education sciences

MDPI

Article

Considering the Lessons of Curriculum Studies in the Design of Science Instruction: Varieties of Meaning and Implications for Teaching and Learning

William F. McComas

College of Education and Health Professions, University of Arkansas, Fayetteville, AR 72701, USA; mccomas@uark.edu

Abstract: This article is an introduction to the rich domain of curriculum studies with specific reference to science teaching and learning. It is designed not as a systematic review or theoretical treatise but rather as an overview for those charged with transforming science content and processes into a classroom curriculum. In other words, while written from the scholarly perspective of curriculum studies, the hope is that it will be seen by teachers as a set of possibilities rather than recommendations while reminding educators that what happens in classrooms to students and their parents is the curriculum, but it is only one of many that might have been delivered. To accomplish this, this paper explores the complex definition of curriculum including the notions of the kinds of curriculum from *null*, to *formal*, *received*, and *learned* with an emphasis on what occurs as a specific curriculum design results in effective and even faulty learning, a unique consequence proposed here. Next, we explore the common curriculum ideologies or orientations including those focused on academic advancement, tradition, student-centeredness, and social improvement. Finally, a formal recommendation for the content of science instruction in the U.S.—the *Next-Generation Science Standards*, is are considered as a conclusion by applying the expansive perspective of the term and nature of curriculum discussed throughout.

Keywords: curriculum studies; science education; learning standards; curriculum rationales

Citation: McComas, W.F. Considering the Lessons of Curriculum Studies in the Design of Science Instruction: Varieties of Meaning and Implications for Teaching and Learning. *Educ. Sci.* **2024**, *14*, 238. https://doi.org/10.3390/educsci14030238

Academic Editors: Myint Swe Khine and João Piedade

Received: 27 September 2023
Revised: 29 January 2024
Accepted: 21 February 2024
Published: 25 February 2024

1. Introduction

One of the most common terms in education must be curriculum. It is reasonable to assume that most educators have something of a shared understanding of this term, probably approaching that of the oft-quoted view of U.S. Supreme Court Justice Potter Stewart who stated, "*. . . I know it when I see it. . .*", offered while reflecting on the nature of obscenity. However, in practice, curriculum is not a simple concept; only the most seasoned educators likely appreciate the full range of meanings and implications the term conveys. So, it would be best to conclude—even here in the Introduction—that the best definition of curriculum must include the phrase, *it is complicated.*

As is the case with many labels in a sophisticated domain such as education, the term curriculum has a multiplicity of meanings that, when considered in totality, look more like the layers of an onion than a singular and straightforward entity. Even whether one should use an indefinite article such as *a curriculum* or a definite one as in *the curriculum*, reveals the underlying complexity. Therefore, this term joins other jargon-rich and discipline-specific words that demand agreement on a shared definition before one can have a fruitful conversation involving it.

So, let us start at the beginning, peel back the strata of meaning and nuance, and explore the concept of curriculum generally. Later, once a full definition has been provided, it will be possible to consider what a/the curriculum looks like with specific reference to the teaching of science. For many teachers and their students, instructional choices (i.e., the curriculum) applied in a classroom setting may feel like running a race from the first day of class to the last.

For teachers, there is the inevitable clock ticking with respect to how much of the target content can be "covered" in the time available. Students, from their perspective, likely think and even worry about the hurdles—assignments, assessments, and understanding—to be found associated with that same block of material in that classroom with that instructor. The notion of a race is more appropriate than many might guess. Leyendecker [1] tells us that the term curriculum comes from the Old French and Latin verb *currere*, meaning to run, with the noun translated as *racecourse* or *racetrack*. Ellis [2] adds the interesting twist that our words current, courier, and currency also stem from the same root.

Of course, the notion of running a race has faded from the common meaning of curriculum but a singular definition is still elusive. However, as a start, consider the foundational work of education scholar Hilda Taba [3] who defines curriculum simply as a plan for learning. This is the definition most likely held by classroom teachers, but as those onion-like layers of meaning around the notion of curricula are peeled back and revealed, things become more interesting. For instance, consider a definition from John Franklin Bobbit [4], an early curriculum theorist, who believed that what happens in school should be designed to move children toward success as adults. Few would likely disagree with this, but it is now possible to see that the basic definition provided by Taba [3] should relate to specific goals, in this case becoming productive adult members of society. So now, what is taught must be coupled with specific behaviors and knowledge linked to a defined end state, and this becomes the foundation for establishing the curriculum.

