be 'clinically proven' to whiten teeth. Consumers purchasing that toothpaste are likely to expect to have whiter teeth after use. However, what happens—as often may be the case—if it does not whiten their teeth? The word 'proven' implies a false claim in context. Of course, those in research understand that the word's use is a marketing ploy, given that 'clinically proven' sounds more reassuring to consumers than 'there is evidence to suggest . . . '; but, by incorrectly using words like 'proven' in our daily language, we reinforce a misunderstanding of what it means to assess, measure and evaluate—particularly from a scientific standpoint (e.g., again, see Popper [1934] 1959, 1999).

Though this example may seem like a semantic issue, it has great implications for CT in the population. For example, a vast majority of us grew up being taught the 'factual' information that there were nine planets in our solar system; then, in 2006, Pluto was reclassified as a dwarf planet—no longer being considered a 'major' planet of our solar system. As a result, we now have eight planets. This change might be perceived in two distinct ways: (1) 'science is amazing because it's always developing—we've now reached a stage where we know so much about the solar system that we can differentiate celestial bodies to the extent of distinguishing planets from dwarf planets'; and (2) 'I don't understand why these scientists even have jobs, they can't even count planets'. The first perspective is consistent with that of an individual with epistemological understanding and engagement that previous understandings of models and theories can change, not necessarily because they were wrong, but rather because they have been advanced in light of gaining further credible evidence. The second perspective is consistent with that of someone who has failed to engage epistemological understanding, who does not necessarily see that the change might reflect progress, who might be resistant to change, and who might grow in distrust of science and research in light of these changes. The latter point is of great concern in the CT research community because the unwarranted cynicism and distrust of science and research, in context, may simply reflect a lack of epistemological understanding or engagement (e.g., to some extent consistent with the manner in which conspiracy theories are developed, rationalised and maintained (e.g., Swami and Furnham 2014)). Notably, this should also be of great concern to education departments around the world, as well as society, more broadly speaking.

Upon considering epistemological engagement in more practical, day-to-day scenarios (or perhaps a lack thereof), we begin to see the need for CT in everyday 21st-century life—heightened by the 'new knowledge economy', which has resulted in exponential increases in the amount of information made available since the late 1990s (e.g., Darling-Hammond 2008; Dwyer 2017; Jukes and McCain 2002; Varian and Lyman 2003). Though increased amounts of and enhanced access to information are largely good things, what is alarming about this is how much of it is misinformation or disinformation (Commission on Fake News and the Teaching of Critical Literacy in Schools 2018). Truth be told, the new knowledge economy is anything but 'new' anymore. Perhaps, over the past 10–15 years, there has been an increase in the need for CT above and beyond that seen in the 'economy's' wake—or maybe ever before; for example, in light of the social media boom, political unrest, 'fake news', and issues regarding health literacy. The 'new' knowledge economy has made it so that knowledge acquisition, on its own, is no longer sufficient for learning—individuals must be able to work with and adapt information through CT in order to apply it appropriately (Dwyer 2017).

Though extant research has addressed the importance of epistemological understanding for CT (e.g., Dwyer et al. 2014), it does not address how *not* engaging it can substantially hinder it—regardless of how skilled or disposed to think critically an individual may be. Notably, this is distinct from 'inadequacies' in, say, memory, comprehension, or other 'lower-order' cognitively-associated skills required for CT (Dwyer et al. 2014; Halpern 2014; see, again, Note 1) in that reflective judgment is essentially a pole on a *cognitive continuum* (e.g., see Cader et al. 2005; Hamm 1988; Hammond 1981, 1996, 2000). Cognitive Continuum Theory postulates a continuum of cognitive processes anchored by reflective judgment and intuitive judgment, which represents how judgment situations or tasks relate to cognition, given that thinking is never purely reflective, nor is it completely intuitive; rather, it rests somewhere in between (Cader et al. 2005; Dunwoody et al. 2000). It is also worth noting that, in Cognitive Continuum Theory, neither reflective nor intuitive judgment is assumed, a priori, to be superior (Dunwoody et al. 2000), despite most contemporary research on judgment and decision-making focusing on the strengths of RJ and limitations associated with intuitive judgment (Cabantous et al. 2010; Dhami and Thomson 2012; Gilovich et al. 2002). Though this point regarding superiority is acknowledged and respected (particularly in non-CT cases where it is advantageous to utilise intuitive judgment), in the context of CT, it is rejected in light of the example above regarding the automaticity of thinking skills.

