



What is learning? A complex conceptual systems analysis of conceptualizations of learning

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ABSTRACT

Beliefs about the nature of learning have implications for learner agency, empowerment, and justice. Conceptualizations held by learning scientists and STEM professors were analyzed as complex conceptual systems and were found to be different for each group. A Transfer-Acquisition conceptualization of learning was dominant in the STEM professor group, and a Construction-Becoming conceptualization was dominant in the learning scientists group. The practices emergent in the Transfer-Acquisition conceptualization were found to be inconsistent with critical pedagogy. The insights in this study not only support claims in the literature that conceptualizations of learning impact practices in teaching and learning, but also suggest that complex systems theories and methodologies may be a fruitful new approach to understanding the relationships between conceptualizations and practices.

1. Introduction

What is learning? The question itself may be of much greater importance than any answer. In this paper we will not seek to answer the question. For readers who desire an answer which satisfies most educational researchers, see Alexander et al. (2009). Rather, we will argue that behind this fundamental question are complex systems with powerful implications for teaching, learning, and justice.

There is a robust body of literature regarding high-impact practices in teaching and learning (Bransford et al., 2000; National Academies, 2018). Research regarding practices in teaching and learning has not achieved the anticipated impact on practices in higher education (Hora, 2014; Hora & Ferrare, 2013), and the impact in PK-12 has been limited (Chi, 2021; Kriz et al., 2021).

There have been many studies investigating teacher beliefs, as well as the impact teacher beliefs have on their practices (Fives & Gill, 2015; Hativa & Goodyear, 2002). These studies have framed teacher beliefs as either one-dimensional or as vague collections of beliefs (Gill & Fives, 2015). These studies have generally built upon work by Trigwell and Prosser (1996) who developed a framework which categorized teacher beliefs about learning on a continuum ranging from learning as accumulating information and acquiring concepts to conceptual development, and beliefs about teaching on a continuum from transmitting

concepts and knowledge to helping students develop or change conceptions. Although there have been mixed findings, there has been general consensus that there is an important relationship between beliefs and practices (Buehl & Beck, 2015).

Our study differs from the teacher beliefs literature in that we are developing a complex systems theory which frames conceptualizations of learning as consisting of large numbers of self-organizing interdependent ideas. Furthermore, we propose a mechanism through which to explain the relationship between conceptualizations and practices not through linear causality as has been assumed in much prior research on teacher beliefs (Buehl & Beck, 2015), but through the complex systems principle of emergence. Another differentiation in our approach is that we frame conceptualizations as contextually, socially, and historically situated and distributed rather than entities which exist within specific human minds. Rather than accessing conceptualizations in their own minds, we propose that human beings participate in various conceptualizations.

Work around teacher beliefs is important in reducing the research-to-practice gap and developing strategies toward adoption of practices in teaching and learning based on educational research (Hora, 2014). While this literature has provided important forward movement in the field, there is an emerging strand of the literature that centers critical theories and praxis to uncover new knowledge (Esmonde, 2017).

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Critical perspectives offer educators and educational researchers the tools needed to interrogate power and privilege, while seeking to empower in a variety of teaching and learning contexts (Bang & Vosoughi, 2016). Impactful designs for learning must always involve attention to conceptualizations of learning and issues of power. We argue that conceptualizations are complex conceptual systems, and practices in teaching and learning are emergent from conceptualizations of learning. We develop this new approach to critical theory analysis and development of critical pedagogy principles through which purposeful design moves can be made to engage learners and educators in problematization, reflection, and action regarding conceptualizations of learning and power. Through this study we build the argument that practices in teaching and learning cannot change without changing conceptualizations of learning, and that problematic relationships and structures of power cannot be changed without changing conceptualizations of learning.

1.1. Conceptualizations and critical theory

Critical theory encompasses a diverse set of theories which share a central purpose of helping us “challenge normativity and address how power circulates and sorts” (Esmonde & Booker, 2017). Critical pedagogy takes on this challenge by engaging learners, educators, and researchers in analyzing “the relationship between education and oppression in order to help bring about social transformation” (Vosoughi & Gutiérrez, 2017). Critical theory proclaims that conceptualizations of learning are inextricably related to practices, and that both inherently involve issues of power, authority, privilege, oppression, marginalization, and empowerment (Freire, 1970/2005; Kincheloe, 2008). Critical perspectives on teaching and learning have continued to develop a needed stance in the field of education (Apple, 2014; Giroux, 2013; Kincheloe, 2008; Ladson-Billings & Tate, 1995). Building on Freire’s (1970/2005) pedagogy of the oppressed, Giroux (2013) argued that we must change how education and learning are conceptualized. This change in thinking is the aim of critical pedagogy, which challenges commonly accepted assumptions regarding who has the authority over educational practices, values regarding the purpose of education, and the construction and curation of knowledge (Giroux, 2013) through practices in which teachers and students collaboratively transform knowledge (Kincheloe, 2008).

