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# Decomposing the Complexity of Value: Integration of Digital Transformation of Education with Circular Economy Transition

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**Abstract:** In this article, we highlight the pressing need for integrating the windows of opportunities that digital transformation of education opens up with circular economy education to accelerate the achievements of sustainability outcomes. Circular economy transition, as a multi-scalar process, relates to several contexts, e.g., product, firm, industry-level transformations ranging from designing local socio-technical solutions to greening global value chains, with multi-level policy and business implications for finance, production, distribution, consumption that are fundamentally consequential to everyday life, work and learning. Drawing on theories of neo-capital, multi-level perspective and structuration, and as methodology, using content analysis and qualitative meta-synthesis of scientific publications in digital education for sustainability, we blended our findings into multi-level, multi-domain structuration blueprints, which capture the complexity of value emanating from the interactions among external structures, internal structures of agents, active agencies and outcomes, for circular economy open online education and massive open online course instructional designs. We conclude that learning and creating multiple values to increase social–ecological value, complementarily to economic value, necessitate activating the complexity of value embedded in digital education and circular economy transitions with customizable niches of learning preferences and journeys of individuals and groups, within broader (and evolving) technological, organizational and institutional structures.

**Keywords:** sustainability; circular economy; education; digital transformation of education; open online education; open educational resources; massive open online courses; MOOCs; complexity; multiple value

## 1. Introduction

Transition to a circular economy (CE) requires a systemic change in an educational context and content at all levels and stages of teaching and learning (e.g., curriculum design, professional development, lifelong learning). The most pressing and complex issues of globally connected financing, production, distribution and consumption patterns of our times challenge policymakers, financiers, managers, administrators, educators and learners, as well as entrepreneurs, to ideate about and demonstrate various reliable regenerative solutions in various domains and disciplines (e.g., in sciences, design technologies, information and communication technologies (ICT), business models, finance, economics, environmental sciences, geography; Ellen MacArthur Foundation (2019)) in order to help accelerate linear systems to move beyond the destructive "take–make–waste" model in creative ways

by creating multiple value propositions (for an extended discussion on value propositions, please see Corvellec and Hultman (2014)).

CE transition in this comprehensive scope also relates itself to several sustainable development goals (SDGs), targets and outcomes regarding SDG 6 Clean Water and Sanitation, SDG 7 Affordable and Clean Energy, SDG 8 Decent Work and Economic Growth, SDG 9 Industry, Innovation, Infrastructure, SDG 11 Sustainable Cities and Communities, SDG 12 Sustainable Consumption and Production, SDG 13 Climate Action, SDG 14 Life Below Water, SDG 15 Life on Land (United Nations 2018). However, in this article, we also emphasize the role of education, SDG 4 on Quality Education, especially, the importance of integrating the digital transformation of education with CE education and transition for achieving economic, social and environmental sustainability outcomes through CE open online education (OOE) and CE Massive Open Online Course (MOOC) instructional designs.

It is noted by many scholars that moving towards a CE consists of highly complex tasks and is an integrated action and process among ecological, social, economic, and even political dynamics (Bocken et al. 2017; Blomsma and Brennan 2017; Geissdoerfer et al. 2017; Geng et al. 2012; McDowall et al. 2017; Türkeli et al. 2018). Yet educational processes that are characterized by teacher-centered unidirectional instruction of the current socio-technical regime of education is not a competent fit for teaching and learning about CE, let alone developing tangible sustainable production and consumption solutions that are in line with a CE. The complexity of CE transition which introduces three knowledge constraints about circular economic systems, such as input-stage constraints (e.g., unknowns about the initial state of the linear and circular systems), process-stage constraints (e.g., unknowns about the process between input and output stages which also consists of unknown barriers to a CE system), and output-stage constraints (e.g., the targeted/desired state of an emerging CE system), makes pure theoretical teaching incompetent to capture the complexity of designing and implementing multiple value solutions for a systemic circular economic change while moving away from a linear economy.

While in CE literature, the use and the role of digital technologies are discussed in terms of new circular economic (digital) business models and technologies, CE digital education is overlooked (Türkeli et al. 2018). Moreover, although digital, online technologies, utilization of technology-enhanced learning (TEL) solutions, and the use of emerging digital technologies have started to demonstrate their potentials in transforming education (e.g., systems, modes, methods, activities relating to teaching and learning) (Papadakis 2016). The facilitation of these digital educational technologies for teaching and learning CE, and thus, supporting the acceleration of a transition towards CE, in practice, have also been and remain limited. Their potential has not been used to a large extent, even for education for sustainability, in an integrated manner (Zhan et al. 2015). Although micro-level adoption and application of educational technologies to make traditional teaching practices easier with a focus on utilizing more efficient ways to traditional teaching is an appropriate starting point, education for a CE transition remains underdeveloped. Currently, with a rather limited and closed—instead of open—use of available digital, online educational technologies, technologically advanced and enhanced ways of learning and teaching, potential benefits of digital transformation of education by CE open educational resources (OER), CE MOOCs and CE OOE remain significantly underutilized. In this sense, compared to unidirectional teaching, non-unidirectional teaching, interactive instruction (e.g., problem, peer, project, consultancy-based learning) and OOE initiatives that incorporate interactive instruction in a massive setting (e.g., connectivist massive open online courses (cMOOCs) concentrating on knowledge co-construction, contrary to xMOOCs) are more promising in being able to create multiple value solutions and capture the dynamism of interactive learning processes, which are inherent to the interdisciplinary characteristics of real-world sustainability issues and solutions, thus, education (Wals and Jickling 2002; Steiner and Posch 2006). Yet, there are no studies in particular, focusing on the educational and instructional design needs of such OER, OOE and MOOCs for CE teaching and learning.

Supported by the advance of information and communication technologies (ICTs), as well as networking technologies; e-learning, OOE, TEL, OER and MOOCs operate on virtual learning environments (VLEs) and networks benefitting from physical capital such as the availability of technological infrastructures, networking and incumbent technologies in use and emerging technologies in development. While digital technologies enable economic growth as they are being applied within a wide range of sectors and transform many organizations at an increasingly fast pace (Orlikowski 2000), digital transformation of education globally is still a socio-technical niche. Moreover, further educational informatization, networking and emerging education technologies day by day become inevitable (e.g., networked OERs, MOOCs, and VLEs). Digital technologies, as a source and/or enabler of innovation, continue changing and cumulatively transforming the form and functioning of the organization of education, educational organization, and thus, education itself. The emerging agreement or consensus on the positive effects of digitization of (and within) education actually benefits from further enabling and rapid transfer of (big) data in various formats (text, image, video, sound), information and (codified) knowledge. Also, emerging digital technologies have the potential to make education more flexible, as they allow for learning anywhere and anytime (e.g., through forms of OOE, seamless learning). Indirectly, they, therefore, also help to increase the possibility of access to education. These, among other technological possibilities, accelerate the use of technology and especially, newly emerging ICTs in education. In its basic sense, CE OOE can present several starting attributes of the new pedagogical models via integrating gamification, as well as high-impact short videos, infographics and OER in the presentation of CE content. These novelties are supporting elements while integrating a multidisciplinary team around several CE-related issues and tasks. Activities are then defined by collaboration, communication and commitment of the educators and learners and enabled, monitored and/or evaluated processes by emerging technologies. While all these socio-technical developments go well together with the idea of a knowledge society, including an attention to lifelong learning in a context, they also demand continual updating of human knowledge and skills, as well as continuous research and development of new educational technologies. The process of designing and implementing such open, collaborative and multidisciplinary infrastructures and technologies are prone to many challenges, yet carry progressive potentials (Schophuizen et al. 2018).