2.3. Intuitive Judgment

The manner in which human beings think and the evolution of which, over millions of years, is a truly amazing thing. Such evolution has made it so that we can observe a particular event and make complex computations regarding predictions, interpretations, and reactions in less than a second (e.g., Teichert et al. 2014). Unfortunately, we have become so good at it that we often over-rely on 'fast' thinking and intuitive judgments that we have become 'cognitively lazy', given the speed at which we can make decisions with little energy (Kahneman 2011; Simon 1957). In the context of CT, this 'lazy' thinking is an impediment (as in opposition to reflective judgment). For example, consider a time in which you have been presented numeric data on a topic, and you instantly aligned your perspective with what the 'numbers indicate'. Of course, numbers do not lie . . . but people do—that is not to say that the person who initially interpreted and then presented you with those numbers is trying to disinform you; rather, the numbers presented might not tell the full story (i.e., the data are incomplete or inadequate, unbeknownst to the person reporting on them); and thus, there might be alternative interpretations to the data in question. With that, there most certainly are individuals who will wish to persuade you to align with their perspective, which only strengthens the impetus for being aware of intuitive judgment as a barrier. Consider another example: *have you ever accidentally insulted someone at work, school, or in a social setting? Was it because the statement you made was based on some kind of assumption or stereotype?* It may have been an honest mistake, but if a statement is made based on what one thinks they know, as opposed to what they actually know about the situation—without taking the time to recognise that all situations are unique and that reflection is likely warranted in light of such uncertainty—then it is likely that the schema-based 'intuitive judgment' is what is a fault here.

Our ability to construct schemas (i.e., mental frameworks for how we interpret the world) is evolutionarily adaptive in that these scripts allow us to: make quick decisions when necessary and without much effort, such as in moments of impending danger, answer questions in conversation; interpret social situations; or try to stave off cognitive load or decision fatigue (Baumeister 2003; Sweller 2010; Vohs et al. 2014). To reiterate, research in the field of higher-order thinking often focuses on the failings of intuitive judgment (Dwyer 2017; Hamm 1988) as being limited, misapplied, and, sometimes, yielding grossly incorrect responses—thus, leading to faulty reasoning and judgment as a result of systematic biases and errors (Gilovich et al. 2002; Kahneman 2011; Kahneman et al. 1982; Slovic et al. 1977; Tversky and Kahneman 1974; in terms of schematic thinking (Leventhal 1984), system 1 thinking (Stanovich and West 2000; Kahneman 2011), miserly thinking (Stanovich 2018) or even heuristics (Kahneman and Frederick 2002; Tversky and Kahneman 1974). Nevertheless, it remains that such protocols are learned—not just through experience (as discussed below), but often through more 'academic' means. For example, consider again the anecdote above about learning to apply CT skills so well that it becomes like 'second nature'. Such skills become a part of an individual's 'mindware' (Clark 2001; Stanovich 2018; Stanovich et al. 2016) and, in essence, become heuristics themselves. Though their application requires RJ for them to be CT, it does not mean that the responses yielded will be incorrect.

Moreover, despite the descriptions above, it would be incorrect, and a disservice to readers to imply that RJ is always right and intuitive judgment is always wrong, especially without consideration of the contextual issues—both intuitive and reflective judgments have the potential to be 'correct' or 'incorrect' with respect to validity, reasonableness or appropriateness. However, it must also be acknowledged that there is a cognitive 'miserliness' to depending on intuitive judgment, in which case, the ability to detect and override this dependence (Stanovich 2018)—consistent with RJ, is of utmost importance if we care about our decision-making. That is, if we *care* about our CT (see below for a more detailed discussion), we must ignore the implicit 'noise' associated with the intuitive judgment (regardless of whether or not it is 'correct') and, instead, apply the necessary RJ to ensure, as best we can, that the conclusion or solution is valid, reasonable or appropriate.