Scholarly and practical books abound in curriculum studies, which might provide consensus on what the term curriculum means. So, with help from classic works by Bobbit [4], Tyler [5], Taba [3], and Eisner [6] to more contemporary contributions from scholars such as Schiro [7] and Olivia and Gordon [8], a range of definitions may be explored. These definitions include but are not limited to the following: curriculum as a set of materials, sequence of courses/projects, a set of performance objectives, a course of study, everything taught in a school, the experiences of each individual learner while attending and participating in school, and everything that goes on within the school (planned and unplanned) including extra-class activities, guidance, or lack thereof, along with the impact of interpersonal relationships.

Entire chapters have been dedicated to unpacking each of these potential definitions of curriculum, but for our purposes, one conclusion is that not only is a definition of curriculum complicated, but even trying to provide a universal one is akin to climbing a "slippery slope" according to Goodson [9]. Finally, even as we approach a shared understanding of curriculum, supporters of *Universal Design for Learning* (UDL) such as Gordon, Meyer, and Rose [10] remind us that all well-designed curricula have four interrelated moving parts including goals for instruction, methods of teaching, instructional materials, and assessment tools and techniques. Experienced educators have long known that teaching is complicated.

2. Curriculum Definitions and Associated Nuances

Another important issue associated with curriculum focuses on what might be called the impact, reception, or other implications of what lies at the core of instruction. Again, in reviewing the work of a variety of scholars, an almost unending set of descriptors in this regard appears, several of which seem to mean essentially the same thing. For instance, if we accept a definition of curriculum to refer to everything that the child experiences in school or in the classroom, there will be lessons that are intentionally taught and those that are communicated unintentionally, or unofficially. This may be in evidence in a science class, where the instructor delivers the usual range of content and subtly teaches effective communication skills too by "marking up" students' written work. As a former secondary school biology teacher, I was this sort of instructor. I distinctly remember an exchange with a student who once complained about my edits, stating with some annoyance, "that's not fair, you're not an English teacher". My response: "all teachers are English teachers". This notion that a biology teacher holds instructional views beyond the disciple of science itself is a good example of the distinction between the *visible* versus the *hidden curriculum*, a term that first appeared in Jackson's book *Life in Classrooms* [11]. Similar notions, with subtle distinctions, include the labels "*official* vs. *unofficial*" and "*written* vs. *unwritten*" curricula.

Consider here the idea of the *null curriculum*, or the litany of what schools do not teach in any form—explicitly or implicitly [12]. This has both obvious and less obvious meanings. Of course, schools cannot teach everything and, in many cases, should not try to do so. In public school environments in many countries, it is not proper (and in many cases, not legal) to provide specific religious instruction, leaving such lessons to parents and religious institutions. The less obvious example of a *null curriculum* is what most agree should be taught but is deliberately attacked or even excluded. Book banning in the U.S., which has always been pernicious, is reaching new levels of impact and concern to those who advocate for openness across the academy. In science, for example, in recent times, books that include discussion of the biology of gender differences are being removed from libraries. For years, evolution, the unifying principle of biology, has been minimized or even ignored by teachers concerned about parental reactions to such a focus, even though the topic has long been included in state and national standards documents. What is not taught or otherwise unavailable in a particular school or instructional domain is part of the null curriculum.

The discussion of the final range of curriculum distinctions will likely resonate with every educator and relates to games such as "telephone" or "whisper down the lane". As shown in Figure 1, instruction begins with the *formal* or *desired* curriculum, which is what the teacher is ultimately supposed to share (i.e., the goal of instruction) perhaps by formal learning standards, mandated or otherwise. Whatever curriculum is generated should be based on the desire of what students should have an opportunity to learn. Arguably, this first step is the most important in developing an effective curriculum, but teachers must recognize that a set of standards is not "a" or "the" curriculum per se. This theme will reemerge when discussing the U.S. *Next-Generation Science Standards* later.

