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A design framework for enhancing engagement in student-centered learning: own it, learn it, and share it

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Abstract Student-centered learning (SCL) identifies students as the owners of their learning. While SCL is increasingly discussed in K-12 and higher education, researchers and practitioners lack current and comprehensive framework to design, develop, and implement SCL. We examine the implications of theory and research-based evidence to inform those who seek clear guidelines to support students' engagement and autonomous learning. SCL is rooted in constructivist and constructionist as well as self-determination theories. Constructs of these theories have been studied respectively; however, the intersections among the three theories require further exploration. First, we identify autonomy, scaffolding, and audience as key constructs of SCL engagement. Then, we propose a design framework that encompasses motivational, cognitive, social, and affective aspects of learning: Own it, Learn it, and Share it. It is recommended that students: (a) develop ownership over the process and achieve personally meaningful learning goals; (b) learn autonomously through metacognitive, procedural, conceptual, and strategic scaffolding; and (c) generate artifacts aimed at authentic audiences beyond the classroom assessment. Furthermore, we suggest ten design guidelines under the framework and conclude with questions for future research.

Keywords Student-centered learning · Constructivism · Constructionism · Self-determination theory · Autonomy · Scaffolding

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Introduction

Student-centered-learning (SCL) is a learning approach during which students generate learning opportunities and reconstruct knowledge dynamically in an open-ended learning environment (Hannafin et al. 2014). As the name suggests, students assume increased autonomy and responsibility for their own learning. Often, students identify individual learning goals to pursue external goals. Students build on unique background knowledge and experiences and further explore, select, and use tools and resources. Students navigate unspecified paths, monitor progress, and develop personal strategies. Whether an individual or a group project, students communicate and consult with others (Bransford et al. 2000; Brush and Saye 2000; Hannafin et al. 2014).

We argued that SCL is a complex learning process that students must be thoroughly supported in the motivational, cognitive, and social aspects. A common but poorly supported SCL assumption is that students will perform independently without external guidance (Hannafin et al. 2014). Instead, students should be scaffolded through the process from owning the project, researching for the project, and sharing the project outcomes. According to McCombs and Whisler (1997), learner-centered approaches focused on how to support unique individuality of varying interests, needs, capacities, backgrounds, and perspectives.

In pursuit of a SCL framework, nearly two decades ago, Grabinger and Dunlap (1995) promoted the Rich Environments for Active Learning (REAL) model in which students assumed increased ownership, engaged in multiple higher-order thinking activities, and articulated and present an artifact. More recently, Casey (2013) presented a SCL framework that focused on the social aspect of SCL capitalizing active learning and peer support via social media. Keller's ARCS model (Keller 1987) provided a motivational design approach to instruction to systemically enhance attention, relevance, confidence, and satisfaction. Previous design frameworks for learning and instruction have not adequately embodied the intersections of the key motivational, cognitive, social, and affective constructs afforded by emerging technologies. Particularly, existing frameworks typically failed to scaffold student autonomy.

We propose an alternative SCL design framework that encompasses motivational, cognitive, social, and affective aspects of learning. We identify key constructs of SCL engagement as (a) autonomy from Self-Determination Theory (Ryan and Deci 2000), (b) scaffolding from constructivism (Vygotsky 1978), and (c) authentic audience from Constructionism (Harel and Papert 1991). We examine previous research on autonomy, scaffolding, and audience and apply efforts to promote enhanced engagement by adapting these principles in the Own it, Learn it, and Share it (OLSit) framework. As we support students to be fully engaged, we acknowledge and maximize the autonomy of students while providing appropriate scaffolding and capitalizing on emerging Web 2.0 technologies.

This paper aims to provide a conceptual framework and practical guidelines to the researchers and practitioners who seek to enhance student engagement with SCL. We first review chronological emergence of SCL and examine the characteristics of SCL. Then, we examine Self-Determination Theory and constructivist-and constructionist-inspired epistemologies and key constructs. Furthermore, we present the OLSit model and research-based design guidelines to support instructors' and students' efforts to create autonomous

learning climate and scaffold the process of developing an artifact for an authentic audience. We conclude by discussing remaining questions and needs for future research.

Emergence and characteristics of student-centered learning

Expectations of student engagement vary in the industrial age and the emerging information society. In the industrial age, behavioral and cognitivist-inspired approaches defined performance requirements across education and workforce populations. Traditionally, curriculum and teaching methods were characterized as emphasizing compliant understanding (McCaslin and Good 1992), expecting and receiving explicit directions from instructors, and documenting concordance with external expectations. In externally directed learning, many consider student engagement to be needlessly passive, focusing on narrowly prescribed outcomes over depth of individual understanding or independent learning (Maclellan and Soden 2003).

In contrast, The current and approaching information society demands flexible, adaptive skills and abilities. We now expect the workforce to reason dynamically and critically, make informed decisions, solve unknown problems, and work collaboratively to address unanticipated priorities (ISTE 2015). We cannot be certain which challenges will emerge and under what circumstances the workforce will need to adapt. It is therefore critical that formal educational systems prepare students to negotiate and resolve future uncertainties. Hence, SCL has been touted as a needed alternative to traditional, teacher-centered instruction to develop the flexible, adaptive skills essential in the 21st century workforce (Clinton and Rieber 2010; Land et al. 2012).

Since expectations of student engagement are different in age and society, researchers suggest different approaches to learning. Behaviorists such as Thorndike and Skinner advocated and applied human learning in the form of stimuli-response-reinforcement systems (Driscoll 2000). As represented in "cats in puzzle boxes," when desired responses were rewarded, learned behaviors were reinforced. Conversely, when responses were not rewarded or punished, undesired responses extinguished (Thorndike 1911). Learning from the objectivist epistemology practiced in the form of receiving, storing, and recalling information given from external sources (e.g., instructors) (Jonassen 1991).

From a different perspective of constructivist epistemology, students do not passively receive and process information. Rather, they actively construct knowledge and skills and reorganize their understanding via interactions with their environment as well as other encounters and past experiences (Jonassen 1991). Historically, Dewey (1916) described learning as "that reconstruction or reorganization of experience which adds to the meaning of experience, and which increases ability to direct the course of subsequent experience" (p. 76). Subsequently, Dewey (1938) advocated the need for providing students with opportunities to test hypotheses and explore issues more critically. Piaget's (1954) cognitive approaches to education highlighted person-environment interaction. A. Aebli enunciated Piaget's theory in the form of discovery learning: "creating a free, problem-solving situation whereby the learner selects a task and is free to do what he (or she) likes to complete it. The teacher may intervene by asking appropriate questions so the student can develop hypotheses and test them" (as cited in Saettler 1990. p. 329). Vygotsky (1978) discussed that learning was a social process in which students explored concepts that were of interest to them, and negotiated the meaning of those concepts with others.

These constructivist epistemologies have been reified as SCL. Glasgow (1997) described SCL as in which: "students learn to decide what they need to know to find success within the class and educational format. Although the teacher may have considerable responsibility in facilitating investigative and discovery activities, it is expected that the student will gradually take responsibility for their own learning (p. 34)." Brush and Saye (2000) noted that SCL is designed for students to assume a more active role in their learning by assuming responsibilities to organize, analyze, and synthesize rather than merely acquired content from the teacher. Students, in effect, are empowered to refine their learning processes with support from teachers and peers (Estes 2004).