In the United States, the legacy of No Child Left Behind (NCLB) and its continuation in the Every Student Succeeds Act (ESSA) situates education as a consumer good (Davidson et al., 2015; Tyack & Cuban, 1995), and learning as the commodity acquisition of bits of knowledge (Goatly, 2007; Labaree, 1997). Similar views are dominant internationally in policy, academia, and among students (McMahon et al., 2021), views that can be traced back to a positivist paradigm (Kincheloe et al., 1999). The logic of the ‘common sense’ conceptualization of learning as commodity acquisition is profoundly entrenched in our society (Hager & Hodgkinson, 2009). If knowledge is a commodity, acquisition can (and must) be measured. In this dominant perspective, standardized tests measure an individual’s value by measuring one’s accumulation of knowledge (Clark, 2005), and thus anything which cannot be measured through tests has no educative value (Aarseth, 2022; Giroux, 2013).

Conceptualizations have political consequences (Lakoff & Johnson, 1980) because they contain within themselves structures of power that play out in real-world contexts. Schooling becomes not only the site of knowledge transfer and acquisition, but also—and equally important—it becomes the vehicle for the hidden curriculum (Labaree, 1997). At the core of this hidden curriculum is reproduction of the *acquisition* conceptualization (Kincheloe, 2008), which functions as a means by which oppression is hidden (Giroux, 2013). These interactions between various aspects of the dominant conceptualization of learning thus remain entrenched as the common-sense approach (Apple, 2014). Critical pedagogy is necessary in all fields but is particularly crucial in STEM

education because these fields have traditionally situated themselves as the arbiters of objective truth, a position which critical theorists have identified as mechanism of oppression and a means to limit learner agency, autonomy, and authority (Apple, 2014; Giroux, 2013; Kincheloe, 2008).

1.2. Complex conceptual systems theory

Complex conceptual systems theory (Donaldson, 2019; Donaldson & Allen-Handy, 2020) describes conceptualizations as complex dynamic systems (Bar-Yam, 1997) and expands upon conceptual metaphor theory (Gibbs, 2014; Lakoff & Johnson, 1980). Conceptualizations are composed of numerous interacting and interdependent ideas which can be analyzed in terms of four categories. *Conceptual metaphors* are clusters of related metaphors and analogies (Cameron & Maslen, 2010). Non-metaphorical characterizations and memories of experiences have also been found to cluster in ways similar to the way metaphors cluster in conceptual metaphors, and therefore can be categorized as *conceptual stories*. Complex conceptual systems also include ideas which are neither metaphorical nor non-metaphorical characterizations—ideas such as beliefs and values. Beliefs and values regarding the nature of social structures and relationships are categorized as *conceptual worldviews*. Epistemic and ontological stances regarding the nature of knowledge and reality are categorized as *conceptual paradigms*. Conceptualizations of learning can then be characterized by describing the patterns of interactions between elements (ideas) within each category, as well as between interactions between categories. These conceptualizations are not located inside individual human brains. Rather, they exist in societies and communities and individual human beings participate in particular conceptualizations to varying extents. Complex conceptual systems have emergent properties in the form of sets of potentials (action potentials, linguistic potentials, perceptual potentials, and valuation potentials) which lead to emergent phenomena in the form of practices, use of terminology, cognitive filtering, and value propositions and enactments.

1.3. The current study

This study seeks to contribute to our understanding of these complex conceptual systems by analyzing conceptualizations of learning among learning scientists, and to do so in greater depth by analyzing them in comparison to other researchers in science, technology, engineering, and math (STEM) fields. We also analyze these complex conceptual systems through the lens of critical theory as we seek to understand how issues of empowerment, agency, marginalization, and oppression are related to phenomena emergent from conceptualizations of learning. The research questions that guided our inquiry were:

- RQ1: How is learning conceptualized within a group from the Learning Sciences and within a group of STEM professors?
- RQ2: How do these conceptualizations of learning translate into emergent practices in teaching and learning within the respective fields?
- RQ3: How can critical theory be applied to understand the implications of these different conceptualizations of learning and their associated practices?

2. Method

2.1. Method overview

This study investigated conceptualizations of learning through a complex conceptual systems design. We chose this design because complex conceptual systems analysis allows for identification and description of unique conceptualizations, along with emergent practices (Donaldson, 2019). We also used comparative case methods for comparison of two bounded cases, and therefore deeper understanding of the

conceptualizations of learning in each case (Merriam & Tisdell, 2016). In the first phase of this study, we sought to understand how learning is conceptualized in the Learning Sciences in comparison to discipline-specific STEM education, and to illuminate the relationship between conceptualizations and practices in teaching and learning. In the second phase of our study, we identified emergent potentials and analyzed these insights through a critical lens.