Considering the systems thinking at its core and the complexity of CE transition as a systemic transformation, among others, the theory of online collaborative learning (OCL) provides us a correspondingly multifaceted basis for operationalizing complex teaching and learning in transformative ways (Scardamalia and Bereiter 2006). OCL, unlike the classical behaviorist and cognitivist focus on instructions for replication of facts, emphasizes the process of building knowledge (Scardamalia and Bereiter 2006). In this respect, it also differs from constructivist learning by locating active learning within a process of social and conceptual development based on knowledge discourse (Harasim 2017). Online and technology-enhanced interactions then enable an active learning space via two major actors, the learner and the teacher, and their (technology-enhanced) interactions in learning, and with content matter (Anderson 2004). This process and interaction-based approach fits with teaching and learning CE and to build CE solutions since a community of inquiry, with synchronous and asynchronous activities (e.g., video lectures, podcasts, conferencing, chats, or virtual global interactions), if designed well, constitutes several technology-enhanced online learning environments which support rich interactions for learning and building novel knowledge content, and developing social skills through development of personal relationships among participants, which eventually lead to online collaborative co-construction of knowledge within a community of inquiry (Gunawardena et al. 2006). For education in ill-structured knowledge domains (e.g., education for and on a CE), an instructional design in which active learning and knowledge building can be combined, and a community of inquiry in which learner support, mentoring and knowledge innovation can be provided, are well suited due to the fact that this setting allows for perspective transformations as an end goal, which occurs (and required) at both the individual and community.

Yet, the question remains which specific modes, methods and activities are most used and found suitable for teaching and learning for a CE transition. As we indicated above, while the use and the role of digital technologies in education have received increasing attention from scholars, and an emerging attention for education for sustainability, they have still yet to emerge for CE education (Türkeli et al. 2018). Therefore, the current challenge we address in this article is to investigate and discuss the ways (modes, methods and activities), in short, the constituents, which are, in principle, deemed and discussed to be most effective, in creating and distributing quality TEL solutions for accelerating the transition towards a CE.

Considering the aforementioned complexities of both research fields, the main research question of this article is: What are the ways in which the constituents of structuration dynamics among various agents, technologies and structures contribute to the extents to which the digital transformation of education has been utilized in education for sustainability, and how they relate to and can be further utilized for circular economy education to accelerate a transition towards a circular economy?

To answer our research question and to position our contribution in the current state of the research fields and literature in CE and OOE, the empirical evidence needs to be processed and appraised with respect to several theoretical and conceptual lenses. While decomposing the complexity of value emanating from integration of digital education with CE transition, we draw on theories of neo-capital, multi-level perspective and structuration theory (Section 2.1). As methodology, we use content analysis and qualitative meta-synthesis of scientific publications in the field of digital education for sustainability, in particular, the scientific publications (n = 36) concentrating on OOE and MOOCs in the field of education for sustainability (for details on data source, data and methodology, please refer to Sections 2.2 and 2.3). We present our findings in Section 3, which are further discussed in Section 4. We provide our conclusion, and future research directions in Section 5.

## 2. Materials and Methods

### *2.1. Materials: Theoretical Lenses*

We draw upon three theoretical lenses (theories of neo-capital (Section 2.1.1), multi-level perspective (Section 2.1.2) and structuration theory (Section 2.1.3)) to be able to decompose the complexity of value (theories of neo-capital) into multi-level (multi-level perspective) and multi-domain (structuration theory) into interrelating analytical categories for the integration of digital transformation of education with CE education, and thus a CE transition. By taking various varieties of capital (value) formation at individual and group level, varieties of agents, emerging as well as broader and evolving technological, organizational and institutional structures into account, we present our multi-level and multi-domain findings in tables, discuss them, and build a multi-level and multi-domain thematic synthesis for CE OOE and CE MOOC designs. In the following subsections, each theoretical lens with their conceptual apparatus is positioned and substantiated with respect to our research question, research goal, presentation of the results, and follow-up discussions, conclusions and future research directions around CE OOE and CE MOOC instructional designs.

#### 2.1.1. Neo-Capital Theories: The Necessity of Varieties of Capital Formation by Digital Education for CE Teaching and Learning

Due to their inherent multi-dimensional complexities, digital transformation of education (Anderson 2004; Scardamalia and Bereiter 2006; Gunawardena et al. 2006; Cano 2015; Harasim 2017; Schophuizen et al. 2018) and CE transition (Geng et al. 2012; Bocken et al. 2017; Blomsma and Brennan 2017; Geissdoerfer et al. 2017; McDowall et al. 2017; Türkeli et al. 2018), and especially, a synergetic integration of them is not a straightforward endeavor. Taking different material interests and discrete ideas of various agents in teaching and learning CE into account, this integration calls for and demands varieties of capital formation, and capital-intensive efforts from a multitude of agents (e.g., policymakers, administrators, educators, entrepreneurs, intrapreneurs), institutions and

organizations (e.g., public, private and social sector organizations). The varieties of capital formation exceeds (co-)investing in financial and/or physical capital (e.g., funds, subsidies, infrastructures and technologies) and necessitates (co-)developing relevant human capital (e.g., the skills, knowledge), social capital (e.g., access and use of connected/networked resources such as data, information, tools, courses), cultural capital (e.g., norms, mindset, attitudinal trainings) in designing, improving and implementing novel CE VLEs with a view on novel natural capital formation (e.g., novel waste-to-resource and energy transformations for bio-ingredients and technical materials) (Lin 2017; Stahel 2019; Caruso and Gattone 2019; D'Adamo 2018). Systems thinking being at its creative core, such circular economic system-wide interactions among agents and structures necessitate creating and sustaining aforementioned varieties of (neo-)capital formations and economic, societal, environmental returns via extending towards experiential learning activities (e.g., see Kolb 2014), interdisciplinary approaches and tasks, multi- and transdisciplinary inquires, projects, collaborations, demonstrations and commercialization activities for a CE transition. Classical, traditional teaching, learning philosophies, modes, methods and activities, in short, the constituents of the current socio-technical regime of education, are challenged daily, even in terms of being able to deliver reliable regenerative sustainability solutions for an integrated economic, societal, and ecological survival, let alone, welfare (UNESCO 2015). Thus, in this article, as levels to varieties of capital formation, we concentrate on socio-technical transitions and transition management literature (Geels 2004; Geels and Schot 2007; Kemp 2011; Geels 2011), in particular, on the multi-level perspective (MLP) which assesses socio-technical transitions and change by focusing on the interrelationship of three analytical levels:

(1) Socio-technical niche innovations at micro level (e.g., related agents (educators, learners, entrepreneurs ... ); technologies (CE OER, CE MOOCs, emerging education technologies ... ); structures (e.g., classroom, course, university ... )),
(2) Socio-technical regimes at meso level (e.g., related agents (policy makers, administrators, businesses ... ); technologies (e.g., CE OOE, incumbent education technologies ... ); structures (e.g., higher education system, public education policies, labour market conditions ... )),
(3) Socio-technical landscapes at macro level (e.g., related agents (politicians, policymakers, businesses ... ); technologies (e.g., next-generation OOE technologies, technology visions ... ); structures (e.g., international organizations, OOE and/or CE policy visions ... )).