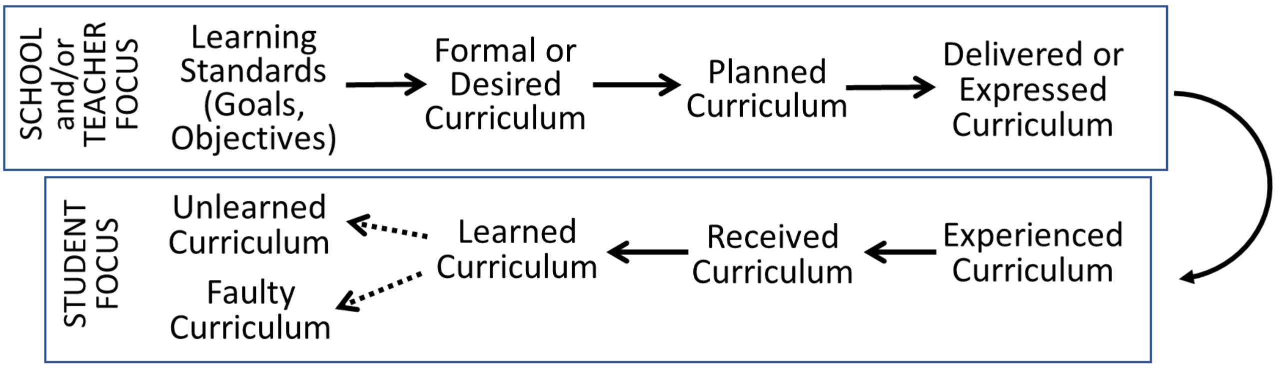

Figure 1. The relationship among various curriculum definitions associated with instruction. The first three aspects are the responsibility or focus of the instructor, and the final elements relate to what occurs in the minds of students.

Next, this goal must be put into some instructional frame (the *planned curriculum*) and then enacted in the classroom through various means of appropriate instruction that could include a laboratory activity, textbooks, lecture–discussion, the use of media, or countless other instructional modalities. This is called the *expressed* or *delivered curriculum*. In turn, students individually and collectively encounter and interact with instruction (called the *experienced curriculum*), but there will inevitably be a winnowing effect with respect to what students "get" or receive from instruction (hence the name, the *received curriculum*). Finally, there is now the potential for students to learn something significant related to the goal of the lesson (the *learned curriculum*). Of course, the student may gain nothing from this instruction and, not surprisingly, there is a label for this too. Despite having had an opportunity to learn, those who fail at this task demonstrate the *unlearned curriculum.* However, there is another subtlety to this chain of events that should also be considered, particularly with respect to a constructivist view of learning. Suppose what the student "learns" is not an accurate representation of the objective of instruction or suppose that instruction and related instructional choices reinforced students' prior faulty ideas.

In such cases, it may be useful to introduce a label not yet in the literature and propose a *faulty curriculum* for learning experiences that either teach incorrect lessons or further substantiate students' prior but incorrect notions. In science, this could easily happen, even in classrooms of experienced instructors. In thinking about the topic of evolution again, there is a commonly held conception that organisms can "adapt" to changes in their environment that somehow applies to individuals. However, it is only populations of organisms that show adaptive change through successive generations of offspring, and this is true only because, as the environment altered, those individuals without the necessary traits failed to survive or thrive and left significantly fewer offspring with the traits that were not as useful in supporting survival. Those survivors in the new population had characteristics that allowed them to be successful. Teachers must take care to point out that individuals either have or do not have the traits that permit survival in a particular situation. Individuals cannot simply "adapt" to survive, in the commonsense use of that term. Unfortunately, teachers may use the term adaptation incorrectly, and/or students may "hear" this label incorrectly, with the result that the lesson fails and, in this case, the curriculum is faulty.

It should be clear that while considering this example and, indeed, reviewing the implications of Figure 1, a constructivist learning scheme is implied. A full description of constructivist teaching and learning [13] is not possible here but, suffice it to say, that constructivism is a learning theory that posits that what students already know must be used and tested in instruction. Reinforcing what students already know that aligns with a scientific worldview must be validated, and challenging students' ideas that are at odds with the conclusions of science should be the challenges. Teachers must consider what students already know and how terms are used both in science and commonly to design effective science instruction. This may be seen as more a pedagogical orientation than a curricular one, but it could be argued that one could develop a curriculum that engages a constructivist orientation.

3. Curriculum Ideologies: A Taxonomy of Curricular Rationales and Orientations

It may seem that the word curriculum has been determined or revealed in much of its complexity, but there is an additional consideration; this is the idea of the overarching curriculum ideology that lies "on top" of the finer points illustrated in Figure 1. Together, the curriculum ideology works with the various elements discussed previously to provide the clearest view of any particular plan for instruction.

To begin a brief discussion of ideologies, consider the view of Eisner [6] (1994, p. 47), a prominent curriculum theorist, who stated that such views

> . . . are defined as beliefs about what schools should teach, for what ends, and for what reasons. Insofar as an ideology can be tacit rather than explicit, it is fair to say that all schools have at least one ideology–and usually more than one–that provides direction to their functions.

Unfortunately, it is somewhat difficult to represent the totality of Einer's thoughts because earlier he published with a collaborator [14] and alone wrote two editions of his book *The Educational Imagination* [6,15]. However, by considering Eisner's contributions while drawing from additional curriculum scholars such as Adler [16], Dewey [17], Freire [18], Sizer [19], and others, it is possible to distill various common rationales for curriculum into the descriptions to be presented next. Even in their abbreviated forms, we must recognize that these categories represent dominant but not wholly mutually distinct orientations for the nature or orientation of what any curriculum might be. Those who design curricula in formal ways or enact classroom instruction to engage any curricular goals would be wise to consider how their final product communicates both spoken and unspoken messages to students and other stakeholders.