2.2. Researcher positionality

It is critically important to acknowledge our positionality, and the subjective experiences that frame our work (Peshkin, 1988). By employing our researcher positionalities, we seek to highlight what Holmes (2020) refers to as our a) world views which are inclusive of ontology (belief about social reality), b) epistemology (nature of knowledge), and c) human agency (one's interaction with their environment). As our study focuses on conceptions of learning, our positionality serves as a tool of transparency to more fully illuminate our research dispositions as the research instruments and the filter by which we designed, conducted, and represented our findings (Sybing, 2022). Our individual and collective self-reflections and reflexivity throughout the project concerning the ways in which our backgrounds, identities, biases, and lived experiences have interacted with and impacted the research process are shared here. The first author, a White heterosexual male, has worked as an educator and researcher for several decades. He grounds his work in constructivist and critical epistemologies and ontologies. He identifies as a learning scientist and critical pedagogy practitioner. He developed the current study because he is committed to the proposition that conceptualizations of learning are often a mechanism through which oppression, marginalization, and epistemic injustice are reproduced, but that they can also be the site for addressing injustices. The second author is a Black heterosexual, able-bodied, middle-class, cis-gendered woman, and mother-scholar whose theoretical perspectives are anchored in critical race theory and more specifically critical race feminism, intersectionality, and Black feminist theory. As a former K-12 teacher and counselor and currently an Urban Education professor, she internalizes conceptions of learning within a critical paradigm that uplifts socially constructed lived experience. In addition, her work moves from a place that recognizes learning as a conduit for the advancement of social justice prerogatives that inspire human agency, particularly for the most marginalized. The second author was a professor and mentor to the first author during his doctoral studies, after which the authors have continued to collaborate and support each other's continued professional growth and reflective development.

2.3. Selection and recruitment of participants in two cases

The first case is a sample of researchers in the field of the Learning Sciences which emerged in the early 1990's out of discontent with dominant narratives of learning among educators, educational researchers, cognitive scientists, and artificial intelligence researchers (Hoadley, 2018). In the Learning Sciences, terms have been used to critique the dominant conceptualization of learning and education including 'instructionism' (Papert & Harel, 1991), 'didactic' (Collins & Halverson, 2009), 'transmission' (Schank & Jona, 1991), and 'acquisition' (Sfard, 1998). These descriptions of the common frame through which learning is understood are juxtaposed to constructivist frames, wherein issues of authority and power are central (Schank & Jona, 1991; Schank, 2016).

Our second case is a sample of STEM professors in higher educational contexts because educational research literature routinely calls for certain 'evidence-based high-impact' practices which are often lacking in STEM education (Jacobson et al., 2016) and in general higher education (Campbell et al., 2017; Hora & Ferrare, 2013). Also, there has been an increasing call for STEM education to adopt critical perspectives

(Esmonde, 2017; Kokka, 2018; O'Hara, 2022). This population would provide a significant contrast in terms of both conceptualizations of learning and practices in comparison to the first case, therefore allowing deeper analysis of conceptualizations in both samples as complex conceptual systems and identify practices which are potentially emergent from different conceptualizations of learning.

The participants in this study ($N = 20$) consist of learning scientists and professors in STEM fields. Theoretical saturation with a limited number of participants is an issue debated in the literature, with a diversity of recommended minimum sample sizes ranging from six to thirty (Low, 2019). For instance, in a study involving sixty interviews, Guest et al. (2006) found that within six interviews 94% of all thematic codes are identified and within twelve interviews 97% of all thematic codes are identified. In consultation with a number of experts, it was determined that each case would include ten participants for a total of twenty participants while recognizing that a larger number of interviews may have increased the quality of theoretical saturation. The first case was defined narrowly to include only researchers who both self-identify as Learning Sciences researchers and are seen as influential learning scientists and leaders in the field by other members of the field. The second case was defined narrowly to include only content-area professors of applied mechanics, astronomy, bioengineering, biology, computer science, environmental engineering, mathematics, mechanical engineering, and physics who teach first-year or second-year students in institutions of higher education, and who are actively engaged in research activity. All participants were in the United States of America (see supplemental materials for more demographic details). By using this comparative case approach, we anticipated that we would be better able to characterize conceptualizations in each case in a broader sense, thus enabling us to understand each community as well as further develop the complex conceptual systems theory.

An intermediary was chosen to recruit Learning Sciences participants because he has been a member of the learning sciences community since the beginning of the field and has worked extensively in STEM education. This recruitment resulted in a sample of learning scientists across North America, and therefore we decided to recruit STEM professors from the same geographic area.

2.4. Phase 1 data collection and analysis

Data were collected through in-depth semi-structured face-to-face interviews (IRB approved) which elicited participants' experiences, beliefs, practices, and stances regarding the nature of learning, the purpose of education, and high-impact practices in teaching and learning.