The background and relevance of MLP are provided in the following subsection.

#### 2.1.2. Multi-Level Perspective: Niche, Regime and Landscape-Level Transitions for Digital Education for CE Teaching and Learning

MLP, as an analytical tool, conceptualizes overall dynamic patterns in a socio-technical transition, the complexity of change, and resistance to change at the socio-technical regime level (Geels 2011). Socio-technical transitions in this sense are the fundamental shifts in the socio-technical systems (Geels 2004; Geels and Schot 2007; Kemp 2011). Such transitions necessitate changes in material, technological, organizational, institutional, political, economic and socio-cultural dimensions (Markard et al. 2012). Change is both co-initiated from bottom-up via socio-technical niche innovations (micro, e.g., CE OOE, CE MOOCs) (which form the micro-level, are incubated from regulatory and market pressures, protected from the rules of the dominant socio-technical regime regarding varieties of capital formation and continuity, or not, or not yet) and socio-technical landscape developments (macro, e.g., OOE policies and visions, see European Commission (2013), CE policies and visions, and McDowall et al. (2017)) which exert pressure on socio-technical regimes (meso). A socio-technical regime in this sense is an institutionalized set of rules that organizes the actions of agent groups who, in turn, reproduce or transform the constituents of a socio-technical system (Geels 2004, 2011). The macro level, the socio-technical landscape, is the broader environment that influences both the socio-technical regime and niche innovations. These landscape factors are beyond the direct control of agents (Geels 2004, 2011; Geels and Schot 2007). In this regard, CE education, digital transformation

of education, digital education for CE, and CE transition are all socio-technical niche areas in which the integration of digital transformation of education with teaching and learning for a CE transition would challenge the status quo—the socio-technical regime of education. Particularly, what the current socio-technical regime of the education system, as a socio-technical system, offers for sustainability, and in particular, CE education, are institutionalized set of rules and structures that influence the actions of agents and agent groups, who in turn, reproduce or transform the constituents of the current education socio-technical system. Thus, we utilize structuration theory to reveal such multi-level and multi-domain structuration dynamics over and on the constituents of change. We elaborate on our findings (Section 3) in detail in Section 4. The next subsection provides the quadripartite nature of structuration throughout mutual shaping processes between agency and structure, which is utilized in framing and revealing the multi-level and multi-domain structuration dynamics over and on the constituents of change towards CE OOE.

#### 2.1.3. Quadripartite Nature of Structuration: Mutual Shaping of Agency and Structure through the Constituents of Change towards CE OOE

Giddens (1984) proposed the concept of structuration to capture and explain the mutual shaping and interactions between agents and structures. In his constructive critique, Stones (2005) pointed out the quadripartite nature of structuration (Figure 1):

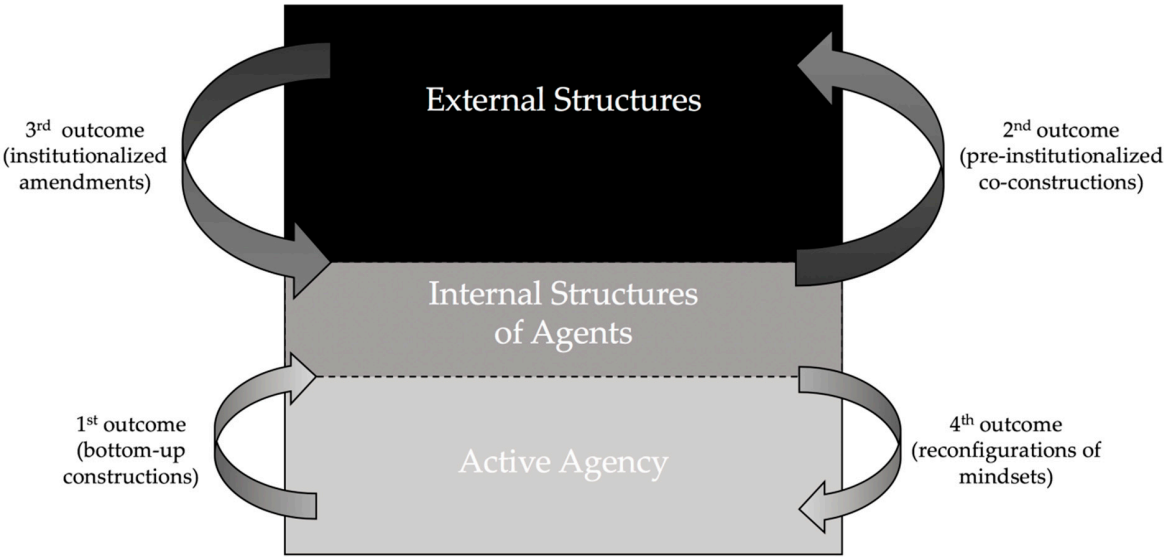


**Figure 1.** Quadripartite nature of structuration. Source: Authors' work.

*External structures of structure (autonomous from the agents in focus):* External structures form the conditions of actions for agents. They are top-down or else hierarchical external structures that come with institutionalized set of rules, norms and values, reflected in (e.g., OOE and/or CE) policies, programmes, plans, politico-administrative, organizational strategies, set-in rules and allocated resources. Structures have a dominant institutionalized design encouraging and/or challenging the continuity and/or coherence of actions of agents via institutionalized amendments (towards transformation) or institutional repudiation (reproduction) (Figure 1).

*Internal structures of agents:* Field corresponds to conjuncturally specific knowledge of external structures within position–practice relations (e.g., action-informing assessment of relational norms, power relations, action-informing conclusions of relevant (and/or networked) agents-in-context) and general-dispositions (Stones 2005), or following Bourdieu (1972), habitus, (e.g., generalized world-views, frames, cultural schemas, classifications, associative chains and connotations of discourse methodologies for adapting generalized knowledge to a range of particular practices in particular locations in space and time). These internal structures (internal structures within each agent and community of agents)

are based on the evidence of positively or negatively institutionalized perceptions and perspectives (normative and cognitive rules and resources) of professional agents (e.g., policymakers, administrators, entrepreneurs, educators, learners about OOE and/or CE), of professional bodies (e.g., legislative, executive, accreditation, standardization bodies) and/or networks of such agents and bodies (Figure 1).