Although, such a recommendation is much easier said than done. One problem with relying on mental shortcuts afforded by intuition and heuristics is that they are largely experience-based protocols. Though that may sound like a positive thing, using 'experience' to draw a conclusion in a task that requires CT is erroneous because it essentially acts as 'research' based on a sample size of one; and so, 'findings' (i.e., one's conclusion) cannot be generalised to the larger population—in this case, other contexts or problem-spaces (Dwyer 2017). Despite this, we often over-emphasise the importance of experience in two related ways. First, people have a tendency to confuse experience for expertise (e.g., see the *Dunning–KrugerEffect* (i.e., the tendency for low-skilled individuals to overestimate their ability in tasks relevant to said skill and highly skilled individuals to underestimate their ability in tasks relevant to said skills); see also: (Kruger and Dunning 1999; Mahmood 2016), wherein people may not necessarily be expert, rather they may just have a lot of experience completing a task imperfectly or wrong (Dwyer and Walsh 2019; Hammond 1996; Kahneman 2011). Second, depending on the nature of the topic or problem, people often evaluate experience on par with research evidence (in terms of credibility), given its personalised nature, which is reinforced by self-serving bias(es).

When evaluating topics in domains wherein one lacks expertise, the need for intellectual integrity and humility (Paul and Elder 2008) in their RJ is increased so that the individual may assess what knowledge is required to make a critically considered judgment. However, this is not necessarily a common response to a lack of relevant knowledge, given that when individuals are tasked with decision-making regarding a topic in which they do not possess relevant knowledge, these individuals will generally rely on emotional cues to inform their decision-making (e.g., Kahneman and Frederick 2002). Concerns here are not necessarily about the lack of domain-specific knowledge necessary to make an accurate decision, but rather the (1) belief of the individual that they have the knowledge necessary to make a critically thought-out judgment, even when this is not the case—again, akin to the Dunning–Kruger Effect (Kruger and Dunning 1999); or (2) lack of willingness (i.e., disposition) to gain additional, relevant topic knowledge.

One final problem with relying on experience for important decisions, as alluded to above, is that when experience is engaged, it is not necessarily an objective recollection of the procedure. It can be accompanied by the individual's beliefs, attitudes, and feelings—how that experience is recalled. The manner in which an individual draws on their personal experience, in light of these other factors, is inherently emotion-based and, likewise, biased (e.g., Croskerry et al. 2013; Loftus 2017; Paul 1993).

2.4. Bias and Emotion

Definitions of CT often reflect that it is to be applied to a topic, argument, or problem of importance that the individual *cares* about (Dwyer 2017). The issue of 'caring' is important because it excludes judgment and decision-making in day-to-day scenarios that are *not* of great importance and *do not* warrant CT (e.g., 'what colour pants best match my shirt' and 'what to eat for dinner'); again, for example, in an effort to conserve time and cognitive resources (e.g., Baumeister 2003; Sweller 2010). However, given that 'importance' is subjective, it essentially boils down to what one *cares* about (e.g., issues potentially impactful in one's personal life; topics of personal importance to the individual; or even problems faced by an individual's social group or work organisation (in which case, care might be more extrinsically-oriented). This is arguably one of the most difficult issues to resolve in CT application, given its contradictory nature—where it is generally recommended that CT should be conducted void of emotion and bias (as much as it can be possible), at the same time, it is also recommended that it should only be applied to things we care about. As a result, the manner in which care is conceptualised requires consideration. For example, in terms of CT, care can be conceptualised as 'concern or interest; the attachment of importance to a person, place, object or concept; and serious attention or consideration applied to doing something correctly or to avoid damage or risk'; as opposed to some form of *passion* (e.g., *intense, driving or over-powering feeling or conviction; emotions as distinguished* *from reason; a strong liking or desire for or devotion* to some activity, object or concept). In this light, care could be argued as more of a dispositional or self-regulatory factor than emotional bias; thus, making it useful to CT. Though this distinction is important, the manner in which care is labeled does not lessen the potential for biased emotion to play a role in the thinking process. For example, it has been argued that if one cares about the decision they make or the conclusion they draw, then the individual will do their best to be objective as possible (Dwyer 2017). However, it must also be acknowledged that this may not always be the case or even completely feasible (i.e., *how can any decision be fully void of emotional input?*)—though one may strive to be as objective as possible, such objectivity is not ensured given that *implicit* bias may infiltrate their decision-making (e.g., taking assumptions for granted as facts in filling gaps (unknowns) in a given problem-space). Consequently, such implicit biases may be difficult to amend, given that we may not be fully aware of them at play.