This study used innovative methodologies we developed for complex conceptual systems analysis (Donaldson, 2019; Donaldson & Allen-Handy, 2020) which uses a combination of statistical correlation analysis (Chen & Krauss, 2004) and network analysis methods (Hanneman & Riddle, 2005) inspired by conceptual metaphor analysis (Cameron & Maslen, 2010). Network analysis is a method through which to investigate the multiple interdependencies of elements within a complex system, usually resulting in network maps (Hanneman & Riddle, 2005).

The interview transcripts (132,984 words) were coded for ideas within each of the following categories: metaphors of teaching and learning, non-metaphorical characterizations of teaching and learning, value statements regarding the nature of social structures and relationships (worldview stances), ontological and epistemic stances (paradigmatic stances), and practices in teaching and learning. Intra-rater reliability testing found an acceptable Kappa of 0.70. The final codebook consisted of 581 unique codes and 3837 coded segments.

Correlation matrixes were created for all pairs of codes (how likely it was for two codes to both appear in an interview) within each of the coding categories except practices in teaching and learning, and network analysis was used to construct network maps. Girvan-Newman analysis (Girvan & Newman, 2002) was used to identify clusters of

correlated codes. Correlations between unique conceptual metaphors, conceptual stories, conceptual worldviews, and conceptual paradigms were calculated, and correlated sets were used to describe the different conceptualizations of learning. Correlation matrixes were created for all pairs of codes regarding practices and conceptualizations of learning, which were used to identify practices emergent from each conceptualization of learning.

Finally, conceptualizations of learning and emergent practices were analyzed in each case for within-case similarities and differences and between-case similarities and differences.

2.5. Phase 2 analysis

The second phase of this study analyzed the insights from the first phase through a critical theory lens. The relationship between the complex systems of conceptualizations and the emergent phenomena was described through identification and analysis of potentials (Donaldson, 2019). In this study, *action potentials* were the set of actions deemed appropriate in teaching and learning. *Linguistic potentials* were the set of possible terms to use. *Perceptual potentials* were the set of things deemed most relevant and worthy of attention. *Valuation potentials* were the set of things that were characterized as important and valuable. For each of the sets of potentials we analyzed all the data categorized as emergent practices, communications, cognitive filtering, and values. We interpreted these potentials through the lens of critical theory and critical pedagogy.

3. Results and discussion

3.1. Complex conceptual systems

Our analysis led to in-depth descriptions of two salient conceptualizations of learning, each characterized by unique conceptual metaphors, conceptual stories, conceptual paradigms, and conceptual worldviews. Network and cluster analysis of correlations of metaphors at the $p < 0.001$ level revealed seven distinct clusters with a Girvan-Newman cluster confidence of $Q = 0.76$. Further analysis (see supplemental materials) narrowed this down to two overall clusters forming the Construction, Becoming, and Apprenticeship conceptual metaphor and Acquisition-Object-Manipulation conceptual metaphor. Network analysis of non-metaphorical characterizations correlations ($p < 0.001$) revealed nine clusters at $Q = 0.70$. Further analysis (see supplemental materials) found two salient conceptual stories: Object Possession and Situated Becoming. We found three clusters of conceptual paradigm codes ($p < 0.05$ at $Q = 0.47$) and seven clusters of conceptual worldview codes ($p < 0.05$ at $Q = 0.40$). Through further analysis (see supplemental materials) we were able to identify the Collaborative-Cooperative and Individualist-Competition conceptual worldviews and Interpretivist-Constructivist and Positivist-Postpositivist conceptual paradigms.

3.1.1. Conceptualizations of learning

Correlations between conceptual metaphors, conceptual stories, conceptual worldviews, and conceptual paradigms were calculated, resulting in characterizations of two conceptualizations of learning. For the Construction-Becoming conceptualization of learning we found a set of elements with correlations at the $p < 0.001$ level: the Construction-Becoming-Apprenticeship conceptual metaphor, the Situated-Becoming conceptual story, the Collaborative-Cooperative conceptual worldview, and the Interpretivist-Constructivist conceptual paradigm. For the Transfer-Acquisition conceptualization we found a different set of elements with correlations at the $p < 0.01$ level: the Acquisition-Object-Manipulation conceptual metaphor, the Object-Possession conceptual story, the Individualist-Competition conceptual worldview, and the Positivist-Postpositivist conceptual paradigm. The network map of all elements can be found in supplemental materials.