*Active agency:* Active agency includes the ways the agents, either routinely, pre-reflectively or strategically and/or critically draw upon their aforementioned internal structures, and take action (Stones 2005) (Figure 1).

*Outcomes:* Outcomes are events through which external structures and internal structures of agents evolve (Stones 2005). Outcomes are bottom-up, constructed, pre-institutionalized amendments, proposals for gradual change in external and internal structures, if institutionalized and aggregated, they are the constituents of an accumulated change, top-down (e.g., novel understanding/mindsets, policies and visions, strategies for creating incentives which include novel rationales, rules and resources for OOE and CE) (Figure 1).

### 2.2. Materials: Data Source and Data

Three main data sources for detecting peer-reviewed, high-quality scholarly publications of scientific and international relevance are Web of Science (WoS) of Thomson Reuters, Scopus of Elsevier, and Google Scholar of Google Inc. (Türkeli et al. 2018). We chose using the WoS scientific citation indexing service due to the facts that WoS has the most strict quality criteria for selection and inclusion of scientific publications in its indexing services as a trusted and authoritative source of bibliometric data and information for peer-reviewed global research knowledge across disciplines, for a comparison of these three data sources, please refer to Falagas et al. (2008), Harzing and Alakangas (2016) and Tennant et al. (2019). WoS provides a curated collection of over 21,177 peer-reviewed, high-quality scholarly journals and over 74 million records published worldwide, including open access journals in over 250 science, social sciences, and humanities disciplines (Tennant et al. 2019). To be able to capture the broadest range of peer-reviewed scientific activity and all international publications of scientific relevance in the field of education for sustainability, our unit of analysis is a scientific publication, which can be an article, a proceedings paper, book review, editorial material, letter, meeting abstract, review, in all languages available, and English translations of abstracts. Our WoS Core Collection query with the search term "education for sustainability", which is an umbrella term for all forms of education that promote rethinking of educational programmes (contents and methods) and systems for sustainable societies, returned 386 international publications of scientific relevance. In order to detect the relevant subset for the digital transformation of education within these high-quality scientific publications around the world, this dataset is then refined by a combinatorial keyword query set such as: "digital education", "online", "online education", "open education", "open online education", "massive open online course", "MOOC". In total, we retrieved 36 scientific publications by 29 March 2019 with these strict quality and query criteria (please refer to the supplementary file for an extensive list of publications).

### 2.3. Method: Qualitative Metasynthesis

We applied qualitative meta-synthesis on these 36 scientific publications. Qualitative metasynthesis is a research approach to analyze data across scientific publications. The intention is to reach a coherent state of structured information which enables researchers to classify findings of earlier scientific studies, as latent indicators, as constituents and their building blocks, of a latent outcome, while interactions of which, manifest or do not manifest a hypothesized meta-model. In this respect, qualitative metasynthesis as an interpretive analytical technique relies on content analysis and uses the findings reported in previous scientific publications, as constituents and their building blocks for gaining a deeper understanding of particular phenomena, and to build up a new thematic synthesis (Finfgeld-Connett 2014).

We followed a five-step qualitative metasynthesis process (Erwin et al. 2011) to reach our research goal by providing answers to our research question. These steps are:

1. Framing (WoS Core Collection query: "education for sustainability") (Section 2.2),
2. Searching (Refinement of the WoS results (n = 386 scientific publications) with our keywords of interests "digital education", "online", "online education", "open education", "open online education", "massive open online courses", "MOOC", as the query is often refined and reduced in scope over the course of undertaking the qualitative meta-synthesis (please refer to Walsh and Downe 2005) (Section 2.2),
3. Selecting and appraising the relevant scientific publications (manual check of the relevance and reading of remaining 36 scientific publications with respect to the sample quality criteria (please refer to Atkins et al. 2008)),
4. Summarizing and synthesizing (gathering findings, constituents and their building blocks from resulting scientific publications either falling in or outside the theoretical lenses used in this article (Section 2.1)),
5. Combining and reporting the evidence by identifying the key themes/concepts in each study via lines-of-argument synthesis, while developing a general interpretation of the phenomena of interest (e.g., CE OOE, CE MOOC instructional designs) that is grounded in the themes/concepts of each study. As a result, we generate analytical themes that emerge from, and step beyond the descriptive themes as a new thematic synthesis (Thomas and Harden 2008). This last step constitutes the building blocks (Tables in Section 3) for our research, and addresses our research question.

The overall process synthesizes the constituents of existing findings of earlier scientific publications to construct a greater meaning through an interpretative process, discussions and concluding remarks which intellectualize an abstract phenomenon into a tangible proposal (Sections 3–5). In this regard, this article exceeds the category of a systemic literature review, and incorporates original research article elements in its endeavor, and allows other researchers to replicate and build on these published results.

## 3. Results

### *3.1. Structuration Constituents among Classical Capital and Neo-Capital*

We start our analysis by presenting the findings relating to the structuration constituents among classical capital and neo-capital.

Our findings indicate that a close alignment of the course topics and subject matters with learners' personal ideas and material interests, by supplying and/or offering them a set of attractive value propositions regarding the demanded time and financial commitments compared to formal education or training (Grealy 2015; Leire et al. 2016; Howarth et al. 2016; Meinert et al. 2018) is among the most important determinants for a competent OOE and/or MOOC instructional design in digital education for sustainability. However, exceeding the time and financial commitments, our findings (n: 22) justify that these value propositions extend to various structuration dynamics over and on the constituents relating to both classical capital and neo-capital (Table 1). Our findings cluster around classical capital needs (e.g., money/time, physical, technological capital (five findings)) and neo-capital formation supply by educators and demand needs by learners (human capital (seven findings), social capital (six findings), and cultural capital (four findings)). We further discuss these results in Section 4.