With that, explicit biases are just as concerning, despite our awareness of them. For example, the more important an opinion or belief is to an individual, the greater the resistance to changing their mind about it (Rowe et al. 2015), even in light of evidence indicating the contrary (Tavris and Aronson 2007). In some cases, the provision of information that corrects the flawed concept may even 'backfire' and reinforce the flawed or debunked stance (Cook and Lewandowsky 2011). This cognitive resistance is an important barrier to CT to consider for obvious reasons—as a process; it acts in direct opposition to RJ, the skill of evaluation, as well as a number of requisite dispositions towards CT, including truth-seeking and open-mindedness (e.g., Dwyer et al. 2014, 2016; Facione 1990); and at the same time, yields important real-world impacts (e.g., see Nyhan et al. 2014).

The notion of emotion impacting rational thought is by no means a novel concept. A large body of research indicates a negative impact of emotion on decision-making (e.g., Kahneman and Frederick 2002; Slovic et al. 2002; Strack et al. 1988), higher-order cognition (Anticevic et al. 2011; Chuah et al. 2010; Denkova et al. 2010; Dolcos and McCarthy 2006) and cognition, more generally (Iordan et al. 2013; Johnson et al. 2005; Most et al. 2005; Shackman et al. 2006)[2]. However, less attention has specifically focused on emotion's impact on the application of *critical* thought. This may be a result of assumptions that if a person is inclined to think critically, then what is yielded will typically be void of emotion—which is true to a certain extent. However, despite the domain generality of CT (Dwyer 2011, 2017; Dwyer and Eigenauer 2017; Dwyer et al. 2015; Gabennesch 2006; Halpern 2014), the likelihood of emotional control during the CT process remains heavily dependent on the topic of application. Consider again, for example; there is no guarantee that an individual who generally applies CT to important topics or situations will do so in *all* contexts. Indeed, depending on the nature of the topic or the problem faced, an individual's mindware (Clark 2001; Stanovich 2018; Stanovich et al. 2016; consistent with the metacognitive nature of CT) and the extent to which a context can evoke emotion in the thinker will influence what and how thinking is applied. As addressed above, if the topic is something to which the individual feels passionate, then it will more likely be a greater challenge for them to remain unbiased and develop a reasonably objective argument or solution.

Notably, self-regulation is an important aspect of both RJ and CT (Dwyer 2017; Dwyer et al. 2014), and, in this context, it is difficult not to consider the role *emotional intelligence* might play in the relationship between affect and CT. For example, though there are a variety of conceptualisations of emotional intelligence (e.g., Bar-On 2006; Feyerherm and Rice 2002; Goleman 1995; Salovey and Mayer 1990; Schutte et al. 1998), the underlying thread among these is that, similar to the concept of self-regulation, emotional intelligence (EI) refers to the ability to monitor (e.g., perceive, understand and regulate) one's own feelings, as well as those of others, and to use this information to guide relevant thinking and behaviour. Indeed, extant research indicates that there is a positive association between EI and CT (e.g., Afshar and Rahimi 2014; Akbari-Lakeh et al. 2018; Ghanizadeh and Moafian 2011; Kaya et al. 2017; Stedman and Andenoro 2007; Yao et al. 2018). To shed light upon this relationship, Elder (1997) addressed the potential link between CT and EI through her description of the latter as a measure of the extent to which affective responses are *rationally-based*, in which *reasonable* desires and behaviours emerge from such rationally-based emotions. Though there is extant research on the links between CT and EI, it is recommended that future research further elaborate on this relationship, as well as with other self-regulatory processes, in an effort to further establish the potentially important role that EI might play within CT.