The STEM Professors group conceptualized learning primarily

(94.7% of data from this group) through the Transfer-Acquisition conceptualization of learning. This Transfer-Acquisition conceptualization of learning sees learning as the acquisition and manipulation of knowledge objects which are explanations of reality resulting from logical rational thinking and scientific processes, and therefore objective and decontextualized. As STEM professor Alex stated, “*we are discovering objective facts.*” Learning starts with acquiring a foundation of basic knowledge and skills, and then progresses through acquisition of a hierarchy of increasingly valuable knowledge and associated skills in manipulating knowledge. The role of the teacher is to transmit knowledge through various content-delivery practices including lectures, well-designed problems or projects, and textbooks, often in a standardized way as described by Tracy, a STEM professor: “*there’s a very well-established idea of what the content of such a course should be ... you go on any math department, website, anywhere in the country, or the world.*” Because knowledge objects can be quantified and measured, learning should be measured and assessed in terms of the degree to which learners’ knowledge aligns with the truth, as well as the quantity of knowledge objects they have accumulated and are able to manipulate appropriately: “*you just have to memorize or learn them, and those things ... yeah, if you give the student an exam ... that’s a way that you can measure whether or not they learned it*” (Caden, STEM professor). This is important in this conceptualization because it helps learners become competitive in the job market, which in turn helps the nation maintain a competitive edge against other nations.

The Learning Scientists group conceptualized learning primarily (93.6% of the data from this group) through the Construction-Becoming conceptualization of learning. This conceptualization sees learning as a process involving both becoming and constructing knowledge. Learning is not isolated in an individual learner’s mind, nor is knowledge an object which can be transmitted or received. Instead, learning is distributed between individuals and their contexts situated within historical time and culture. Learning is sometimes a cognitive process, but not exclusively so because it is mediated by human relationships and interactions as described by the learning scientist Ashton: “*I think of it as, not surprisingly, a socially mediated process of engaging with—through artifacts and tools.*” Learning in this conceptualization is most effective through participation in a community of practice and involves identity exploration, along with engaging in interest-driven project work with immediate real-world impact. Also important here is reflection and action on the world, with an emphasis on examination of power and problematizing assumptions about truth and the nature of knowledge. In this conceptualization, teaching was not conceptualized as the transmission of knowledge, but rather a combination of mentorship and designing learning experiences which bring learners into a community and its practices, histories, and ways of knowing. Teaching involves a scaffolding process with gradual release in which the teacher and students share authority as agency gradually shifts increasingly to the learners. Assessment is context-dependent since knowledge and learning are context-dependent and cannot be measured through direct instruments such as exams. Learning is observed, rather than assessed by “*seeing the ways that people’s participation changes over time. I can see the ways that people’s doing of stuff changes over time ... I can see the ways that they interact changing over time*” (Darcey, learning scientist). Via this perspective, the learning trajectories of learners are situated and mediated by context, and therefore cannot be pre-determined in standardized curricula, but can be characterized by greater identification with communities of practice and the ability to engage in and influence the practices of those communities, as well as the larger society. Ashton (learning scientist) expanded upon this concept:

I think that learning how to be in relation with other people, learning how to build democratic community, and learning how to enact just political and social systems should be the primary purpose of education. ... The development of ethical, thoughtful humans that know how to take care of the earth and know how to take care of each other I think should be the

primary goal of education ... becoming the kind of person that is solidarity minded and community minded.

We found that learning is most powerful, according to this conceptualization, when it involves development of empathy, democratic engagement, working for social justice, and commitment to global citizenship in a spirit of respect and cooperation.

3.1.2. Emergent practices

Network and cluster analysis of correlations of practices endorsed and conceptualizations of learning at the $p < 0.001$ level found 6 clusters (confidence of $Q = 0.54$), with three clusters each emergent from the two conceptualizations. Emergent from Transfer-Acquisition conceptualization were practices such as active learning (defined as pausing lectures to take questions), clickers, lecture interaction technologies, content (knowledge, facts) work, cooperative learning, exams, grading, individualized learning, lectures, note-taking, teacher-directed problem solving, textbooks, and writing essays. Emergent from the Construction-Becoming conceptualization were practices including community of practice building, critical analysis of power, deep-dive learning, design work, epistemic problematization, feedback, identity exploration, interest-based learning, learner agency, learner-directed problem solving, metacognition, non-cognitive learning (emotion, body, relationships), real-world impact work, reflection, and learner self-evaluation. We found that the STEM professors tended to use practices emergent in the Transfer-Acquisition conceptualization of learning, while the learning scientists tended to use practices emergent in the Construction-Becoming conceptualization.

3.2. Conceptualizations of learning and critical pedagogy

To better understand the implications of these insights, we now turn to analysis through the lens of critical theory. Critical pedagogy seeks to help learners empower themselves to become critical change agents in their world. Complex conceptual systems theory suggests that conceptualizations give rise to emergent properties in the form of action potentials, linguistic potentials, perceptual potentials, and valuation potentials (Donaldson, 2019). Critical theory is concerned with power, and in practical terms power can be seen as a function of potentials because conceptualizations lead to action potentials which lead to actions. The following sections are critical analyses of our findings.