SCL has been described using various names that follow problem-based learning (Barrows 1980), project-based learning (Blumenfeld et al. 1991), case-based learning (Christensen 1987), and inquiry learning (Kuhn et al. 2000). In a problem-based learning approach, students work collaboratively in a group to identify what and how to learn in order to solve a problem; students learn in a self-directed manner, devise and test a plausible solution, and reflect on what they have learned and the effectiveness of their solution (Hmelo-Silver 2004). Typically in project-based learning, students are engaged in a challenging, complex project that is similar to those they might encounter in the real world (Brush and Saye 2000). In a case-based approach, students review a realistic scenario that represents the problem to solve, discuss it with peers, evaluate the proposed solutions, and reflect on what is learned and what needs to be learned (Flynn and Klein 2001). Fundamentally, therefore, students process, interpret, and refine meaning and understanding based on individual experiences.

Instruction vs. learning environment

SCL highlights the importance of the organic *learning environments* over traditional instruction. Table 1 contrasts traditional direct instruction with SCL approaches.

As contrasted in Table 1, SCL is neither rigidly prescribed nor strictly externally structured. Learning environments focus on knowledge acquisition, individual's reasoning and understanding of key concepts, or different combinations. The importance of understanding and reasoning resides within the individual who may address externally-required

Table 1 Comparison between directed instruction and student-centered learning

	Directed instruction	Student-centered learning
Theoretical framework	Objectivism	Constructivism
Nature of learning	Students process specified content	Students construct knowledge by exploring and analyzing
Methods	Directed learning	Scaffolded learning
Content	Well-defined	Ill-defined
Learning goals	Defined by curriculum or teacher	Negotiated and endorsed by students
Student's roles	Knowledge receiver	Knowledge generator and evaluator
Teacher's roles	Knowledge transmitter	Facilitator, scaffolding provider
Locus of control	External	Internal

Adapted from Jonassen (1991)

learning goals or initiate and pursue their own learning goals. In effect, students determine the means to pursue external as well as individual learning goals, including making decisions about how, when, and whether to proceed based on emergent understanding (Hannafin et al. 2014). In contrast, during direct instruction, designers and instructors prescribe paths to follow (Merrill 2002). They establish instructional objectives, select resources, provide the context, organize the content, and specify and assess canonical understanding based on external requirements.

SCL, therefore, requires a paradigm shift for both students and instructors' roles during learning. Students' roles transform from recipient of information to owners of learning goals, decisions, and actions. Consequently, instructors need to learn how to relinquish control and support students to become the owner of their learning. Both students and instructors must be supported to realize this transformation. Students may be ill-prepared to assume greater autonomy for their learning: "accustomed to more passive roles in the college lecture hall may initially resist the active requirements of constructivist pedagogy" (Reeves 2006, p. 304). College students who have benefited from producing externally-based outcomes via didactic instruction often encounter difficulty when teaching and learning approaches assume or require greater individual mediation (Kember 2001).

Likewise, instructors may question the value or effectiveness of student-centered pedagogical approaches (Kember 1997) or lack strategies to engage students in self-directed learning (Blumberg 2009). Classroom methods, in turn, influence students' expectations and learning strategies as well as outcomes (Kember and Gow 1994) and epistemologies (Sheppard and Gilbert 1991). Reconciliation of alternative roles is "teachable and learnable" but requires the ability and willingness to identify differences between instructor and student epistemological beliefs about teaching and learning and "willingness to adapt strategies accordingly" (Song et al. 2007, p. 35).

The debate

Contemporary scholars have disputed the effectiveness of these "discovery" approaches to learning. Mayer (2004) reviewed a half-decade of past research and reported consistent evidence in favor of fully-guided direct instruction as opposed to "pure discovery learning." Kirschner et al. (2006) analyzed inquiry-based learning research in K-12 mathematics and science education and problem-based learning in medical education and concluded that these "minimally guided" approaches are not compatible with human cognitive architecture and less effective and inefficient than instruction that is designed with explicit cognitive guidance (Kirschner et al. 2006). Sweller (2009) argued that the skills needed for discovery, problem-based, inquiry-based learning evolve immaturely and must be explicitly taught. In effect, Clark argued that maximum guidance is effective for all types of learning regardless of its goals and context (Clark and Hannafin 2011).

Contrastingly, proponents of constructivist learning responded that problem-based learning was designed with flexible adaption of guidance and management of cognitive load and was compatible with human cognitive structure (Hmelo-Silver et al. 2007). Schmidt et al. (2007) added that constructivist learning approaches are not minimally guided; rather, they provide extensive scaffolding and guidance to facilitate student learning. Additionally, de Jong (2010) proposed that existing research on cognitive load needed to be extended to explore approaches to help learners manage cognitive load during SCL.

Furthermore, from the instructional design perspectives, constructivist approaches have been criticized to be ineffective to support externally defined objectives with ordered paths

(Dick 1992; Merrill 1991). In actuality, learning may occur spontaneously in the absence of previously established external goals and paths. Kuhn (2007) clarified that direct instruction could address highly structured, well-defined problems; however, students should be prepared for real world, complex, messy, and ill-structured problems in which no neatly packaged solution paths are available. Hannafin noted that "optimally guided learning," not fully-guided direct instruction, employs an adaptive approach to guidance to accommodate differences in individual needs as some learning situations and performance requirements are difficult or impossible to identify explicitly in advance (Clark and Hannafin 2011).

The emergence and characteristics of SCL can be further understood by its theories. Constructs of constructivist learning have been studied. However, the design implications for how to facilitate SCL in the umbrella of constructivist, constructionist, and Self-determination theory collectively are new. Therefore, we review literature derived from Self-determination theory and constructivist-and constructionist-inspired epistemologies and examine the synthesized effects of the key engagement constructs from each theory. Then, we present the new design framework and research-based design guidelines for the implementation of the framework.

Theoretical framework

SCL engagement is supported by theories that encompass motivational, cognitive, social, and affective aspects of learning. Self-determination theory provides explanations about how autonomy plays a key role as a motivational factor in SCL. Constructivism offers an underpinning epistemology about how learners negotiate their learning to construct meaning, particularly with regard to the role of scaffolding to facilitate learning. Constructionists note that students invest affectively in personally meaningful projects that involve design, development, and presentation of artifacts relevant for authentic audiences. In the following section, we describe their underlying epistemologies and associated assumptions as well as their implications for autonomy, scaffolding, and authentic audiences in the design of SCL.

Self-determination theory

Self-determination theory (SDT) highlights autonomy, competence, and relatedness as basic human needs to influence high quality motivation (Ryan and Deci 2000). According to SDT, behaviors vary in relation to the degree to which they are mediated autonomously versus externally. Motivation ranges from controlled, extrinsic motivation through increasingly autonomous level to intrinsic motivation (Ryan and Deci 2000). Ryan and Deci further note that intrinsic motivation, the most autonomous form, is directly associated with individual satisfaction and autonomy. Autonomous behaviors emanate from one's integrated sense of self, are experienced as volitional, and reflect interest or personal importance (Deci and Ryan 2000).