3. Discussion

3.1. Interpretations

Given difficulties in the past regarding the conceptualisation of CT (Dwyer et al. 2014), efforts have been made to be as specific and comprehensive as possible when discussing CT in the literature to ensure clarity and accuracy. However, it has been argued that such efforts have actually added to the complexity of CT's conceptualisation and had the opposite effect on clarity and, perhaps, more importantly, the accessibility and practical usefulness for educators (and students) not working in the research area. As a result, when asked what CT is, I generally follow up the 'long definition', in light of past research, with a much simpler description: CT is akin to 'playing devil's advocate'. That is, once a claim is made, one should second-guess it in as many conceivable ways as possible, in a process similar to the Socratic Method. Through asking 'why' and conjecturing alternatives, we ask the individual—be it another person or even ourselves—to justify the decision-making. It keeps the thinker 'honest', which is particularly useful if we're questioning ourselves. If we do not have justifiable reason(s) for why we think or intend to act in a particular way (above and beyond considered objections), then it should become obvious that we either missed something or we are biased. It is perhaps this simplified description of CT that gives such impetus for the aim of this review.

Whereas extant frameworks often discuss the importance of CT skills, dispositions, and, to a lesser extent, RJ and other self-regulatory functions of CT, they do so with respect to components of CT or processes that facilitate CT (e.g., motivation, executive functions, and dispositions), without fully encapsulating cognitive processes and other factors that may hinder it (e.g., emotion, bias, intuitive judgment and a lack of epistemological understanding or engagement). With that, this review is neither a criticism of existing CT frameworks nor is it to imply that CT has so many barriers that it cannot be taught well, nor does it claim to be a complete list of processes that can impede CT (see again Note 1). To reiterate, education in CT can yield beneficial effects (Abrami et al. 2008, 2015; Dwyer 2017; Dwyer and Eigenauer 2017); however, such efficacy may be further enhanced by presenting students and individuals interested in CT the barriers they are likely to face in its application; explaining how these barriers manifest and operate; and offer potential strategies for overcoming them.

3.2. Further Implications and Future Research

Though the barriers addressed here are by no means new to the arena of research in higher-order cognition, there is a novelty in their collated discussion as impactful barriers in the context of CT, particularly with respect to extant CT research typically focusing on introducing strategies and skills for enhancing CT, rather than identifying 'preventative measures' for barriers that can negatively impact CT. Nevertheless, future research is necessary to address how such barriers can be overcome in the context of CT. As addressed above, it is recommended that CT education include discussion of these barriers and encourage self-regulation against them; and, given the vast body of CT research focusing on enhancement through training and education, it seems obvious to make such a recommendation in this context. However, it is also recognised that simply identifying these barriers and encouraging people to engage in RJ and self-regulation to combat them may not suffice. For example, educators might very well succeed in teaching students how to apply CT *skills*, but just as these educators may not be able to motivate students to use them as often as they might be needed or even to value such skills (such as in attempting to elicit a positive disposition towards CT), it might be the case that without knowing about the impact of the discussed barriers to CT (e.g., emotion and/or intuitive judgment), students may be just as susceptible to biases in their attempts to think critically as others without CT skills. Thus, what such individuals might be applying is not CT at all; rather, just a series of higher-order cognitive skills from a biased or emotion-driven perspective. As a result, a genuine understanding of these barriers is necessary for individuals to appropriately self-regulate their thinking.