Academic Rationalism: This curriculum focus is grounded in the idea that students need certain content and must learn specific skills to advance to the next level of their education. The content in such a curriculum is that of disciplinary specialists (i.e., scientists) with a focus on transmitting the "canon" or traditions of that specialization in each science class [6,20]. Science examples of this view might include having students explore how knowledge is created in science, what are the stages of the cell cycle, or an examination of Newton's laws.

Essentialism: This view of curriculum manifests in an instructional focus on a few traditional and time-tested core subjects such as English language arts, mathematics, science, and even vocational subjects along with core knowledge—sometimes culturally bound—with the teacher generally in charge, with the overall goal being that students should be taught the *common* (i.e., *"essential"*) *concepts and skills that belong to a particular culture or group (such as science)*. Proponents often cite lax standards in schools as the prime reason to support essentialism with "back to basics" and "less is more" justifications [19,21]. Science examples here could include the design of the periodic table and how to use that knowledge to make predictions about chemical bonding.

Progressivism: The foremost proponent of this curriculum rationale is John Dewey [17] in the early 20th centry, who wrote extensively about the focus on what he called the whole child, the interests of children, and an educational mode featuring students who learn by doing, problem-solving, exploring personal directions, and experiencing firsthand as advocated more recently byt Kohn [22]. In science class this might include giving students an opportunity to to explore the stages of a butterfly life cycle for those curious about this phenomenon or assisting students in the control of variables as students design an experiment addressing a personally relevant question.

Perennialism: This is the view that some ideas and some authors have lasted for centuries and remain meaningful and relevant. Therefore, students should learn these ideas and experience these great thinkers directly. An outgrowth of this philosophical orientation was the *Great Books* program advocated by Adler [16] and others [23], a model which still has its proponents. At least one U.S. higher education institution, St. John's, has based its curriculum on this approach. An illustration in science instruction would be for students to read Darwin's *Voyage of the Beagle* and draw inferences about which experiences on that voyage led to his theory of evolution by natural selection.

Social Reconstructionism (accompanied by *Critical* Pedagogy): The goal of education grounded in reconstruction is to address problems of social concerns, enhance social justice, and, therefore, create a new and more inclusive social order. The term "critical", often associated with this curriculum rationale, is used in the sense that it is *critical* that instruction should focus the educational enterprise on such goals. Education for citizenship could also fit into this curriculum ideology. The most well-known proponent is Brazilian Paulo Friere [18]. Science examples may include an exploration of the health of a local stream by examining chemistry and biology and then taking action to correct problems discovered or recognizing the value and safety of vaccines and the rationales of participating in mass vaccination plans, an important topic in current world events.

Of course, as noted with the various definitions and nuances of curricula discussed in the previous section, entire treatises and criticisms have been written about each of these major curriculum ideologies. Some have advocated that it is enough to recognize that it is possible to simplify these orientations further simply by looking at who or what is impacted or involved. This might result in a commonly cited trifecta of *subject-centered*, *learner-centered*, and/or *problem-based curriculum* design, which could even be extended to include a category of *citizenship-centered curriculum*. No one orientation is "better" than any other nor is it likely that any formal curriculum plan would focus exclusively, on any single rationale. However, it is vital that those who design and apply any curriculum understand that such plans are not neutral but are purposeful and value-laden. Finally, note that the taxonomy just offered is not a fully mutually exclusive set of rationales. For instance, it is easy to conceive of a curriculum focused on students' interests (progressivism) that involves reading the works of great scientists (perennialism). Of course, many other such syntheses are possible, blending various curriculum orientations. The point here is that while there may be "pure" originations from a scholarly perspective, that is rarely the case in practice.

To conclude this part of the discussion, it may be useful to refer to Figure 1 and its reasonably exhaustive list of implications or "types" of curricula that may result at various steps in the instructional process. Considering these labels along with the rationales just discussed, one can see that these rationales or orientations are umbrella-like in their character, and all the delineation that occurs along the way from the "learning goal" to the "experienced" curriculum can and do still apply. In other words, one could certainly have an essentialist orientation to the science curriculum but would still encounter the "whisper down the lane" reduction mentioned earlier in reception by, students as instruction proceeds. There cannot be a perfect curriculum orientation or fully effective instructional curricular program when recognizing the vast number of variables (both human and procedural) involved in the transmission of knowledge, skills, and attitudes that comprise the educational equation.