SDT provides a key frame to understanding the influence of autonomy during learning. Ryan and Deci (2000) argued that intrinsically motivated individuals strive to extend their ability and enjoy doing the activity itself. Intrinsically motivated activities include those that individuals find interesting and would pursue even in the absence of externally imposed pressure (Ryan and Deci 2000). When intrinsically motivated, students tend to set

goals to understand a task, acquire new knowledge, and develop their abilities. Intrinsically motivated, autonomous behaviors help to engage students in deep, individual, meaningful processing. Students who pursue intrinsic goals tend to engage their learning tasks more actively than those who pursue primarily external affirmation, recognition by instructors, or avoidance of negative consequences (Meece et al. 1988).

In contrast, when extrinsically motivated, individuals act in accordance with external requirements rather than the individual's perceived value of learning (Deci and Ryan 2000). Extrinsically-motivated performance goals emphasize demonstrated competence in defined outcomes. External forces may confound relationships between individual student needs and their outcomes, particularly when learning tasks involve flexible, heuristic, creative, or autonomous motivation for successful performance (Deci et al. 1999). However, distinctions between autonomous and controlled motivation do not adequately account for the complexities and intricacies of academic motivation (Alexander 1997). Interactions between autonomous and controlled motivation influence students' learning and performance in SCL.

In effect, SDT suggests that individual autonomy enhances volition, motivation, and engagement and enhances performance, persistence, and creativity (Deci and Ryan 2000). When students solve complex problems that require creativity and flexibility, intrinsic motivation and combined strategies tends to enhance performance more than externally-based performance goals alone (Deci and Ryan 2000). When students make autonomous decisions, they assume greater responsibility for directing their learning, become more personally engaged, and deepen their understanding (Ryan and Deci 2000). Accordingly, SCL promote opportunities to cultivate individual responsibility for engaging learning opportunities, which enhances academic performance as well as student autonomy.

Constructivism

Constructivism is not a single, unified theory; rather, constructivism represents an epistemological perspective as to the nature and evolution of individual understanding. Schunk (1991) explains, "constructivism does not propound that learning principles exist and are to be discovered and tested, but rather learners create their own learning" (p. 236). Despite ongoing debates related to ontological assumptions and nomenclature, constructivism provides assumptions underlying SCL (Sharma et al. 2008).

Constructivist learning involves iterative processes of discovery as students use their own mind to obtain knowledge for themselves and "rearranging or transforming evidence" to assemble "additional new insights" (Bruner 1961, p. 22). Constructivism variants commonly suggest that learner, context, and understanding are connected and interdependent (Gauvain 2001; Lave 1988; Rogoff 1990). Further, social constructivism suggests that students interact reciprocally with peers and more knowledgeable others to support richer understanding than is possible individually (Vygotsky 1978).

During SCL, students experience diverse models and feedback on their actions, which subsequently promote interaction between the student and others. Students communicate their ideas and make their thoughts explicit; they examine both their own perceptions and others' views and react accordingly. Thus SCL activities would engage students in a challenging, real-life task, with technology as a tool for learning, communication, and collaboration. These activities would provide students with opportunities to view problems from a variety of perspectives, allow students to collaborate and negotiate solutions to problems, and test those solutions within a real-world context (Bransford et al. 2000; Hannafin et al. 1999).

Constructionism

Constructionism is similar to constructivism in that students actively "construct" rather than simply receive, store, and retrieve knowledge. Bruner's early emphasis on learning by discovery was subsequently refined and extended to learning by negotiating and sharing (Bruner 1986). Bruner (1986) characterized learning as "a communal activity, a sharing of the culture" (p. 127). Students individually internalize knowledge within communities that include others who share their sense of belonging to a culture (Bruner 1986).

However, constructionism differs from constructivism as constructionism highlights the hands-on construction of physical artifacts that communicate one's understanding (Ackermann 2001). Extended from Piaget's constructivism, which viewed learning as the process whereby students construct their own unique systems of understanding, Papert focused on projecting one's understanding in a public entity (Harel and Papert 1991).

Constructionists produce external and shareable artifacts, reflecting the belief that "constructivist processes are more evident when students collaborate to produce and share representations of their understanding of the world" (Jonassen et al. 1996, p. 94). Students become designers whose artifacts reflect complex cognitive negotiations with external constraints. Activities such as making, building, programming, teaching, and consulting provide rich contexts for learning; products from these construction activities reflect and embody student learning (Harel and Papert 1991). Failure, reflection, and iterative revisions refine understanding of concepts and associated skills and practices (Kolodner et al. 2003).

Constructionists also note that learning occurs both during the design process as well as through sharing products. Constructionist learning environments create a culture and community as students share one another's creations and gain a deeper understanding of other people's perspectives about the product and ideas related to the product (Evard 1996). Environments promote learning by doing as well as learning by thinking and discussing what you do (Kafai and Resnick 1996). Products require students to represent their thinking explicitly.

Finally, constructionists regard affect as critical for learning, whereas constructivists focus principally on cognitive development (Kafai and Resnick 1996). Constructionists suggest that students become intellectually engaged when they work on personally meaningful activities and projects and thus become personally invested. This enthusiasm influences both students' attitudes toward the subject matter as well as their performance (Harel and Papert 1991). Students become cognitively and emotionally engaged as they employ resources in a social context and design and refine both their understanding and artifact (Price and Marshall 2013).

According to constructionist, learning is an iterative process in which students "invent for themselves the tools and mediations that best support the exploration of what they most care about" (Ackermann 2001, p. 4). Accordingly, a student's responsibility for individual understanding increases as associated ownership of both learning processes and products increase (Grabinger and Dunlap 1995). Thus, the learning environment should support individual efforts as students construct personal meaning through artifact development (Wilson 1996). In the following section, we discuss how autonomy, scaffolding, and

authentic audiences are applied in SCL and present a framework for supporting autonomy, designing scaffolds, and incorporating authentic audiences.

Assumptions of student-centered learning

Synthesizing the theories previously reviewed, we extract the key constructs of engagement for SCL: autonomy, scaffolding, and audience. While existing literature has presented the effects of each key construct in an isolated manner, no previous research has synthesized the effects of the three constructs combined for the purpose of enhancing engagement in SCL. Table 2 summarizes the contributions of the key constructs to learning and the evidence of its influence in student engagement from previous research.

Autonomy

We adapted Deci and Ryan's study (2000) to define autonomy as one's self-endorsed will to make one's own decisions and take voluntary actions. Autonomy is considered an important factor across all facets of human living, including educational settings as well as workplaces, health, sports, and leisure. Autonomy fosters affective benefits, such as engagement, satisfaction, happiness, and wellbeing. When individuals perceive autonomy, they believe their action supports their own will, choices, and self-determination (Ryan and Deci 2006).