Moreover, though the issues of epistemological beliefs, bias, emotion, and intuitive processes are distinct in the manner in which they can impact CT, these do not have set boundaries; thus, an important implication is that they can overlap. For example, epistemological understanding can influence how individuals make decisions in real-world scenarios, such as through intuiting a judgment in social situations (i.e., without considering the nature of the knowledge behind the decision, the manner in which such knowledge interacts [e.g., correlation v. causation], the level of uncertainty regarding both the decision-maker's personal stance and the available evidence), when a situation might actually require further consideration or even the honest response of 'I don't know'. The latter concept—that of simply responding 'I don't know' is interesting to consider because though it seems, on the surface, to be inconsistent with CT and its outcomes, it is commensurate with many of its associated components (e.g., intellectual honesty and humility; see Paul and Elder 2008). In the context this example is used, 'I don't know' refers to epistemological understanding. With that, it may also be impacted by bias and emotion. For example, depending on the topic, an individual may be likely to respond 'I don't know' when they do not have the relevant knowledge or evidence to provide a sufficient answer. However, in the event that the topic is something the individual is emotionally invested in or feels passionate about, an opinion or belief may be shared instead of 'I don't know' (e.g., Kahneman and Frederick 2002), despite a lack of requisite evidence-based knowledge (e.g., Kruger and Dunning 1999). An emotional response based on belief may be motivated in the sense that the individual knows that they do not know for sure and simply uses a belief to support their reasoning as a persuasive tool. On the other hand, the emotional response based on belief might be used simply because the individual may not know that the use of a belief is an insufficient means of supporting their perspective– instead, they might think that their intuitive, belief-based judgment is as good as a piece of empirical evidence; thus, suggesting a lack of empirical understanding. With that, it is fair to say that though epistemological understanding, intuitive judgment, emotion, and bias are distinct concepts, they can influence each other in real-world CT and decision-making. Though there are many more examples of how this might occur, the one presented may further support the recommendation that education can be used to overcome some of the negative effects associated with the barriers presented.

For example, in Ireland, students are not generally taught about academic referencing until they reach third-level education. Anecdotally, I was taught about referencing at age 12 and had to use it all the way through high school when I was growing up in New York. In the context of these referencing lessons, we were taught about the credibility of sources, as well as how analyse and evaluate arguments and subsequently infer conclusions in light of these sources (i.e., CT skills). We were motivated by our teacher to find the 'truth' as best we could (i.e., a fundament of CT disposition). Now, I recognise that this experience cannot be generalised to larger populations, given that I am a sample size of one, but I do look upon such education, perhaps, as a kind of transformative learning experience (Casey 2018; King 2009; Mezirow 1978, 1990) in the sense that such education might have provided a basis for both CT and epistemological understanding. For CT, we use research to support our positions, hence the importance of referencing. When a 'reference' is not available, one must ask if there is actual evidence available to support the proposition. If there is not, one must question the basis for why they think or believe that their stance is correct—that is, where there is logic to the reasoning or if the proposition is simply an emotion- or bias-based intuitive judgment. So, in addition to referencing, the teaching of some form of epistemology—perhaps early in children's secondary school careers, might benefit students in future efforts to overcome some barriers to CT. Likewise, presenting examples of the observable impact that bias, emotions, and intuitive thought can have on their thinking might also facilitate overcoming these barriers.

As addressed above, it is acknowledged that we may not be able to 'teach' people not to be biased or emotionally driven in their thinking because it occurs naturally (Kahneman 2011)—regardless of how 'skilled' one might be in CT. For example, though research suggests that components of CT, such as disposition, can improve over relatively short periods of time (e.g., over the duration of a semester-long course; Rimiene 2002), less is known about *how* such components have been enhanced (given the difficulty often associated with trying to *teach* something like disposition (Dwyer 2017); i.e., to reiterate, it is unlikely that simply 'teaching' (or telling) students to be motivated towards CT or to value it (or its associated concepts) will actually enhance it over short periods of time (e.g., semester-long training). Nevertheless, it is reasonable to suggest that, in light of such research, educators can encourage dispositional growth and provide opportunities to develop it. Likewise, it is recommended that educators encourage students to be aware of the cognitive barriers discussed and provide chances to engage in CT scenarios where such barriers are likely to play a role, thus, giving students opportunities to acknowledge the barriers and practice overcoming them. Moreover, making students aware of such barriers at younger ages—in a simplified manner, may promote the development of personal perspectives and approaches that are better able to overcome the discussed barriers to CT. This perspective is consistent with research on RJ (Dwyer et al. 2015), in which it was recommended that such enhancement requires not only time to develop (be it over the course of a semester or longer) but is also a function of having increased opportunities to engage CT. In the possibilities described, individuals may learn both to overcome barriers to CT and from the positive outcomes of applying CT; and, perhaps, engage in some form of transformative learning (Casey 2018; King 2009; Mezirow 1978, 1990) that facilitates an enhanced 'valuing' of and motivation towards CT. For example, through growing an understanding of the nature of epistemology, intuitive-based thinking, emotion, bias, and the manner in which people often succumb to faulty reasoning in light of these, individuals may come to better understand the limits of knowledge, barriers to CT and how both understandings can be applied; thus, growing further appreciation of the process as it is needed.