4. What Knowledge Is Worth Knowing and Therefore Worth Teaching?

So far, this overview has focused on definitions that are useful to provide an overview of the notion of curriculum per se, but what science elements (content, processes of science, deeper insights, skills, perspectives, etc.) are included in instruction are just as important as the orientation of that curriculum. These debates are timeless and are frequently summed up in the words of Herbert Spencer [24] in who asked, "What knowledge is of most worth?" and added… "before there can be a rational curriculum, we must settle which things it most concerns us to know; we must determine the relative values of knowledges". True then, and just as true now.

In science, perhaps more than in any other discipline, knowledge growth is exponential, and it would be impossible to update traditional textbooks with everything new and not recognize that such introductory texts would become so bloated that they would fall out of their bindings. However, it seems that textbook publishers want books to be all things to all people. It is simply not necessary to attempt to include all such knowledge, particularly for those in introductory (i.e., K-12) settings. What must happen periodically is to remove outdated material and add well-established and necessary new information while maintaining a reasonable size of the textbook (which often is a proxy for the desired curriculum). This task requires judicious and potentially contentious decision making. Perhaps surprisingly, let me suggest that scientists, while important for checking content accuracy, should have a minor role in determining what science knowledge is of most worth. That task should be up to discipline-based science educators who are in a much better position than scientists to know what teachers and students can handle in the typical 180-day school year. However, this typically does not happen when content standards are being considered and committees are convened for such purposes, in which scientists are overrepresented. Support for this point comes from curriculum expert Michael Apple [25] who added a qualifier to Spencer's earlier question by asking "*Whose* knowledge is of most worth?" He states "… Rather, what counts as legitimate knowledge is the result of complex power relations and struggles among identifiable class, race, gender, and religious groups. Thus, education and power are terms of an indissoluble couplet". One might add that the struggle also extends to who the subject area experts are when the original goals for instruction are debated.

Those making decisions about what to include in texts are guided by many viewpoints including content expertise, pedagogical appropriateness, and political and religious perspectives. Consider the motivations of those who lobby for the removal of considerations of climate change and human origins from an otherwise robust science curriculum. Some scientists might also work to ensure that their discipline appears throughout the curriculum to the point that it may be overrepresented. For instance, if a botanist is invited into discussions about what biology content is of most worth, it may be no surprise that the plant sciences might begin to dominate their proposals. It is possible to predict this will follow as one science expert after another defends the inclusion of content from their disciplines. This is true as well in the arena of "how science works", or the *nature of science*. When asking philosophers of science to offer opinions about what of their content should be included in potential curriculum plans, the result will likely be recommendations that are too deep, too obscure, too impractical, and potentially too dense even for teachers and certainly for their students. This aspect of science instruction is of particular interest [24,26], however, because learning about the content of science without learning how science works and its strengths and limitations will result in little more than a long list of scientific achievements. We saw evidence of this lack of understanding almost daily during the pandemic. Adults did not appreciate that knowledge in science is both additive and evolutionary. Therefore, many failed to understand that, as with any new disease, scientists, and policymakers could not be expected to provide "final" advice because knowledge of the virus and its transmission was constantly being updated as the pandemic unfolded. This reality should have allowed people to understand and even embrace the advice offered, but anger and confusion ensued because many lacked an understanding of how science works. Future science standards and resulting curricula developed must draw from our shared pandemic experience.

Science educators and science teachers know what science content should inform any proposals for a science curriculum, particularly in the K-12 environment. Stuckey, Hofstein, Mamlok-Naaman, and Eilks [27] would seem to be correct by adding "relevance" as an important guidepost in determining content goals for any school science experience. One might also add balance and accessibility as additional keys in making decisions regarding the content to be targeted in science curriculum plans, along with the mode of instruction such as inquiry learning experience to model the way in which scientists work. All these considerations frame the nature of the curriculum orientation students ought to experience and the impacts of the curricular concerns that were outlined earlier in this paper.

5. "A" or "The" Science Curriculum: Considering the *Next-Generation Science Standards*

Given the complexity of "curriculum", it should be clear that it can never be "the" science curriculum on "a" science curriculum at any given place and time. A review of Figure 1 and further consideration of the various curriculum orientations make this clear. Even if each grade level had a firm set of government-mandated science content goals, there would be countless ways that instruction through the *planned or expressed curriculum* would differ from one school to the next and even from one classroom to another. In addition, the nature of instruction would vary considerably, resulting in distinct curriculum ideologies. Teachers who hold an academic rationalist view of curriculum might have students memorize important facts and learn about specific science processes to get them ready for the next science class, while those with a more progressive philosophy might have students explore some phenomenon of interest and then, on their own, endeavor to learn more about underlying science concepts to make sense of what they see in the natural world. Some teachers will include scores of laboratory experiences, while others will include none. Some would assess scientific understanding using multiple-choice tests, while others would measure such understanding through authentic problem-solving experiences. At best, it is reasonable to refer to *a science curriculum*, but the more generalized version of *the science curriculum* seems elusive or, at best, ill-definable because of the considerations offered by even a cursory view of curriculum studies.