Autonomy has been associated with locus of control by personality theorists (e.g., Rotter 1966). When individuals perceive internal control, they believe they control events that affect their lives; the outcomes of their actions result from their own decisions and abilities. In contrast, when control is perceived as externally regulated, individuals believe they have limited influence on outcomes. They perceive future success or failure depends on external circumstances beyond their control, such as task- difficulty or luck (Rotter 1975). Rather than only internal or external perceived control, individuals may perceive combinations of control, referred to as Bi-locals. Bi-locals may take personal responsibility for their actions and the consequences thereof while remaining susceptive to cooperating with external resources (Palenzuela 1984). The perceived locus of control may well explain different psychological influences of autonomy in educational settings.

To imply in the SCL framework, autonomy is important to ensure that students own their learning processes. Students mediate learning processes when they determine and accomplish learning goals; instructors, in effect, support rather than dictate learning responsibility (Dochy et al. 2003). By varying the locus of perceived control, students maintain personal responsibility for learning as they utilize external resources. As depicted in Fig. 1 autonomy supports two roles in SCL: sovereignty and responsibility. In terms of sovereignty, students assume the power and control to determine learning goals, decisions, and actions required to achieve those goals. When encouraged to make decisions, students perceive it as taking control of their learning and develop personal ownership. For responsibility, students become accountable for the consequences of their goals, decisions, and actions. They assume responsibility for managing their learning processes and project completion.

Designers and practitioners of SCL should incorporate the notion of autonomy with caution. Autonomy is not synonymous with independence, but rather involves how self-determination reflects one's will. Autonomy is not only limited to independent initiatives,

Table 2 Description of engagement constructs of student-centered learning environments

Constructs	Contribution to learning	Supporting literature
Autonomy	Students have an internal locus of control	Behaviors emanate from an integrated sense of self, are volitional, and are guided by interest or personal importance (Deci and Ryan 2000)
	Autonomy influences positively on academic performance	A mastery goal leads to better performance than having performance goals (Meece et al. 1988) Autonomous goals yield positive effects on college students' academic performance (Acee et al. 2012) Autonomy fosters a high level of volition, motivation, and engagement and results in enhanced performance, persistence, and creativity (Deci and Ryan 2000)
	Students can feel autonomous even when engaged in an imposed activity	Autonomous behavior is not limited to independent initiatives (Ricoeur 1966; Dworkin 1988; Reeve et al. 2002; Jang 2008)
	Teachers should support student autonomy	Teacher's autonomy support is favorably related to students' engagement, concentration, better time management, self-regulation, and higher performance (Jang et al. 2010; Reeve 2006)
	Autonomy support and structure should be provided together	When combined with structured guidance, autonomy support is effective in fostering students' self-regulation (Reeve et al. 2004; Sierens et al. 2009) Providing both autonomy support and structure yielded positive effects on intrinsic motivation and learning outcomes (van Loon et al. 2012)
Scaffolding	Provide multiple and extensive support	Scaffolding is provided to support procedural, conceptual, metacognitive, and strategic performances separately or combined (Hannafin et al. 1999; Weigend 2014) Providing extensive metacognitive support serve students more effectively than minimal or intermediate support (Rodicio et al. 2013)
	Scaffold until students can function without it	When student demonstrates competence, scaffold is withdrawn to promote independent functioning (Vygotsky 1978)
	Procedural scaffolds walk through the process	Students were provided detailed instructions on what to do and how to do it for each science problem solving activity (Oliver and Hannafin 2000; Davis and Linn 2000)
	Conceptual scaffolding helps determine how new content can be organized	A study guide and a concept map template scaffolded 5th graders' collection of relevant information and to connect information associated with the WebQuest topic. (MacGregor and Lou 2004) Students who received knowledge integration scaffolds made intentional efforts to identify concepts and relationships and performed significantly better when developing and justifying solutions and considering alternatives (Chen and Bradshaw 2007)

Table 2 continued

Constructs	Contribution to learning	Supporting literature
	Strategic scaffolds support approaching and resolving challenges and considering multiple perspectives	Expert modeling of thinking processes enables novices to embrace alternative strategies (Pedersen and Liu 2002) Peer interaction during problem solving enables identifying alternative views, building upon others' ideas to develop solutions, considering more information, and offering suggestions and feedback (Ge and Land 2003) Reflections on others' ideas encourage identifying one's own weaknesses and modifying the approach to the activity (Choi et al. 2005)
	Metacognitive scaffolds guide in goal setting, planning, organizing, self-monitoring, and self-evaluation at various points	Eighth graders who received conceptual and metacognitive scaffolding wrote better articles and exhibited more task-focused and self-directed behaviors (Wolf et al. 2003) College students received metacognitive prompts via peer feedback monitored learning and adapted strategies and were likely to plan, evaluate, and revise their assignment (Kim and Ryu 2013)
	Scaffolding can be dynamic or static	Static scaffolding has proven effective in learning basic information but often ineffective in promoting the reasoning and thinking skills (Kim and Hannafin 2011) College students who received adaptive advice for complex problem solving outperformed those who received advice from the virtual teacher at fixed time intervals (Clarebout and Elen 2006) Students who received dynamic scaffolds demonstrated increased activation of prior knowledge, greater changes in mental models, more frequent and regulated planning and monitoring of progress, and help seeking and effective strategy (Azevedo 2005)
	Instructors, peers, and technology can offer scaffolds separately or together	Fourth grade students' peer feedback and social processing through appropriate technology enhance engagement and learning (Roschelle et al. 2010) College students using the Web-based formative peer assessment (WFPAS) performed better and displayed higher level of reflection and self-regulatory skills (Kim and Ryu 2013)
Audience	Students' motivation is enhanced when constructing artifacts for authentic audiences	Seventh-grade students performed better when their paper was intended for peers at distance than for instructors (Cohen and Riel 1989) Native Spanish-speaking students preferred blogging than traditional writing and demonstrated improved fluency and grammatical improvements (Montero-Fleta and Pérez-Sabater 2010) Elementary and secondary students, who produced digital videos and shared with their peers, demonstrated increased autonomy and task ownership (Kearney and Schuck 2006)

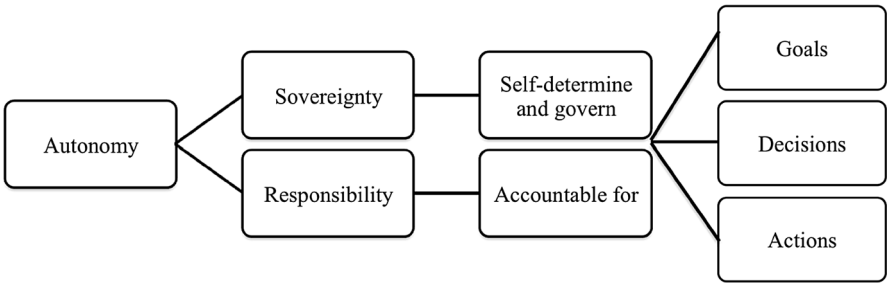

Fig. 1 The role of autonomy in student-centered learning (adapted from Deci and Ryan 2000)

but also applies to actions evoked voluntarily to address external expectations, rules, and pressures (Ricoeur 1966; Reeve et al. 2002). Similarly, autonomy does not necessarily equate to acting without regard to constraints or demands (Dworkin 1988). An individual may exhibit self-determination even when acting in accordance with external demands when he or she fully concurs with or endorses the value of the activity (Ryan and Deci 2006).