To reiterate, research suggests that there may be a developmental trajectory above and beyond the parameters of a semester-long training course that is necessary to develop the RJ necessary to think critically and, likewise, engage an adequate epistemological stance and self-regulate against impeding cognitive processes (Dwyer et al. 2015). Though such research suggests that such development may not be an issue of time, but rather the amount of opportunities to engage RJ and CT, there is a dearth of recommendations offered with respect to how this could be performed in practice. Moreover, the *how* and *what* regarding 'opportunities for engagement' requires further investigation as well. For example, does this require additional academic work outside the classroom in a formal manner, or does it require informal 'exploration' of the world of information on one's own? If the latter, the case of motivational and dispositional levels once again comes into question; thus, even further consideration is needed. One way or another, future research efforts are necessary to identify how best to make individuals aware of barriers to CT, encourage them to self-regulate against them, and identify means of increasing opportunities to engage RJ and CT.

4. Conclusions

Taking heed that it is unnecessary to reinvent the CT wheel (Eigenauer 2017), the aim of this review was to further elaborate on the processes associated with CT and make a valuable contribution to its literature with respect to conceptualisation—not just in light of making people explicitly aware of what it is, but also what it is not and how it can be impeded (e.g., through inadequate CT skills and dispositions; epistemological misunderstanding; intuitive judgment; as well as bias and emotion)—a perspective consistent with that of 'constructive feedback' wherein students need to know both what they are doing right and what they are doing wrong. This review further contributes to the CT education literature by identifying the importance of (1) engaging understanding of the nature, limits, and certainty of knowing as individuals traverse the landscape of evidence-bases in their research and 'truth-seeking'; (2) understanding how emotions and biases can affect CT, regardless of the topic; (3) managing gut-level intuition until RJ has been appropriately engaged; and (4) the manner in which language is used to convey meaning to important and/or abstract concepts (e.g., 'caring', 'proof', causation/correlation, etc.). Consistent with the perspectives on research advancement presented in this review, it is acknowledged that the issues addressed here may not be complete and may themselves be advanced upon and updated in time; thus, future research is recommended and welcomed to improve and further establish our working conceptualisation of critical thinking, particularly in a real-world application.

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Notes

1 Notably, though inadequacies in cognitive resources (apart from those explicitly set within the conceptualisations of CT discussed; e.g., see Section 2.1) are acknowledged as impediments to one's ability to apply CT (e.g., a lack of relevant background knowledge, as well as broader cognitive abilities and resources (Dwyer 2017; Halpern 2014; Stanovich and Stanovich 2010)), these will not be discussed as focus is largely restricted to issues of cognitive processes that 'naturally' act as barriers in their functioning. Moreover, such inadequacies may more so be issues of individual differences than ongoing issues that *everyone*, regardless of ability, would face in CT (e.g., the impact of emotion and bias). Nevertheless, it is recommended that future research further investigates the influence of such inadequacies in cognitive resources on CT.

2 There is also some research that suggests that emotion may mediate enhanced cognition (Dolcos et al. 2011, 2012). However, this discrepancy in findings may result from the types of emotion studied—such as task-relevant emotion and task-irrelevant emotion. The distinction between the two is important to consider in terms of, for example, the distinction between one's general mood and feelings specific unto the topic under consideration. Though mood may play a role in the manner in which CT is conducted (e.g., making judgments about a topic one is passionate about may elicit positive or negative emotions that affect the thinker's mood in some way), notably, this discussion focuses on task-relevant emotion and associated biases that negatively impact the CT process. This is also an important distinction because an individual may generally think critically about 'important' topics, but may fail to do so when faced with a cognitive task that requires CT with which the individual has a strong, emotional perspective (e.g., in terms of *passion*, as described above).

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