The U.S. has experienced more than a century of reports offering suggestions for the focus of science teaching, most specifically at the secondary level. The famous *Committee of Ten* report [28] written in the late 19th century offered the recommendation that science instruction consist of natural history (physiology, zoology, botany); physics, chemistry, and astronomy; and geography (physical geography, geology, meteorology). Another report, *Cardinal Principles of Secondary Education* [7], was published in 1918 [29], followed two years later by the *Reorganization of Secondary Education* [8,30]. The *Cardinal Principles* recommended that science instruction focus on health, worthy home membership, vocation, citizenship, worthy use of leisure time, and ethical character. Curiously, the latter report dropped an earlier recommendation for a focus on the command (understanding) of fundamental processes, which many would likely have interpreted as classic science content.

Education in the United States is the responsibility of the states, and the U.S. federal government has little direct control. Therefore, following these earlier national reports, for the next century, individual states developed their own science instructional goals. From a curriculum perspective, the learning goals for science, the order of instruction, and even some of the ancillary activities such as laboratory investigations were suggested by whatever textbook the school purchased for use in science class. Of course, teachers were generally free to use those books in whatever way they chose. In the late 1990s, a small revolution brewed in areas such as mathematics instruction, which resulted in the development and release of standards for the teaching of that subject. Organizations interested in supporting science instruction took notice of this emerging trend and quickly produced two distinct sets of content recommendations. These were the 1990 *Science for All Americans* [31] from the American Association for Advancement of Science and the *National Science Education Standards* of 1996 [32] from the U.S. National Research Council. The documents stirred much conversation within the science education community about the importance of having shared science learning goals, and many curricula across the nation were developed in response to their release. However, few states adopted many of the recommendations offered in either report, but that changed with the release of *The Next Generation Science Standards* (NGSS) about a decade ago [33].

The NGSS development process began with the release of the 2012 *Framework* [34] that laid out a conceptual plan for the recommendations that would ultimately appear in the final standards document which now is commonly just referred to as the NGSS. Those tasked with developing the NGSS elicited support from a group of states with the expectation that those states would use the resulting recommendations. In the years since the release of the final document, this has been the case with most U.S. states "fully" adopting the guidelines and many more producing their own standards related to the NGSS.

The NGSS, as released, consistsof three highly visible elements including science content (called *Disciplinary Core Ideas or DCI*) recommended for each grade level loosely based on a scaffolding approach to education. The other prominent aspect is a set of *Crosscutting Concepts (CCCs)* said to link all sciences together with patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change. A final prominent element are the *Science and Engineering Practices (SEPs)*, which consist of shared processes such as questioning, developing/using models, investigating, interpreting data, etc.

NGSS almost universally is said to feature 3D science learning because of the three elements just mentioned. Teachers, schools, and many third-party developers, textbook authors, and publishers are now referencing the NGSS to produce teaching tools. Regularly, science teachers encounter advertisements about a textbook, laboratory module, or a range of other products that said to be *3D-oriented* or *NGSS-ready*.

Unfortunately,, the public draft of the NGSS omitted the extremely important area known as the *nature of science.* This issue was somewhat addressed in the final release, with NOS content goals now included throughout the document as footnotes but ultimately not included as one of the "big three" elements [35] A simple remedy would have been to call the entire plan "*4D science instruction*", but that will not likely come to be the case.

Most agree that the core science ideas (DCIs) generally provide a more reasonable conceptualization of the science content to be taught. However, the cross-cutting concepts (CCCs), while valid and philosophically interesting, have proved to be a challenge for teachers to incorporate into instruction. Finally, the blending of the seemingly shared actions that occur in science and engineering is potentially problematic. Science and engineering are both important disciplines but differ in purpose, history, and underlying philosophical orientation. It would be unfortunate if students reach the conclusion that science and engineering are much the same when they are not and should be discussed with their unique attributes identified [36].

The purpose here is not to provide a critique of the *Next-Generation Science Standards* because the document is a reasonable response to the lack of anything like national science learning goals. The reason for the mention of NGSS is to provide a contemporary reference as a conclusion to this overview of curriculum and science instruction.

At this point, it should be clear that the NGSS is not *a science curriculum* nor are these standards *the science curriculum*. These conclusions would be true even if every school were to adopt the recommendations made in this document. The *NGSS* is a sophisticated standards document that serves as the basis for developing science curricula, and this effort is ongoing in state departments of education, in schools, and in classrooms across the nation. This point is explicitly made in the NGSS itself [33].