**Table 1.** Structuration constituents among classical capital and neo-capital.

| Varieties of Capital Needs for CE OOE and/or CE MOOCs | Constituents | Source in EfS |
|---|---|---|
| Human Capital Development **Focus: Internal structures of individual agents and active agency of individual agents (seven findings)** | Autonomous study and the sharing of global education resources | (Li and Zhou 2018) |
| | Autonomy in, mastery of and purpose of using the tools (e.g., skill-building) via MOOCs | (Fini 2009) |
| | Possibility of developing personal knowledge management skills with options for passive, time-saving mailing lists and interactive, time-consuming discussions forums | (Fini 2009) |
| | Setting up a right balance between theoretical and practical examples by ensuring satisfaction with case studies | (Aksela et al. 2016) |
| | Changing and improving personal perceptions of sustainability | (Aksela et al. 2016) |
| | Improving the understanding of complex systems (e.g., interrelatedness of CE transitions and Sustainable Development Goals) | (Aksela et al. 2016) |
| | Providing other support (e.g., technical and learning strategies for learners) | (Aksela et al. 2016; Cano 2015) |
| Social Capital Development **Focus: Internal structures of groups of agents and active agency of groups of agents (six findings)** | The support for interaction, the integration of a multidisciplinary team around an issue | (Griselda Argueta-Velazquez and Ramirez-Montoya 2017; Ramirez-Montoya 2018) |
| | Communication with other learners and getting feedback from them, as well as from teachers and tutors | (Aksela et al. 2016; Mishra et al. 2017) |
| | Possibility of establishing interdisciplinary MOOC study groups | (Chen and Chen 2015) |
| | Making supporting tools available to convene a conversation about, e.g., circular economy, sustainable development, sustainability, and climate change | (Burch and Harris 2014) |
| | Maintaining an active participant discussion even in the case of the removal of educator facilitation | (Sneddon et al. 2018; Aksela et al. 2016) |
| | Connectivist–heutagogical (social and cultural individual) learning using Garrison's Community of Inquiry Model, e.g., (cognitive, social and teaching presence for educational experiences) | (Kaul et al. 2018) |
| Cultural Capital Development **Focus: Internal structures of agents and active agency of agents and groups of agents (four findings)** | Supporting and logging the processes of negotiation, cultural articulation, and identity formation which occur through e-conversations and which can include large populations from different backgrounds | (Burch and Harris 2014) |
| | Activating the implications of these e-conversations for the broader, e.g., climate change, discourse for the definition of the problem, attributions of responsibilities, and the development of solution offers, options or solutions | (Burch and Harris 2014) |
| | Improving the understanding of the complex systems (e.g., interrelatedness of, e.g., CE transitions and SDGs) in communities | (Aksela et al. 2016) |
| | Changing and improving perceptions of sustainability in communities | (Aksela et al. 2016) |

**Table 1.** *Cont.*

| Varieties of Capital Needs for CE OOE and/or CE MOOCs | Constituents | Source in EfS |
|---|---|---|
| Physical/Technological Capital Development **Focus: External Structures (Organizational, Technological, Institutional) (five findings)** | Presentation of educational content through high-impact short videos, info-graphics and OER | (Griselda Argueta-Velazquez and Ramirez-Montoya 2017; Ramirez-Montoya 2018) |
| | Using a pedagogical model that integrates gamification into teaching and learning | (Griselda Argueta-Velazquez and Ramirez-Montoya 2017; Ramirez-Montoya 2018) |
| | Refining the socio-technical issues of computer-supported collaborative learning | (Wise and Schwarz 2017) |
| | Providing mobile MOOCs, the mobile-based programs, apps, which enable teachers to use the program without space and time constraints or providing learners on the move a seamless accessibility to content, both of which are deemed as key enabling factors in post-qualification and continuing professional development courses for busy practitioners who work full-time. | (Meinert et al. 2018; Grealy 2015) |
| | Technological tailoring for particular learning needs of solicitors and trainees who have time-demanding careers, and who would benefit from being offered flexible options in terms of engaging with their learning processes, supported by digital notifications | (Meinert et al. 2018) |

Source: Authors' compilation, EfS: Education for Sustainability.

### 3.2. *Structuration Constituents among Incumbent Technologies and Emerging Technologies*

Following the synthesized presentation of structuration dynamics over and on classical capital and neo-capital formation needs for CE OOE and/or CE MOOC instructional designs (Table 1), we present the results for the structuration constituents among incumbent educational technologies and emerging technologies. We have identified 11 structuration constituents among emerging technologies and incumbent technologies that are focusing on various agents (learners, educators, managers, entrepreneurs, technologies and their interactions) (Table 2). While learning analytics using neural networks, G-Rubric, semantic analysis models focus on learners, SMART Teaching 3.0 and Creative Commons (CC) licenses for teaching material development focus on educators. These findings indicate the relevance of emerging technologies for both educators and learners for a CE OOE context and CE MOOC designs. Moreover, the focus also extends to improving technologies themselves and the interactions between technologies and human agents (e.g., Fedora Commons Repository, FedX API, Moodle and Elgg integration).

**Table 2.** Structuration constituents among incumbent technologies and emerging technologies.

| Emerging Technologies | Agents in Focus | Constituents | Source in EfS |
|---|---|---|---|
| Learning Analytics using Neural Networks | Learners | Static versus Dynamic: A hybrid neural network (NN) model which integrates a Convolutional Neural Networks (CNN) and with Gated Recurrent Unit (GRU)-based Recurrent Neural Networks (RNN) in an effort to dynamically detect individual learning features | (Li and Zhou 2018) |
| G-Rubric | Learners | Assessment tech versus semantic assessment technologies, via using latent semantic analysis (LSA) as an automatic assessment tool | (Santamaría Lancho et al. 2018) |
| Semantic Analysis Models | Learners | Transition from impassive analysis models to a semantic analysis model (SMA) to track the emotional tendencies of learners | (Wang et al. 2018) |

**Table 2.** *Cont.*

| Emerging Technologies | Agents in Focus | Constituents | Source in EfS |
|---|---|---|---|
| SMART Teaching 3.0 | Educators | Sharing educational experiences of in-service teachers using the community of inquiry (CoI) framework, providing community-centered professional support for in-service teachers | (Jin-Hwa and Kim 2016; Kaul et al. 2018) |
| Creative Commons Licenses (CC) | Educators (Licensing) | A paradigm shift from top-down, institution-centered teacher training to bottom-up, learner-centered professional development in teacher education with reuse and redistribution among instructors due to the privacy of the contents created. Emerging issue: intellectual property right protection of networked teaching and open educational resources | (Jin-Hwa and Kim 2016 ) |
| Fedora Commons Repository | Technology (Managers, entrepreneurs) | Repository for an OER back-end to manage OER resources | (Chunwijitra et al. 2016) |
| Moodle and Elgg | Technology Managers, Entrepreneurs (Interactions) | MOOCs which imply an integration of virtual learning environments | (Coelho et al. 2015) |
| FedX API | Technology Managers, Entrepreneurs (Interactions) | An API including a packet encapsulation and a data transmission module which organizes open educational resources between systems. Resources can be exchanged among the third-party OER repositories by an OAI-PMH harvesting tool, situating an OER-MOOC interaction | (Chunwijitra et al. 2016) |
| OER-MOOC Interaction | Learners, Technology, Educators, Entrepreneurs (Interactions) | Development of online educational resource sharing and analyzing these sharing activities through a comparative analysis of foreign open classes and domestic resource sharing courses, sharing of resources and communication between teachers and students; Open Educational Resources, Open Courses, Open Communities and Open Schooling | (Cai et al. 2016; Okada and Sherborne 2018) |
| WeChat Public Platform Integration | Learners, Technology, Educators (Interactions) | Improving learning efficiency via positive interactions between teachers and students in a network-based teaching mode using the WeChat public platform to build a virtual learning environment that comes with standards for public educational resources | (Cai et al. 2016) |
| Digital Learning Strategies | Learners, Technology, Educators, Entrepreneurs (Interactions) | Situating technology-enhanced learning strategies: such as content curators, information filters (proposing systems), learning algorithms for intelligent and self-adaptive tutorial systems as novel digital learning strategies | (Cano 2015) |

Source: Authors' compilation, EfS: Education for Sustainability.