Furthermore, autonomy does not suggest an infinite number of options, choices, or decisions to make. Schwartz (2000) suggested that having too many options may prove counterproductive. Ryan and Deci (2006) clarified that SDT advocates facilitating the individual's experience of volition rather than providing unlimited choice options. One can have many options yet fail to perceive autonomy, instead feeling resentful toward investing effort associated with decision-making. Alternatively, providing only a single option may improve perceived autonomy when one truly endorses that option. Fostering autonomous motivation involves more than providing opportunities for making individual choices and decisions; autonomy involves endorsement of the activities in which one engages.

Autonomy support facilitates a student's pursuit of individual goals and their endorsement of externally assigned activities. Reeve and Jang (2006) defined autonomy support as "the interpersonal behavior one person provides to involve and nurture another person's internally locused, volitional intentions to act" (p. 210). Students perceive autonomy in their learning when teachers support their interests, preferences, values, and psychological needs (Deci and Ryan 2000). Supportive learning environments provide a compelling rationale for why and how assignments are designed; provide opportunities to make individually relevant and interesting choices so students express psychological needs and integrate them into the classroom activities; allow time to work on a problem in individual ways; empathize with students' perspectives; and avoid externally-controlling languages (e.g., "you must") (Reeve and Jang 2006).

Several researchers have documented the positive influence of teacher's autonomy support on students' engagement, concentration, time management, self-regulation, and academic performance (Jang et al. 2010; Reeve 2006). Students may evolve and exhibit emotional connections with instructors who support their autonomy (Ryan et al. 2005). In one college organic chemistry class, perceptions of instructor autonomy support were associated with increases in student autonomous self-regulation, perceived competence, and interest and enjoyment, and corresponding decreases in anxiety. Changes in autonomous self-regulation, in turn, were positively associated with students' course performance (Black and Deci 2000).

Related research indicates that autonomy support is also enhanced by providing structure, which is translated to scaffolding in SCL. When combined with scaffolding, autonomy support proved effective in fostering students' self-regulation (Reeve et al. 2004; Sierens et al. 2009). Among elementary school students engaged in a digital learning task, providing both autonomy support and structure yielded positive effects on both intrinsic motivation and learning outcomes (van Loon et al. 2012). This suggests that when instructors provide guidance, directions, and expectations in autonomy-supportive ways, they promote student engagement in student-centered learning and obtain desired learning outcomes. Conversely, when autonomous motivation is undermined, performance decreases especially when applied to flexible, heuristic, creative, or complex capacities (Deci et al. 1999). Therefore, autonomy is paramount where students engage complex problems that require more than recall of basic knowledge and skills.

Scaffolding

Scaffolding refers to guidance provided to support one's independent functioning (Vygotsky 1978). The concept of scaffolding in education adopted the metaphor of scaffolding from architectural construction. A temporary structure supports on the outside of a building. As the building is gradually built permanently, the scaffold is removed. More knowledgeable others (instructors, peers, experts, or technology resources) guide and support an individual's learning. Scaffolds make available the knowledge, skill, strategies, and expertise of more knowledgeable others. When the individual demonstrates an acceptable level of competence, the scaffold is gradually faded to promote independent functioning.

Scaffolding is vital to students' success during SCL (Raes et al. 2012). Many students, especially novices with limited background and experience in a domain, require explicit structure to make sense of content, make informed decisions, monitor their progress, and adapt to emergent challenges. Scaffolding assists students to participate meaningfully by supporting efforts to identify relevant goals, pursue and monitor progress toward those goals, reconcile differences between existing understanding and concepts yet to be learned, and construct and refine artifacts (Hannafin et al. 2009). Scaffolding during SCL takes a wide array of strategies including providing discovery questions, peer feedback, architectural solutions, explicit information, and step-by-step instructions (Azevedo and Hadwin 2005; Brush and Saye 2000; Sharma and Hannafin 2007; Weigend 2014).

Scaffolding sources may include peers, instructors, and technology. It can be more effective when scaffolding sources are provided together rather than applied separately. Roschelle et al. (2010) tested a mixed (peer and technology) scaffold with social incentives to ask questions, give explanations, and discuss disagreements about mathematics among peers. Fourth grade students who worked with peers in social activities using handheld networked devices performed superior on fraction problem solving than those who worked alone or on a desktop computer, suggesting group feedback and social processing through appropriate technology enhance engagement and learning. Similarly, Kim and Ryu's (2013) study also revealed that the combination of technology and peer scaffolding was more effective than either source alone. Students using the Web-based formative peer assessment (WFPAS) technology demonstrated higher levels of reflection and self-regulatory skills and performed better than those who engaged in peer feedback activity without assistance of WFPAS.

Some scaffolds adapt to dynamic changes in the state of student understanding per individual needs and progress. Others are static (fixed) within the environment and do not

evolve to accommodate shifting needs of individuals (Kim and Hannafin 2011). In Azevedo's study (2005) on the effects of scaffolding on self-regulated learning, students who received dynamic scaffolds demonstrated increased activation of prior knowledge, greater changes in mental models, more frequent and regulated planning and monitoring of progress toward learning goals, and help seeking and effective strategy use than those who received either fixed or no scaffolding. Clarebout and Elen (2006) compared dynamic with static pedagogical agents to support complex problem solving skills in an open-ended learning environment. College students who received adaptive (dynamic) advice outperformed those who received advice at fixed time intervals.

Scaffolding purposes have been categorized as *procedural* (how to use learning environment features), *conceptual* (what knowledge to consider), *metacognitive* (how to think about the problem), and *strategic* (what the alternative strategies are) (Hannafin et al. 1999). Procedural scaffolds focus on operational, how-to features of the learning environment (Hannafin et al. 1999) and provide cognitive structure to assist students in completing tasks (Sharma and Hannafin 2007). This scaffolding function reduces the learners' cognitive load by providing step-by-step directions and directs their attention to important aspects of the task. Procedural scaffolds are most effective when applied in combination with complementary scaffolds. Davis and Linn (2000) scaffolded eighth graders' completion of specific science problem-solving activities, such as analyzing and critiquing claims. Although activity prompts helped students complete the activity, they engendered fragmented knowledge of individual steps rather than the connections between and among the separate steps. Not only procedural but also conceptual and strategic scaffolds were needed to deepen the understanding of knowledge and strategies involved in the inquiry.

Conceptual scaffolds assist in linking and organizing knowledge related to a topic. This helps students to determine what they already know, what they need to learn, how existing knowledge and to-be-learned content are related, and how new content can be organized with respect to domain knowledge (Bulu and Pedersen 2010). For example, MacGregor and Lou (2004) examined the influence of a conceptual scaffold on fifth graders' WebQuest inquiries. The authors used a study guide and a concept map template to scaffold the collection of relevant information and to connect information associated with the WebQuest topic. They reported that the study guide scaffold helped to identify the information needed to populate the concept map template by providing organizing and synthesizing cues. For college students in other studies, Chen and Bradshaw's (2007) knowledge integration scaffolds emphasized critiquing, interpreting, and explaining key concepts in educational measurement. Undergraduate students read an instructional passage on reliability and validity as they worked to address an ill-structured problem. Students who received knowledge integration scaffolds made intentional efforts to identify concepts and relationships and performed significantly better when developing and justifying solutions and considering alternatives.