The NGSS is an important starting point and one that seems to come from a philosophical melding of academic rationalism and essentialism. However, with the almost infinite numbers of plans—or curricula—that will be developed for translating the content recommendations of NGSS into classroom practice, there will undoubtedly be successes and failures as these goals are enacted in instruction and percolate into classrooms with varying degrees of success, as with all curricula. This conclusion about the orientation of NGSS in the introductory statement that "All students–whether they become technicians in a hospital, workers in a high-tech manufacturing facility, or Ph.D. researchers–must have a solid K-12 science education" [33] and that "The NGSS content is focused on preparing students for college and careers".

The NGSS implication that *the* purpose of science instruction—to educate future scientists and STEM workers—is difficult to accept. All students will become citizens. Therefore, the purpose of science instruction must be to educate and inspire those who pursue careers in science fields while recognizing that all science learners will be consumers of science knowledge and should be empower to act based on their knowledge of science. Everyone can use the processes and skills of science to solve problems; similarly, everyone must be able to understand and judge recommendations made in the name of science, see the strengths and limitations of science, and appreciate the adventure of scientific discovery [37,38]. Furthermore, no set of standards alone could be a complete curriculum in the commonsense notion of a "plan for learning". For instance, the earlier so-called *National Science Education Standards* (NESE) [32,39] relayed a consistent message that students should understand and experience "inquiry" as both a way to learn science and a way that science generates new knowledge. This message is absent in NGSS, which is a curious omission but somewhat understandable since NGSS focuses on *what* to teach rather than *how* (although both ultimately are vital aspects of any curriculum

So, the point here has not been to laud or criticize NGSS but to demonstrate that all plans for science learning must begin with the goals and what students should know and be able to accomplish at the end of their educational experience. But it should be clear that once those goals are defined, the difficult and interesting work must begin to embrace the complexity of the curriculum concept to craft an engaging and effective educational experience for all learners.

6. Conclusions and Implications

The purpose of this article has been to provide a primer to acquaint readers with the complex and fascinating domain of curriculum studies with special reference to science teaching and learning and to recognize the complexity and importance of the various nuances to be considered in the design of curricula to support effective and engaging science learning.

Whatever curricula "course" we ask students to run, whatever content focus is chosen, whatever instructional methods applied, and whatever assessments are applied to gauge student understanding must all blend together and work coherently to produce a high-quality science learning experience. The task of curriculum development is not easy. The core ideas must be relevant and worthy, the curriculum orientation appropriate, and instruction must be predicated on an understanding that no teaching endeavor is perfect or foolproof and that no matter how carefully considered the instruction plan is, what students ultimately take away can be very different from the original intention. Just as important is the realization of what those students take away at more subliminal levels about the nature of what is important, as reflected by the overall curriculum orientation and the challenges indicated by the transmission of knowledge through instruction and activities provided to engage, enlighten, and assess them. Ultimately, our task as science teachers is to leave positive impressions about the value of science in the minds of our students by building curricula on appropriate standards while recognizing that in our classes are future scientists, potential STEM workers, budding poets, and authors. Above all, we must recognize that the next generation of citizens sit before us in each science class, and they deserve the most thoughtful curriculum possible coupled with related and engaging learning experiences. This will only occur when all those involved in the education enterprise recognize the complex nature of and implications provided by knowledge of what a grounding in curriculum studies has to offer.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created.