3.2.1. Emergent potentials in the transfer-acquisition conceptualization

In the Transfer-Acquisition conceptualization of learning we found emergent action potentials involving acquiring knowledge, manipulating knowledge objects, determining truth, and so on (see supplemental materials). Linguistic potentials were bounded by terminology related to acquisition of knowledge, transmission of knowledge, quantification and measurement of knowledge transmitted and received, and transmitting only objective truths, learning primarily from observable and measurable phenomena through scientific and logical processes, and accepting only non-relativistic and abstracted characterizations of reality. The negative perceptual potentials (what is made invisible, incomprehensible, or irrelevant) included being able to see learning as construction of knowledge, mediated and non-cognitive aspects of learning, and learners' authority to construct knowledge. The valuation potentials included observable, measurable, and assessable acquisition of knowledge, covering the necessary and appropriate concepts, objective assessment of knowledge accumulation and quality, basic knowledge and skills, and producing people who understand and accept reality as determined by logic, reasoning, and the scientific process.

3.2.2. Emergent potentials in the construction-becoming conceptualization

The Construction-Becoming was associated with action potentials (see supplemental materials) which included constructing meaning, participating in a community of practice, working as an apprentice, and

developing ability in addressing social justice issues. The linguistic potentials were related to constructing, making, and building knowledge, participation in a community of practice, subjective and intersubjective aspects of learning and knowledge, learning through multiple constructions and interpretations of reality, and contextualization of knowledge and ways of knowing. The emergent negative perceptual potentials emergent included not recognizing knowledge as discrete and delineated objects and inability to see learning as acquisition of knowledge that can be measured and assessed. The valuation potentials included collaboratively and collectively constructed knowledge, participation in communities of practice, transformation of self, community, and society, learners individually and collaboratively taking on agency and authority over their own learning, and the transformation of individuals, groups, and society towards greater social justice.

3.2.3. Agency, authority, and autonomy in the two conceptualizations

The two conceptualizations of learning and their emergent properties found in this study illustrate the importance of interrogating assumptions. We found a fundamental difference in beliefs regarding who should have agency—who should have the power—in decisions about learning. The Transfer-Acquisition conceptualization engendered the assumption that teachers, schools, districts, and instructional designers have the authority to make decisions regarding what students will learn, how they will learn it, and how they will be assessed. Here, the goal of education is the production of people who know what is decided that they should know and do what is determined they should do (Giroux, 2013).

The Transfer-Acquisition conceptualization of learning found in this study potentially reproduces positivist perspectives through its emergent practices, communication, cognitive filtering, and values through interactions which affirm “common-sense” positivist assumptions about the nature of reality, knowledge, the mind, and learning. Permeating all aspects of this conceptualization are elements which authorize only knowledge which is observable, measurable, and the result of scientific methods. All other knowledge and ways of knowing are dismissed and regulated to the lower-status categories of “belief” and “subjective experience,” as evidenced in Alex’s (STEM professor) statement that “*we are discovering objective facts and there would be a lot of pushback against the notion that these are culturally relevant ... we are supposed to agree whether it’s true regardless of where we come from.*” The gatekeepers and certifiers of this knowledge are positioned in society, and their positionality imbues the knowledge they curate with positionality. Those without authoritative positions are seen—and come to see themselves—as having inferior knowledge claims in relation to authoritative sources (Apple, 2014). These imbalanced power relationships interact with numerous other power relationships, resulting in oppression, marginalization, and suppression.

For these reasons, practices in which learners share agency with teachers, or are put in positions of primary agency, are inconsistent with the assumptions inherent to the Transfer-Acquisition conceptualization. When such practices are introduced into learning environments dominated by the Transfer-Acquisition conceptualization, they can only be applied superficially because there may be no fundamental shift in agency without a fundamental shift in conceptualization of learning. If the positivist stance remains intact, learners may never come to see themselves as having the authority and agency to construct knowledge or to problematize knowledge claims (Giroux, 2013).

Learning in the Transfer-Acquisition conceptualization found in this study was primarily about explaining reality, and sometimes about functioning effectively in relation to reality. Finley, a STEM professor was of the opinion that “*the purpose of education is to develop your brain into a thinking organ that can think and solve problems so that you can function in whatever capacity you need to function as a person in society.*” Critical pedagogy makes transformation of realities the responsibility of learners and teachers and insists that all learning—no matter the subject—involve reflection and action through which learners have an

immediate impact on the world around them (Freire, 1970/2005). The primary focus is alleviating the suffering of the most oppressed and marginalized people within the learners' sphere of influence (Kincheloe, 2008). This often involves work to disrupt or destroy systems of oppression, a position that is in direct opposition to elements of the Transfer-Acquisition conceptualization, including issues of authority, agency, the nature of knowledge, and the purposes of learning.