These emerging interactions and connectedness features for learners, educators, managers, entrepreneurs and technologies (e.g., OER-MOOCs interactions, public platform integrations, situating digital learning strategies via TEL strategies) are relevant for a CE OOE context and CE MOOCs instructional design due to the multiplicity of domains (e.g., engineering, design, economics, business perspectives) and systems thinking involved in CE (Ellen MacArthur Foundation 2018). We discuss these results in Section 4.

### *3.3. Structuration Constituents between Agents and Structures*

Following the structuration constituents among traditional, incumbent technologies and novelties that emerging technologies promise (Table 2), we present multi-level and multi-domain structuration dynamics between (varieties of) agents and (varieties of) structures (Tables 3 and 4). Our findings justify

the existence and the importance of varieties of structures (e.g., structure of technological platforms, learning management systems, technological areas, course structure, evaluation structure, societal structure), internal structures of agents (e.g., relevance for agents, learning preferences, motivations of learners), active agency situations (e.g., autonomous study, embedding innovations in education, active involvement), and outcomes (e.g., awards for participation, sharing resources, developing digital scientific literacy). Due to the inflation in the number of potential policy, business, environmental and social issue niches, interventions and innovation entry points for a CE, niche socio-technical CE solutions require such contextualized, personalized, customizable, flexible and self-directed ways of learning with authentic learning tasks and assignments (Table 3). In a CE OOE context and for CE MOOCs instructional designs, these dynamics between actors and structures should be taken into account to activate agency, and improvements, thus, the evolution of broader structures involved in CE OOE and CE MOOC instructional designs (Table 4). We provide a synthesis of these micro-level, meso-level (Table 3) and, broader and evolving macro-level and macro domain constituents in Table 4 with respect to various agents and structures involved. We discuss these results in Section 4.

**Table 3.** Structuration constituents among agents and structures.

| External Structures | Internal Structure of Agents | Active Agency | Outcomes | Source in EfS |
|---|---|---|---|---|
| **Major MOOC platforms, Learning Management Systems (Technological structures)** | Individual learning preferences | Autonomous study (Learners) | Sharing of global education resources, the MOOC platforms offering specific learning paths, relevant contents individually according to learners' identified learning features | (Li and Zhou 2018) |
| **Societal structure relevance** | Vocational relevance | Individual relevance (Learners) | Autonomy, Competence/Mastery, Purpose | (Aksela et al. 2016) |
| **Course structure** | Motivation by peers which increases continuity of interactions | Individual participation (Learners) | Improvement of online learning group processes | (Mayende et al. 2017; Gil et al. 2018) |
| **Mandatory marks (Evaluation structure)** | Virtual handholding | Active involvement (Learners) | Awards for participation | (Grealy 2015) |
| **The areas of technology** | Academic cultural practices | Embedding innovations (Educators) | Digital scientific literacy | (Fitzgerald et al. 2015) |

Source: Author's Compilation, EfS: Education for Sustainability.

### *3.4. Structuration Constituents among Broader Set of Agents and Structures with a View on Technologies*

At the global socio-technical landscape development level, the United Nations Decade of Education for Sustainable Development (DESD) calls for a more coherent, critical and multi-level analysis of learning environments in relation to creating seven competences (e.g., embracing diversity and interdisciplinarity, foresighted thinking, interpersonal competence, normative competence and systems thinking competence) (Mochizuki and Fadeeva 2010).

Mutual shaping of competences among each individual and groups, and such learning environment systems (Mochizuki and Fadeeva 2010), and also mutual shaping of competencies among each individual and groups, and global citizenship and sustainable development education based on competencies (Adomssent et al. 2007; Mannion et al. 2011) open up an investigation, analysis and discussion arena with an initial need of revealing and presenting further structuration constituents and dynamics among a broader set of (varieties of) agents and structures with a view on (varieties of) technologies (Giddens 1984; Orlikowski 2000; Stones 2005) (Table 4).

In this respect, the integration of digital transformation of education with a CE education, thus with an aim of accelerating CE transition, would systemically challenge the current socio-technical regime meso level, socio-technical systems of (CE) education, related organizations, policies, markets, technologies, and agents.

**Table 4.** Structuration dynamics among actors, structures and technologies.

| Partite | Structuration Constituents with Respect to Technologies | Actors | Structures |
|---|---|---|---|
| **External Structures of Structure (three themes)** | (1) Politico-administrative public system, policy and programming (rules and resources) on CE, OOE, TEL, OER, SGs, MOOCs<br>(2) Educational and technical administrative implementation plans and strategies (rules and resources) on CE, OOE, TEL, OER, SGs, MOOCs<br>(3) Dominant curricular, instructional, and technological design structures and trajectories of CE, OOE, TEL, OER, SGs, MOOCs | Policymakers, Ministerial bureaucrats, CE and OOE experts<br>Educational and Technical administrators, Educational technology developers, Educators, Learners, CE agents, Community organizers | Politico-administrative structure, Organizational technical structure, Techno-economic structure, Socio-economic structure |
| **Internal Structures of Agents (two themes)** | (1) Existence of and evidence for positively institutionalized perceptions (cognitive rules and resources) for CE, OOE, TEL, OER, SGs, MOOCs by professional agents (policymakers, ministerial bureaucrats, educational and technical administrators, educational technology developers, entrepreneurs, community organizers, teachers, learners);<br>(2) Existence and evidence for accreditation, standardization bodies (and/or networks of such bodies and agents) relevant for OOE, TEL, OER, SGs, MOOCs in the context of CE education | *Additional to the list above:*<br>Students, Learners, Teachers | *Additional to the list above:*<br>Labor market structure |
| **Active Agency (two themes)** | (1) Existence of and evidence for acting institutional, educational and curriculum architects, CE and OOE entrepreneurs and intrapreneurs at the boundary of education and technology development systems who facilitate educational and technological change/transformation via or within OOE, TEL, OER, SGs, MOOCs in the context of CE<br>(2) Existence of and evidence for involvement of users in OOE, TEL, OER, SGs, MOOCs; in teaching (teachers, instructors, educators) and in learning (students, learners, professionals) MOOCs in the context of CE | *Additional to the list above:*<br>Entrepreneurial OOE and CE agents in public, private and social sectors | *Additional to the list above:*<br>Labor market structure |
| **Outcomes (two themes)** | *Events* that relate to implementation of strategies (rules) for creating incentives (resources) and identification of best educational (technology) practices e.g., in:<br>(1) Science, Technology, Engineering, Mathematics (STEM) subjects,<br>(2) Broader disciplines (e.g., social sciences, design technology, ICT, business, finance, economics, environmental sciences, geography) for CE solutions by introducing OOE, TEL, OER, SGs, MOOCs | Agents and technologies with new rules, resources from organizations<br>(of structures involved)<br>New mindsets<br>(for agents involved)<br>New educational tools and technologies | Geographically, historically institutionalized chains/trajectories of survived/fittest outcomes, and events |

Source: Authors' Compilation, SGs: Serious Games.

We provide a synthesis of these broader and evolving multi-level and multi-domain structuration constituents in Table 4 with respect to a broader set of agents and structures with a view on varieties of technologies. We discuss these results in Section 4.