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

References

1. Leyendecker, R. Curriculum and Learning. In *Encyclopedia of the Sciences of Learning*; Seel, N.N., Ed.; Springer: Berlin/Heidelberg, Germany, 2012.
2. Ellis, A.K. *Exemplars of Curriculum Theory*; Eye on Education: New York, NY, USA, 2004.
3. Taba, H. *Curriculum Development: Theory and Practice*; Harcourt College Publishers: Fort Worth, TX, USA, 1962.
4. Bobbitt, J.F. *The Curriculum*; Houghton Mifflin: Boston, MA, USA, 1918.
5. Tyler, R. *Basic Principles of Curriculum and Instruction*; University of Chicago Press: Chicago, IL, USA, 1949.
6. Eisner, E.W. *The Educational Imagination: On the Design and Evaluation of School Programs*, 3rd ed.; Prentice Hall: Hoboken, NJ, USA, 1994.
7. Schiro, S. *Curriculum Theory: Conflicting Vision and Enduring Concerns*; Sage Publications: Thousand Oaks, CA, USA, 2013.
8. Olivia, P.F.; Gordon, W.R. *Developing the Curriculum*, 8th ed.; Pearson: New York, NY, USA, 2013.
9. Goodson, I. *Studying Curriculum: Cases and Methods*; Teacher's College Press: New York, NY, USA, 1994.
10. Gordon, D.; Meyer, A.; Rose, D. *Universal Design for Learning: Theory and Practice*; CAST Professional Publishing: Sacramento, CA, USA, 2014.
11. Jackson, P.W. *Life in Classrooms*; Holt, Reinhart, and Winston: Austin, TX, USA, 1968.
12. Flinders, D.J.; Noddings, N.; Thornton, S.J. The null curriculum: Its theoretical basis and practical implications. *Curric. Inq.* **1986**, *16*, 33–42. [CrossRef]
13. Gil-Pérez, D.; Guisasola, J.; Moreno, A.; Cachapuz, A.; De Carvalho, A.M.P.; Torregrosa, J.M.; Salinas, J.; Valdés, P.; González, E.; Duch, A.G.; et al. Defending constructivism in science education. *Sci. Educ.* **2002**, *11*, 557–571. [CrossRef]
14. Eisner, E.; Vallance, E. (Eds.) *Conflicting Conceptions of Curriculum*; McCutchan Publishing Company: New York, NY, USA, 1974.
15. Eisner, E. *The Educational Imagination: On the Design and Evaluation of School Programs*, 2nd ed.; McMillan Publishing Company: New York, NY, USA, 1985.
16. Adler, M.J. *The Paideia Proposal: An Educational Manifesto*; Macmillan: New York, NY, USA, 1982.
17. Dewey, J. *How We Think*, Revised ed.; D.C. Heath: Washington, DC, USA, 1933.
18. Freire, P. *Pedagogy of the Oppressed*; Continuum Books: London, UK, 1970.
19. Sizer, T.R. *Horace's Compromise: The Dilemma of the American High School*; Houghton, Mifflin: Boston, MA, USA, 1985.
20. Halvorsen, A.-L.; Nelson, P.M. *Academic Rationalism*; Routledge: Oxfordshire, UK, 2022.
21. Hirsch, E.D. *Cultural Literacy: What Every American Needs to Know*; Vintage Books: Vancouver, WA, USA, 1988.

22. Kohn, A. *Progressive Education: Why It's Hard to Beat, but Also Hard to Find*; Bank Street College of Education: New York, NY, USA, 2008.
23. Beam, A. *A Great Idea at the Time: The Rise, Fall and Curious Afterlife of the Great Books*; Public Affairs Book: New York, NY, USA, 2008.
24. Spencer, H. What knowledge is of most worth? In *Education: Intellectual, Moral, and Physical*; Spencer, H., Ed.; Appleton & Company: Appleton, WI, USA, 1860; pp. 21–96.
25. Apple, M.W. The text and cultural Politics. *Educ. Res.* **1992**, *21*, 4–19. [CrossRef]
26. McComas, W.F. *Nature of Science in Science Instruction: Rationales and Strategies*; Springer: Berlin/Heidelberg, Germany, 2020.
27. Stuckey, M.; Hofstein, A.; Mamlok-Naaman, R.; Eilks, R. The meaning of 'relevance' in science education and its implications for the science curriculum. *Stud. Sci. Educ.* **2013**, *49*, 1–34. [CrossRef]
28. National Education Association (NEA) of the United States. *Report of the Committee of Ten on Secondary School Studies*; U.S. Government Printing Office: Washington, DC, USA, 1894.
29. Department of the Interior Bureau of Education. *Cardinal Principles of Secondary Education*; Report 35; U.S. Government Printing Office: Washington, DC, USA, 1918.
30. Department of the Interior Bureau of Education. *Reorganization Science in the Secondary Schools*; Report 26; U.S. Government Printing Office: Washington, DC, USA, 1920.
31. American Association for Advancement of Science. *Science for All Americans*; Oxford University Press: Oxford, UK, 1990.
32. National Research Council (NRC). *National Science Education Standards*; NRC: Washington, DC, USA, 1996.
33. NGSS Lead States. *Next Generation Science Standards: For States, by States*; The National Academies Press: Washington, DC, USA, 2013.
34. National Research Council (NRC). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*; The National Academies Press: New York, NY, USA, 2012.
35. McComas, W.F.; Nouri, N. The nature of science and the Next Generation Science Standards: Analysis and critique. *J. Sci. Teach. Educ.* **2016**, *27*, 555–576. [CrossRef]
36. McComas, W.F.; Burgin, S.A. Critique of STEM education: Revolution, fad, or instructional imperative? *Sci. Educ.* **2020**, *29*, 805–829. [CrossRef]
37. McComas, W.F. Educating science critics, connoisseurs, and creators: What gifted students should know about how science works. *Gift. Educ. Commun.* **2010**, *41*, 14–17.
38. Rudolph, J.L. *Why We Teach Science (and Why We Should)*; Oxford University Press: Oxford, UK, 2023.
39. National Research Council (NRC). *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*; NRC: Washington, DC, USA, 2000.