Strategic scaffolds support individuals as they address challenges and consider multiple alternatives (Kim and Hannafin 2011) by stimulating consideration of alternative strategies. Pedersen and Liu (2002), for example, examined the influence of an expert-based tool on sixth graders' performance on solving novel science problems during *Alien Rescue*. They compared three conditions: (a) modeling cognitive thinking process, (b) providing didactic instructions on strategy use, and (c) giving strategic advice. The modeling group posed significantly more relevant questions and performed significantly better than the other two groups. Among novices, strategic scaffolding in the form of expert modeling enabled students to apply approaches employed by experts. Ge and Land (2003) examined the effects of peer interaction on undergraduates' information system design processes. By

working in groups, the students were able to identify alternative views on the problem, build upon one another's ideas to develop solutions, consider more factors and information, and offer suggestions and feedback. Reflections on others' perspectives encourage students to assess potential shortcomings in their individual approaches and eventually modify their approach to ultimately improve performance (Choi et al. 2005).

Metacognitive scaffolds guide students in goal setting, planning, organizing, self-monitoring, and self-evaluation (Zimmerman 1990). Metacognitive scaffolds can support the development of two critical skills: domain knowledge acquisition and general self-regulatory strategies. Studies found that providing extensive metacognitive support serve students in transfer and retention of complex conceptual knowledge more effectively than minimal or intermediate support (Rodicio et al. 2013). Wolf et al. (2003) provided metacognitive scaffolds to support eighth graders' writing of a historical event. They used domain specific guides that directed students to consider significant aspects of the event as well as self-regulatory guides that prompted them to reflect on progress and plan for subsequent activities. Their findings indicated that students who received scaffolding both wrote better accounts of the events and exhibited more task-focused and self-directed behaviors than those who did not.

Authentic audiences

Consistent with constructionist epistemology, artifacts resulted from SCL should be shared with authentic, real world audiences. Authentic audiences are for whom student artifacts are designed, and they actually view, use, and critique the artifact. Traditionally, the typical audience of student work is the student's teacher. The teacher assesses the student's submission, and the artifact is not put to use beyond receiving a grade. Student artifact created for the real world audience vitalizes the authentic, lasting value beyond the teacher and the classroom.

The value of student artifacts is enhanced when they address real-world issues and specific purposes (Wigfield and Eccles 2000). For example, Cohen and Riel (1989) compared students' writing for a course requirement with writing to peers at a distance. Seventh-grade students wrote two compositions on the same topic, one addressed to peers in other countries and the other only to their teacher. Significantly higher ratings were reported for papers designed to communicate with peers than those written to demonstrate their skills to the teacher.

To solidify the authentic use of artifacts, artifacts can be disseminated to and used by other students in class, future students, and the society at large as well as globally. Kearney and Schuck (2006) described the influence of sharing student-generated videos among elementary and secondary schools in Australia. Student groups produced and subsequently shared digital videos with their peers. The findings indicated increased student autonomy and task ownership; recognition of authentic audiences was identified as a significant influence on the students' motivation.

Social media such as blogs, YouTube, Facebook, Slideshare, and Prezi have increased accessibility of artifacts worldwide and invite comments and annotations across authors. Montero-Fleta and Pérez-Sabater (2010) reported positive academic and motivational effects of student blogging in a college English language classroom in Spain. Native Spanish-speaking students documented their study in English in personal blogs and shared blogs concerning topics of academic interest. Students expressed a stronger preference for blogging than previous traditional writing lessons, suggesting that creating and sharing artifacts with an authentic audience motivated students to perform at a higher level.

Writing fluency and grammatical construction improved, as active blogging improved student motivation for writing.

The advent of Web 2.0 has blurred boundaries between the producers and consumers. Students can create and readily share digital representations and exchange feedback among collaborators across the globe (Andersen 2007). A number of contemporary scholars have examined Web 2.0 sharing applications in education. Redecker et al. (2009) examined the impact of innovations in education and training in Europe and noted in stances where Web 2.0 tools have been applied to create and share knowledge, increase motivation and participation, and promote diversity and multiple perspectives in a social learning environment. Augustsson (2010) reported that the integration of Web 2.0 (i.e., VoiceThread) in a Swedish face-to-face postsecondary social psychology course increased involvement in group activity as well as identification of the individual's and peer's thoughts and emotions. Bower et al. (2010) aligned technological, pedagogical, and content knowledge as a framework for Web 2.0 design. Lee (2011) proposed guidelines for sustaining student motivation when students generate content using Web 2.0 technologies.

Implications for design

Extracting from the known principles of Self-determination theory, Constructivism, and Constructionism and contemporary research, we present the newly synthesized Own it, Learn it, and Share it (OLSit) framework. Factors believed to enhance engagement—autonomy support, scaffolding, and authentic audiences—are integrated. We present a series of OLSit assumptions and design guidelines to help students identify and endorse learning goals, evaluate and use resources, and create and share artifacts. By supporting student autonomy, scaffolding engagement, and transitioning from traditional academic requirements to authentic audiences, student performance and engagement should improve (Lee et al., under review). Figure 2 represents the relationship between the theories, design assumptions, and guidelines of OLSit framework. Table 3 summarizes the guidelines and supporting literature.

Own it

Own it is designed to develop personal ownership, regarded as important in SCL to promote autonomous motivation (Deci and Ryan 2000). As students assume increased responsibility to make decisions on what to learn and how to learn in SCL, students should be supported to understand what it means to be the owner of their learning and practice to be more autonomous.

Design guideline 1: facilitate endorsement of external goals

Autonomy is not limited to an individual's initiatives but also applies to wholehearted endorsement of external expectations (Ryan and Deci 2006). Students can work autonomously toward external goals when they endorse the value of the activity. To facilitate endorsement, instructors need to communicate the rationale—why the activity is important for their learning and how the activity is designed to facilitate the achievement of the broader learning goal. When an explanation of the purpose and value is provided, students are more likely to become personally engaged (Reeve et al. 2002).