## 4. Discussion

### 4.1. Multiple Value Formation through CE OOE and CE MOOC Instructional Designs

According to our findings, high rates of registration to online courses and high rates of completion require ownership from the learner side. Yet, we argue that in order to activate an ownership at the learners' side, multi-dimensional (individual and societal) value relevance in terms of varieties of neo-capital formation is needed. Necessities of human capital formation (e.g., relevant knowledge, skills) and social capital formation (e.g., interactions via informal learning, harnessing the collective intelligence of the learners, the interactions among other users such as former learners, future prospective learners, business professionals, universities, and organizations) should be taken into account and be provided to learners in a CE OOE context and CE MOOC instructional designs (Table 1). These enhancements help pave the way towards cultural capital formation (e.g., shift in mindsets, creating and adopting (new) ideas, establishing (new) interests). Elaboration on and implementation of customized teaching for learners from diverse backgrounds, different learning preferences, different language barriers, space and time constraints, ICT skills and at different stages of their learning (e.g., adolescents' learning, informal learners, lifelong learning adults) also require various different CE MOOC instructional designs that should come with various portfolios for varieties of neo-capital based multiple value formations possibilities and proposals such as a supporting form to and function of choice-based learning. In this respect, in Table 1, following our 22 main varieties of capital and neo-capital structuration constituents, we argue that, due to several issue niches that are spread throughout the multi-scalar technical material loops and bio-material loops of a CE in different sectors at different levels of a CE system, CE OOE and/or designing CE MOOCs as socio-technical innovation niches require proposing multiple value formation possibilities to many different issue agents (learners). Following our findings in Table 1, it is important to re-emphasize that educational enrolment through the use of technological tools and access to OERs should ensure that customizable varieties and portfolios of neo-capital based value formation possibilities are supplied by the educators, to meet the requirements of the learners. If pedagogical and evaluative treatment of the courses with acceptable educational parameters (e.g., quality versus massiveness) and the components of innovative attributes (e.g., integration of OER and gamification) are also in the educational and instructional designs of CE OOE and/or CE MOOC, these can further support the formation of customized learning portfolios which, in turn, by tapping onto the renewed interests and ideas of learners as agents, can help further shape the structural expansions of the organization of resources, tools, courses, and technologies involved in teaching and learning CE.

### 4.2. Emerging Educational Tools and Technologies for CE OOE and CE MOOC Instructional Designs

CE OOE and CE MOOC instructional designs require interdisciplinarity, online and offline networking, co-construction of knowledge between and among educators and learners. This type of co-construction is substantiated among teachers to increase digital literacy of teachers, targeting both pre-service teachers and in-service teachers and sharing educational experiences of in-service teachers in Oyo et al. (2017) or with community-centered professional support for in-service teachers in Kaul et al. (2018) (Table 2). We argue that through co-construction of innovations (e.g., via interacting OER, MOOCs, VLEs), of processes (e.g., interacting trajectories of teaching and learning) and of outputs (e.g., institutionalized VLEs, development of digital abilities and skills in addition to the learning (Carrera and Ramírez-Hernández 2018)), co-construction of sustainable, circular products, processes, organizations, and even a prospective economy, only then become truly targeted and possible with a contribution from CE OOE substantiated by several various CE MOOC instructional designs. At micro level, by putting the main agent—the learner—in focus, new analysis models, such as semantic analysis models (SMA) to track the emotional tendencies of learners become highly relevant (Wang et al. 2018). Additionally, since the learner is central, looking for the ways in how we facilitate the learning process in the teaching that is provided (e.g., supporting self-regulated learning by dashboards or widgets) also

become central. However, not only the learner has a responsibility to take, but also, the teacher needs to explicitly consider these learner traits in designing education and should be aware of the targeted learner population and their specific needs. In this respect, we argue that active learning space of OCL theory becomes relevant for CE education. As indicated in Table 2, digital transformation of education, especially technology-enhanced educational designs for CE OOE via CE OER and/or CE MOOC instructional designs, and the use, development, and interactions of relevant emerging technologies, can continue to demonstrate a multiplier effect by enhancing CE teaching and learning, as well as an accelerator effect for sustainability outcomes at various geographical levels (community, local, national and global). We argue that due to the multiplicity of domains (e.g., engineering, design, economics, business perspectives) and systems thinking involved in CE (Ellen MacArthur Foundation 2018), these emerging interactions and connectedness features for learners, educators, managers, entrepreneurs, and for technologies (e.g., OER-MOOCs interactions, public platform integrations, situating digital learning strategies via TEL strategies) are relevant for developing a CE OOE context and CE MOOC instructional designs. A finding which makes community of inquiry practices around knowledge co-construction relevant for CE education.

### 4.3. Multi-Level and Multi-Domain Varieties of Agents, Structures and Technologies for a CE OOE Context

Our findings in Tables 3 and 4 also indicate the existence and importance of varieties of structures, internal structures of agents, active agency situations and outcomes that should be taken into account in a CE OOE context and CE MOOC instructional designs. We argue that the structures of existing technological platforms, learning management systems, technological areas, course structures, evaluation structures, societal structures, as well as broader politico-administrative (policies), techno-economic (innovations) and labor market structures (e.g., employability, entrepreneurship) are key determinants for designing competent CE OOE and CE MOOC instructional design solutions. For internal structures of agents, learning relevance, preferences and motivations of learners, as well as for goals of policy makers and administrators as agents aiming at creating/increasing social–ecological returns through education emerge as key dynamics. Active agency situations which involve autonomous study possibility and actualization, active involvement potential, educators' embedding innovations for educating students and citizens, and the goals of educational and CE technology developers and entrepreneurs in commercializing solutions, in addition to their actions on corporate social responsibilities would also be supporting elements for developing a CE OOE context. The outcomes to be targeted range from micro to macro level as awards for participation, sharing resources, developing digital scientific literacy, as well as broader sustainability outcomes, such as developing a circular production and consumption culture among citizens and in overall society. Therefore, we argue that each of these structuration constituents should be taken into serious account in an interacting manner to activate further active agency and improvements in teaching and learning for a CE for the evolution of each type of structure involved in CE OOE and CE MOOC instructional designs.

### 4.4. Implications for Policy and Financing for CE OOE and CE MOOCs

According to our findings, from policy and financial perspective, OOE and MOOC programs do not pose a threat to the sustainability of other forms of transnational higher education (Wilkins and Juusola 2018). Yet, economic and social sustainability of digital transformation of education become day by day more reliant on the provisions of self-directed, motivating, applicable, rich, and technology-supported designs and implementations on offer (Jin-Hwa and Kim 2016). In this sense, from a market perspective, Porter (2015) argues that a freemium and possible new business models for MOOCs to inform decision-making by managers at universities can be relevant. While the main concerns in this cluster are around scalability and robustness of these business models (e.g., OOE, Business models for Sustainability (Täuscher and Abdelkafi 2018)), the main argument is that MOOCs as a marketing platform remain promising (Tobias Martinez et al. 2016) as they raise, e.g., the profile

of the universities (e.g., Northampton Business School, Gateway MOOC) (Anderson et al. 2014). It is also argued that while MOOCs act as part of the information marketing strategy for the universities, they enable the dissemination of various knowledge discourses (e.g., OCL theory) and thematic contents to society (Gallagher 2018) (e.g., sustainability, SDGs, circular economy). In this financial view, benefitting from outsourcing effects, integration and/or interoperability with external virtual learning communities through social networks also opens up a possibility space for cost sharing and cost reductions (Martinez-Nuñez et al. 2016). To reduce costs at micro level, the removal of tutor nodes becomes enabled by different modes of learning driven by participants and within MOOC communities (Mishra et al. 2017). However, we argue that sponsoring, funding or co-funding of OOE for CE teaching and learning can be shared among partners (e.g., municipalities, private companies, non-governmental organizations, universities, both public and private) which target creating social returns (e.g., societal welfare, corporate social responsibility and informing responsible customers, social impact, educating citizens, respectively) on these investments.