In the Transfer-Acquisition conceptualization in our data learners were seen as lacking knowledge and skills that will be given to them by the teachers who "know these things. How do you actually communicate with other people [so that] they know them as well" (Alex, STEM professor). The view of knowledge as objects to be acquired by learners puts learners in a position of lower authority than teachers, but also puts teachers in a position of lower authority than institutions and professional communities of experts. Rigid hierarchies of power appear to be emergent from this conceptualization of learning and become institutionalized in society as "common sense"—the way things are naturally ordered (Apple, 2014). Practices emergent in this conceptualization around measuring and assessing learning as knowledge accumulation and manipulation may further enforce the power structures in which learners — and even teachers — have little or no agency. For instance, "we have exams, because we have to have exams for them, so that's a big chunk of the grade" (Finley, STEM professor). Critical pedagogy practices which disrupt the norms in the Transfer-Acquisition conceptualization (norms such as prescribed curricula, exams, textbooks, or content delivery through lectures) are not only seen as a waste of time because they do nothing to improve test scores, they are sometimes seen as a threat to the stability of existing power structures in education (Giroux, 2013).

We found that the Construction-Becoming conceptualization assumed that learners have agency. Leslie, a learning scientist, put it this way:

What is sitting at the center of all this stuff is this... our notions about the importance of agency ... this is what I think drives the best learning is the opportunity to pose questions that are compelling to you and that you learn how to parse in ways that you can solve.

Not only do learners have the authority to make decisions regarding what they will learn and how they will go about learning, learners are placed in a position of human dignity which respects their intelligence and abilities. Students are expected to create their own meanings and shape their own classroom experiences. In describing learning experience design, Ashton, one of the learning scientists, said:

my goal is that there's a kind of praxis opened up ... of reading the word and the world. Like read your world differently, which might encourage you to engage in your world differently ... intentionality and agency that might open up from that is what I'm after

The goal of education in this conceptualization is aligned with the critical pedagogy goal of empowering people to shape themselves and transform society (Freire, 1970/2005). Opportunities for disruption of conceptualizations on a personal level may be opened up through practices in this conceptualization. Robin, a learning scientist, described leveraging a particular practice with this in mind "activities we can choose as entrance points for learning, taking into account the critical issues which are always present ... to bring the gendered nature of materials in learning into a discussion." Critical pedagogy requires not only that elements of the Construction-Becoming conceptualization be made explicit, but also that elements of the Transfer-Acquisition conceptualization be intentionally analyzed, interrogated, and problematized. The Construction-Becoming conceptualization of learning is not exclusive to critical pedagogy and may be present in environments hostile to the critical pedagogy goals of social transformation and disrupting systems of oppression. However, the incompatibility of critical pedagogy with positivism (Kincheloe, 2008) suggests that the Construction-Becoming conceptualization provides an environment in which critical pedagogy can flourish.

In the Construction-Becoming conceptualization of learning there is an emphasis on real-world impact work, engaging in authentic practices of a community of practice, and interest-based learning (Donaldson, 2019; Chowdhury et al., 2021). This emphasis was explained by Leslie, a learning scientist: "having students work on real, authentic problems, preferably problems that they've helped to scope and define and set and establish ... where they're producing real products that others can evaluate in that public critique form of evaluation." Although these features align with critical pedagogy, they do not necessarily lead to critical reflection and action on the part of learners to transform realities. The Construction-Becoming conceptualization is compatible with critical pedagogy, but the design of learning environments for critical pedagogy requires going beyond the normal practices emergent in this conceptualization to intentionally engage learners in social justice work through the praxis of critical reflection and action upon their worlds (Freire, 1970/2005).

We found that the Construction-Becoming conceptualization was aligned with emergent practices which are consistent with the critical pedagogy principles of developing learner authority and autonomy. In this perspective, low learner agency practices such as content delivery through lectures, exams to measure learning, and textbooks to transmit knowledge are seen as minimally effective: "kids are not learning. There's plenty of evidence that affirms that. Kids who take an AP exam come back three months later and take it again and don't remember anything, right? I mean, we know this." (Leslie, learning scientist). However, this conceptualization also opens up possibilities to view these practices as counterproductive. In discussing the practice of grading, Julian, a learning scientist, argued that grading is "perverse [in] that it focuses teaching on things that are less important ... rather than how to negotiate, how to listen, how to complete things. We can't measure those kinds of things and so we don't teach them." More importantly, this conceptualization allows us to see these practices as mechanisms of oppression to be disrupted. Francis, one of the learning scientists, argued that the result of such practices "is to get people ready for prison. I know that. It's not a hypothesis, and I've seen it and I've watched it happen. That is a purpose of education: to get people ready for prison." There is alignment between the Construction-Becoming conceptualization of learning and critical pedagogy in situating learners in positions of agency and autonomy and helping them develop agency. Designers for critical pedagogy in learning environments grounded in the Construction-Becoming conceptualization must be intentional in making explicit the socially transformative nature and purpose of learner agency (Giroux, 2013; Gutiérrez & Jurow, 2016).