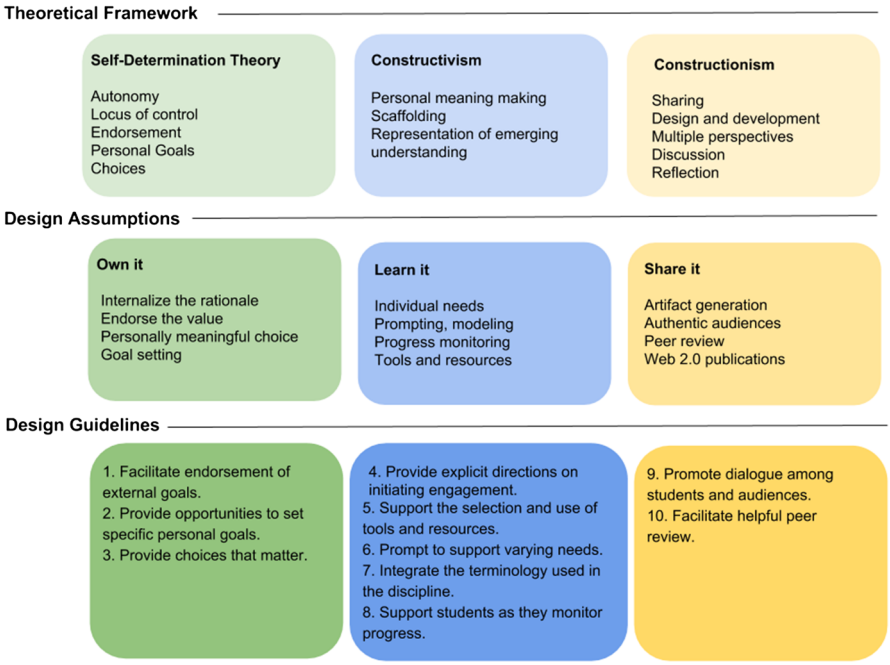

Fig. 2 The own it, learn it, and share it framework for student-centered learning

For example in a community college remedial mathematics course, a virtual change agent appeared at the beginning of each lesson and presented related situations to help students perceive the value of the lesson and a reason to pursue the learning objectives. This was designed for students to "want" to engage and became the basis for the subsequent exercises. Students who interacted with the virtual change agent exhibited more positive recognition of the intrinsic value of the course than those who did not access the agent. The initial desire to learn established at the beginning of the semester was sustained throughout the semester (Kim and Bennekin 2013).

Design guideline 2: provide opportunities to set specific personal goals

Own it encourages setting specific personal goals when engaged in an externally imposed activity. Students clarify their personal goal or outcome, making the value more prominent, and specify paths and milestones to goal completion, thereby increasing its perceived attainability (Wigfield and Eccles 2000). The establishment of clear goals appears to increase engagement, persistence, and strategies uses; and decrease anxiety, disappointment, and frustration (Locke and Latham 2002); and improve academic performance (Acee et al. 2012; Morisano et al. 2010). Although a student's personal goals might have extrinsic value (e.g., grade or graduation), the focus can be placed on instrumental usefulness (Kim 2012). Keller's (2009) motivational design model emphasizes making the project relevant to students' individual needs so as to increase its utility value. Furthermore, when students tackle personally identified projects, they become personally invested

Table 3 Design guidelines and supporting literature for own it, learn it, and share it

Framework	Guidelines	Supporting literature
Own it	1. Facilitate endorsement of external goals	When an explanation of the purpose and value is provided, they are likely to become personally engaged and motivated to engage (Reeve et al. 2002)
	2. Provide opportunities to set specific personal goals	Clear goals increase engagement, persistence, and use of strategies for goal attainment and decrease anxiety, disappointment, and frustration (Acee et al. 2012; Morisano et al. 2010)
	3. Provide choices that matter	When offered choices, students tend to spend more time and effort on the activity (Flowerday and Schraw 2000), perform better, and obtain higher assignment completion rates (Patall et al. 2010) Mediate the quantity and the extent to which students make choices to minimize frustration (Schwartz 2000; Flowerday and Shell 2015)
Learn it	4. Provide explicit directions on initiating engagement	Direct instruction supports the acquisition of essential domain knowledge (Schwartz and Bransford 1998)
	5. Support the selection and use of tools and resources	Expert models can provide conceptual, procedural, metacognitive, and strategic scaffolding about what to search for, where to look, and whether such material is a valid or useful source (Pedersen and Liu 2002)
	6. Prompt to support varying needs	Prompts have proved effective and been widely used across contexts for conceptual (Chen and Bradshaw 2007), procedural (Huang et al. 2012), strategic (King 1991), and metacognitive scaffolding (Ge and Land 2003)
	7. Integrate the terminology used in the discipline	Teachers model scientific discourse and have students justify their decisions using the scientific language (Kolodner et al. 2003)
	8. Support students as they monitor progress	Students should be able to monitor their own cognitive efforts, reevaluate goals, and modify plans (Shin et al. 2003)
Share it	9. Promote dialogue among students and audiences	By sharing, students gain a deeper understanding of others' perspectives (Evard 1996)
	10. Facilitate helpful peer review	Students gain a fresh view on their own products when comparing one's product to others' (Lundstrom and Baker 2009) Students generate richer peer feedback when prompted the use of criteria, specificity, and level (Gan and Hattie 2014)

in their projects. This enthusiasm and ownership can positively influence both the students' affect and attitudes toward the subject matter and their performance.

Instructors can incorporate opportunities for students to document their personal goals and make a plan of action. Additionally, students should reflect their achievement or failure and subsequently revise their plan of action. In the earlier example of the college remedial math course, the virtual change agent related a story about how he created personal goals and plans to guide his actions (Kim and Bennekin 2013). Using a goal contagion approach (Aarts et al. 2004), students were encouraged to adopt the agent's goal and further set their own specific and proximal goals for mastery learning and to plan their actions in anticipation of positive results.

Design guideline 3: provide choices that matter

Choices can enhance perceived autonomy (Reeve and Jang 2006). Choosing among several options can increase students' perceptions of control over their actions (Reeve et al. 2004). When students are offered choices, they tend to spend additional time and effort on the activity (Flowerday and Schraw 2000) and obtain higher assignment completion rates (Patall et al. 2010). However, choice alone may not result in academic engagement and achievement. Recent research suggests that students interest in the topic as well as interest in the choices influence engagement (Flowerday and Shell 2015). Schwartz (2000) cautioned too many choices are rather overwhelming and wasteful for decision-making. It is not about the number of choices but choosing what is more personally relevant than others. Providing choices facilitates an opportunity for students to pursue their own goals and interests, which is essential in motivating students (Hidi and Harackiewicz 2000).

Learn it

Learn it scaffolds accomplishment of goals. SCL proponents suggest scaffolding students' efforts to formulate questions and inferences, monitor progress, identify and evaluate resources, refine thinking, and construct knowledge. *Learn it* provides procedural, conceptual, strategic, and metacognitive scaffolding to guide student-centered inquiries. Procedural scaffolds provide step-by-step guides; conceptual scaffolds guide what to consider; metacognitive scaffolds support learning management; and strategic scaffolds provide alternatives to consider.

Design guideline 4: provide explicit directions on initiating engagement

When students have limited prior knowledge and experience, misconceptions and naïve assumptions may influence their SCL processes (Moos and Azevedo 2008; Shin et al. 2003). A lack of prior domain-specific knowledge is particularly problematic in SCL since students initiate inquiries by generating questions based on their own knowledge and experiences (Kim and Hannafin 2011). Activating existing schema by eliciting prior knowledge has been recognized as an important initial step of instruction (Gagne 1988; Merrill 2002). In such cases, direct instruction supports the acquisition of essential domain knowledge (Schwartz and Bransford 1998). Fixed, directive scaffolds can provide initial procedural and conceptual support to reduce the cognitive load and help students initiate and pursue their goals under way (Weigend 2014).