For instance, for governments and the education system, private sector, NGOs, even from early childhood, elementary education (e.g., in the scope of corporate social responsibility for private firms and social impact for NGOs) are relevant. In this sense, we agree with Davis (2009) that *"early investments in human capital offer substantial returns to individuals and communities and have a far-reaching effect"*. For instance, Spacebuzz.earth, an early-childhood education organization using virtual and augmented reality technologies to give kids (age range 9–12) the experience of an astronaut via creating an overview effect, and make them ambassadors of our planet, aims at reaching 100 million children to get to the experience of this overview effect yearly in a few years. Or, for instance, in CE context, "Alrededor de Iberoamerica", an educational project in partnership Veolia and Organization of Ibero-American States (OEI) for CE education reached 30,000 students aging between 10 and 11 (Living Circular 2015). In the domain of CE, such scales are very relevant for utilizing a CE OOE and/or CE MOOCs.

For professional education, while CE OOE necessitates incorporating the use of real-world cases via, for example, the contextualization of serious games (SGs), technical aspects of playing these SGs, and debriefing after these SGs. Online versions of such SGs are also shown to help learners shift their personal and professional mindsets, paradigms and practices, such that these shifts are needed for reaching sustainability actions and outcomes that are expected from (and the rationale behind) an education for sustainability (Dieleman and Huisingh 2006). We argue that these mechanisms of creating authentic, contextualized learning tasks, SGs in CE MOOC instructional designs can help CE experts receive additional feedback over (unknown initial state, process, and target states of) complex CE systems through experiential learning (Dieleman and Huisingh 2006). While such applications of experiential learning provide opportunities for encouraging and increasing the participation of various professional agents from various sectors (e.g., business, social, and environmental entrepreneurs) and society at large (e.g., citizens) in learning, the education models of most OOE and MOOCs in the field of education for sustainability we analyzed in this article often lack these possibilities in an integrated manner to deliver a competent and comprehensive OOE design and/or MOOC instructional designs, also for a CE education.

Finally, we argue that to allow for moving forward with developing more open, adaptive, reflective interactions and/or partnership models in education which enable participation of local agents and stakeholders, and which accommodate and recognize their specific needs to create multiple value; OOE, OERs and MOOCs for CE education become key means, and this is in accordance with the discourse and realization of a knowledge society, including an attention to lifelong learning in a context, and with the notion of academic developers as agents of change and partners in arms of change to transform educational practices at socio-technical regime level (Debowski 2014).

## 5. Conclusions

One of the first and key conclusions of this article is, despite all potential affordances of OOE, TEL, OER, SGs, MOOCs for CE teaching and learning, their potential has not been used to a significant extent in an integrated manner. Our integrated findings and meta-synthesis contribute to new knowledge in relation to the existing research in OOE (and prospectively, educational technology and content design and development) in the field of digital education for sustainability. In this respect, our theoretical lenses, the use of theories of neo-capital, transition management from a multi-level perspective and structuration theory can provide valuable insights for OOE, OCL and CE researchers and scholars, as well as practitioners in these fields, as shown in this article in detail.

Our contribution for development and implementation of a CE culture via research on educational innovations, and via applied educational innovations, firstly comes with the 22 revealed human, social, cultural and technological neo-capital needs for minimum viable CE MOOC instructional designs in the context of CE OOE. Secondly, we further relate these CE MOOC instructional design constituents to 11 technological advances, which can be incorporated in CE OOE to capture and better manage the complexity of CE teaching and learning. Thirdly, we provide broader and evolving multi-level and multi-domain structuration constituents and dynamics among various types of agents, types of structures, and types of technologies, which should be taken into account when designing CE OOE and CE MOOCs to capture micro-level learning preferences and journeys of individuals and groups within broader and evolving meso and macro level technological, organizational and institutional structures. Finally, by doing so, our contribution also informs policymakers' in their potential efforts directed towards combining OOE, TEL, OERs, SGs, MOOCs, technological infrastructures, communities of inquiry (CoI), practice (CoP), and open schooling to foster inquiry skills and lifelong learning for CE (see EC (2019)) in the context of supranational landscape influences. The 46 revealed structuration constituents and, broader and evolving technological, organizational and institutional structures, can help support informed decisions to be taken by national government authorities, specialized agencies in the context of policy text production targeting OOE in a context, and CE education. In the context of practices, academics, researchers, analysts, educators, educational technology developers, entrepreneurs, and innovators can (co-)benefit from our findings in designing and implementing CE OOE and CE MOOCs, as well as in developing and implementing blended learning, customized webcasting facilities, connected apps, linked mobile devices via Internet of Things (IoT) for seamless learning for the context of CE education.

Thus, we recommend that the supply of CE OOE and/or CE MOOC instructional designs, if our integrated findings (22 findings for capital- and neo-capital-based multiple value formations, 11 for emerging tools and technologies, five for micro/meso-level interactions among actors and structures, and nine for macro-level interactions among a broader set of varieties of actors, structures and technologies) are taken into account in developing and implementing such CE OOE and/or CE MOOCs instructional designs, this can further activate a demand-driven process of social and networked learning as a growing niche, and as a gradual transition from teacher-centered to distributed ways of CE learning in which learners are free to learn at any time and any place. These 46 features and selected utilization of their subsets in CE OOE and CE MOOC instructional designs can provide several combinatorial possibilities to educators and learners to interact (with content, with each other, with technologies) and also to learn with and from peers, and help policymakers, administrators, and entrepreneurs decide which type of resources, rules and tools to invest in, create and/or to further develop for a better and competent fit for the interdisciplinary, multidisciplinary or transdisciplinary needs of the processes of teaching, learning and doing for a CE by attaining sustainability outcomes which accelerate CE transition at broader socio-technical regime, and global landscape levels.

Considering our findings and limitations, some future research directions include the following: research on the determinants of learners' motivations in OOE settings in the context of CE; assessment and evaluation of various instructional designs of CE MOOCs; impact of instructional designs of CE MOOCs on the completion rate of learners, on the employability and/or self-employability of learners,

and on bringing about circular innovations after completing various CE MOOCs; finally, research on the determinants of the scalability of various CE MOOC instructional designs in the context of CE OOE.

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