The critical pedagogy insights in this study suggest a "practical" approach for bridging the theoretical frameworks in the Learning Sciences and critical pedagogy by providing a rudimentary mechanism to describe the relationships between conceptualizations of learning and practices.

4. Limitations and conclusions

Because qualitative data was analyzed, the insights cannot be generalized and replicability of "findings" will not be possible—although replicability of procedures and protocols is possible. Furthermore, the quantitative network analysis methodology we used results in characterizations which contain only the most salient features (statistically significant correlations) while excluding peripheral features and features shared between different clusters, and therefore the insights represent conceptualizations of learning in broad strokes. However, the theoretical and analytical framework used here can inform theoretical advancement regarding conceptualizations of learning. As with all research, researcher bias is an issue which was recognized, acknowledged, and subjected to critical reflection throughout all stages of analysis and interpretation. We used a comparative case method because we believe the contrast between the Learning Sciences and STEM education was a necessary first step towards characterizing conceptualizations of learning broadly. Given the broad range of learning

theories used in the Learning Sciences, it is safe to assume that there are different conceptualizations existing in the field. Future studies will be needed to characterize these conceptualizations, and to determine if they are “nested” within the broader Construction-Becoming conceptualization.

Our analysis led to insights which support claims in the existing literature that there are various conceptualizations of learning (Apple, 2014; Hager & Hodkinson, 2009; McMahon et al., 2021), that they matter (Freire, 1970/2005; Giroux, 2013), and that they impact teaching and learning practices (Buehl & Beck, 2015; Kincheloe, 2008; Kincheloe et al., 1999). Complex conceptual systems analysis such as presented in this study may provide new avenues for critical pedagogy designs for learning and culture change efforts in educational contexts.

Analysis of complex systems by researchers from other domains such as environmental science or biology puts emphasis on describing equilibrium, system stability, and robustness (Yoon, 2018), aspects which could not be analyzed in this study because no contextualized longitudinal data were available. Future studies are needed to provide more robust evidence for the emergent nature of practices in relation to conceptualizations of learning. These studies should involve long-term interventions in which teachers problematize and reframe their conceptualizations of learning, accompanied by observations of their classrooms. When findings in those fields are extrapolated in light of the findings of this study, they suggest that conceptualizations of learning may have internal tendencies toward stability and equilibrium. In other words, it may be quite difficult to shift conceptualizations of learning away from problematic conceptualizations toward new conceptualizations in which emergent practices align more closely with the literature around powerful learning and critical pedagogy.

Our findings of relationships between each of the conceptualizations of learning and unique sets of practices as seen through complex conceptual systems theory provides evidence that practices are emergent phenomena. The practices that have been endorsed by educational researchers through empirical studies may not have an impact at larger scales unless we also communicate the conceptualizations of learning in which such practices were emergent. Educational researchers and educators may also need to develop cultural change strategies designed to produce widespread movement away from conceptualizations of learning in which counter-productive practices emerge.

Complex conceptual systems analysis is a new theoretical framework (Donaldson, 2019; Donaldson & Allen-Handy, 2020) which considers conceptualizations as complex systems, and this study represents an early attempt at an innovative research methodology. Future studies to develop complex conceptual systems theory and methodology will be needed in order to better understand conceptualizations of learning, particularly studies around system equilibrium, system stability, system robustness, and the nature of feedback loops within the system (Yoon, 2018).

We found that conceptualizations of learning among the learning scientists in this study were different than conceptualizations of learning among the STEM educators, and evidence that conceptualizations of learning function as complex systems from which emergent phenomena arise in terms of practices, language usage, perception, and values regarding teaching and learning. In this framework, conceptualizations are not characteristics of individual human beings, nor are they solely characteristics of social groups. Rather, they are context-dependent and partially characteristic of individuals and partially distributed among groups of individuals and their practices, tools, and interactions.

The conceptualizations of learning found in this study aligned with two unique sets of practices in teaching and learning. In other words, how we conceptualize learning is inextricably related to how we go about “doing” learning: the things we do when we try to learn, the things we do as educators, and the learning environments and activities we design. This suggests that in order for findings of studies by educational researchers to be adopted broadly work must be done to help educators, designers, policymakers, and students reconceptualize learning to better

align with conceptualizations of learning in which such findings and associated practices are grounded—and more importantly, to help them construct more empowering conceptualizations of learning. This work of problematizing and reconceptualizing our ideas about the nature of learning is by no means a simple task. Because conceptualizations of learning are complex systems, intentional strategies for conceptual change must simultaneously address the numerous and intricately interacting elements of the complex system with sustained effort over extended periods of time.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.ijedro.2023.100254](https://doi.org/10.1016/j.ijedro.2023.100254).

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