Design guideline 5: support the selection and use of tools and resources

Previous researchers established that students often lacked experience in locating and using resources (Hill and Hannafin 2001). Thus, unsupported access and use of Web resources can affect the accuracy and credibility of student products. Ineffective and inefficient strategies interfere with learning and cause frustration. Furthermore, many students fail to use support devices available in their computer assisted, open-ended learning environment (Clarebout and Elen 2006; Oliver and Hannafin 2000). Expert models provide conceptual, procedural, metacognitive, and strategic support regarding what to search for, where to look, and whether such material is a valid or useful source (Pedersen and Liu 2002). Experts can also (e.g., teacher or librarian) make visible the unobserved thought processes

experts use to guide their actions (Collins et al. 1991). Experts and students work alongside, as students observe the expert perform while verbalizing their thinking.

Design guideline 6: prompt to support varying needs

Prompts have been widely used across contexts to trigger conceptual, procedural, strategic, and metacognitive scaffolding. For conceptual scaffolding, questions prompt students to consider content in ways to support construction of new knowledge or reorganization of existing knowledge (Chen and Bradshaw 2007). Procedural scaffolding, in the form of "thinking before talking," prompts can foster more active participation and effective interactions in the group discussion and promoted individual higher-level thinking skills (Huang et al. 2012). In terms of strategic prompts, guidance on how to pose questions and obtain explanation, justification, information, and methods is essential since students often fail to ask strategic questions without having explicit support to do so (King 1990; 1991). Metacognitive scaffolds helped students focus attention and monitor learning via think-aloud protocols (Ge and Land 2003; Ge et al. 2005).

Design guideline 7: integrate the terminology used in the discipline

Previous researchers cautioned that students may regard the artifact construction as arts and crafts rather than content learning (Hmelo et al. 2000). In a middle school science construction project, Kolodner et al. (2003) overcame this challenge by encouraging teachers to model scientific discourse while having students justify their decisions using appropriate scientific language. In postsecondary engineering education, mathematics is regarded as "the language of engineering" (Dym 1999, p. 6). Before engaging in engineering design curricula, students complete prerequisite mathematics courses. Dym (1999) suggested that subsequent engineering curriculum should expand upon and build from mathematical languages as well as languages of design, such as graphical representations and computing. Instructors need to articulate connections between constructions and domains by integrating the subject specific terms into the design process.

Design guideline 8: support students as they monitor progress

Students who are unfamiliar with SCL can become frustrated and shift their focus to reaching perfunctory, immediate outcomes. SCL requires that "students possess not only the content knowledge but also regulation of cognition, including modification of plans, reevaluation of goals, and monitoring of one's own cognitive efforts" (Shin et al. 2003, p. 23). However, research confirms that students experience difficulty monitoring their progress, managing their time efficiently, and identifying areas in which they need assistance (Brush and Saye 2000). Metacognitive scaffolds support the monitoring of independent inquiry. Expert modeling, cognitive apprenticeships, question prompts, peer feedback, and step-by-step check points support students as they monitor progress, reflect on what has been done, seek clarification, and identify needs.

Share it

Share it is designed to enhance student engagement by presenting and sharing products with authentic audiences. Constructionists argue that learning is optimized when students

design and produce tangible artifacts to embody understanding and to share among others. Sharing artifacts facilitates personal reflection and social interaction (Harel and Papert 1991). The creation of artifacts requires that students think explicitly as they design, develop, and present. As students share and exchange products, they develop stronger personal investments in their learning and artifacts; furthermore, understanding is mutually enhanced by comparing perspectives and negotiating, adjusting, and confirming individual understanding.

Design guideline 9: promote dialogue among students and audiences

Students operationalize thinking by creating products whose value can be understood by others with varied domain knowledge. They need to communicate findings in ways that epitomize the depths of their understanding as it relates to everyday issues. Students self-evaluate their understanding to assess options to translate into artifacts to represent intended interpretation. Audiences, in turn, provide different, potentially complementary or competing, perspectives on the product which affords opportunities to consider alternatives. By sharing creations, students gain a deeper understanding of others' perspectives and ideas related to the artifact (Evard 1996).

Design guideline 10: facilitate helpful peer review

During peer reviews, students assume the role of trained peer reviewers and exchange written and spoken feedback on formative drafts and prototypes (Hansen and Liu 2005). Asking for and receiving alternative explanations enables students to assess and potentially revise their representations (Lundstrom and Baker 2009). Cho and Schunn (2007) found that undergraduate students' informal science learning improved when they received feedback from multiple peers versus those who only received feedback from a single expert.

However, scaffolding for peer review are often needed but overlooked (Belland 2014). Although often incorporated to promote social interaction and learning (Trautmann 2009), students reported negative attitudes toward peer review (Yang and Tsai 2010). Many students lack the experience or guidance needed to provide constructive reviews. Novice reviewers, for example, may provide superficial or uninformed feedback due to limited background knowledge and experience. Effective peer review processes are facilitated and monitored using complementary scaffolds, such as question prompts (Gan and Hattie 2014) and coaching (Lam 2010). Guiding questions and rubrics can orient students' approach to reviewing peer products and articulating their feedback on them.

Unresolved issues and future directions

Few validated measures are currently available to document instructors' and students' beliefs and practices regarding SCL. Researchers will require validated and field-tested instruments to assess the their influence on both engagement as well as learning processes and outcomes. While isolated efforts have been reported in the science (e.g., Erdogan et al. 2011), teachers of adult learners (e.g., Conti 1990), autonomous motivation (e.g., Gorissen et al. 2013) and perceived autonomy in education (e.g., Black and Deci 2000), we will need

more consolidated, integrated models that address varied nuances and depths of applications across.

Advances in assessment of academic achievement through SCL are also needed. Some researchers have incorporated standardized norm- or criterion-referenced assessments as well as alternative assessments such as self-assessment, peer assessment, rubrics, feedback, portfolios, and exhibition (Andrade et al. 2012). The Jasper program (Cognition and Technology Group at Vanderbilt 1992), for example, balanced expected performance measures with indicators of how well students were able to identify, evaluate, pursue and resolve problems. In addition to standardized test data, student performance was assessed using alternative assessments such as Basic Math Concepts Test, Word Problem Test, Planning Test, and Math Attitudes Questionnaire. Jasper students reported comparable performance on standardized measures but superior performance in complex problem solving, planning and subgoal comprehension questions, and improved attitudes toward mathematics. Further research is indicated to increase confidence in students' self-assessment of their individual progress, outcomes, and strategies to manage their learning.

Finally, whereas considerable scaffolding research and theory has been documented, we have limited understanding as to how scaffold can accommodate varying levels of diverse student preparedness and motivation. For example, at-risk students, refugee youths, and English as Foreign Language students, who under-perform historically and lack background and skills to engage their learning environments (Nelson et al. 2012), present needs in managing individual learning decisions. For the range of individuals, we need to scaffold uniquely different needs in order to empower them to assume ownership for their learning.

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