End-User Development and Learning in Second Life: The Evolving Artifacts Framework with Application

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Abstract We explore the relationship of end-user development (EUD) and learning in a case study informed by a new conceptual framework (evolving artifacts). The case is an online distance education program for training in-service teachers in special education in the 3D virtual world Second Life (SL). The "box," a specific building block in the SL environment became a multipurpose tool for EUD in the study. The professor of the course designed the learning environment by creating and combining 3D boxes and then used boxes as containers to share course materials to the class. Some of the in-service teachers created boxes to personalize their learning activity. The conceptual framework for analysis integrates EUD concepts and concepts from sociocultural and constructivist learning theories (duality of learning; adaptation). We present an analysis of the participants' spoken utterances and turn taking around the use of the boxes through the lens of two different EUD and learning situations (technology-adaptation and knowledge-adaptation). We show how participants take up these features to become engaged in the activity. One of the situations required the learners to adopt EUD techniques (technology-adaptation), and the professor used EUD techniques to enable knowledge-adaptation.

Keywords 3D virtual world · adaptation · empirical analysis · end-user tailoring · EUD · evolving artifacts framework · in-service teacher · knowledge adaptation · Second Life · qualitative study · special education · tailorable component · teacher education · technology adaptation

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1 Introduction

Second Life (SL) is a multi-user virtual environment (MUVE) and a virtual world (VW) in which individuals interact in real time as avatars with other people and virtual objects in a three-dimensional space (Sardone & Devlin-Scherer, 2008). MUVEs offer course organizers new opportunities to design advanced learning environments composed of computer-based tools and virtual spaces for interaction and to stage authentic learning activities with resources that would be difficult to match in a traditional classroom setting.

Second Life provides a platform for teaching distance education courses as synchronous interactions (Baker, Wentz, & Woods, 2009). Faculty members in a teacher preparation program at a research university in the US have been teaching in SL for 5 years, and it has been the educational platform for six online graduate courses, at both the Master's and Doctoral level. It has also been incorporated into undergraduate, campus-based courses for role-play simulation. The present study reports on a course designed for preservice and in-service special education teachers and held entirely in Second Life (Caruso, Mørch, Thomassen, Hartley, & Ludlow, 2014; Mørch, Hartley, & Caruso, 2015); specifically, we focus on the participants' involvement with end-user development (EUD) and the relationship of EUD to learning activities. The professor created the flexible learning environment using the embedded Second Life build feature (a design environment), and the participants used this virtual campus to collaboratively create and enact role-play scenarios as part of their online learning activities. Fig. 1 shows part of the virtual campus.

A specific building block in the SL environment is the "box." The box originated as way of packaging and purchasing goods in the SL marketplace (building units, furniture, clothing, etc.); in our study, this tool was used for EUD by a professor and a group of fulltime in-service teachers following an evening master's degree program. The professor created the virtual campus, learning resources and information sharing containers using boxes, and the in-service teachers used, created and sometimes further developed (tailored) these containers in the collaborative learning activities (Caruso, Hartley, & Mørch, 2015; Mørch, 2016).

Fig. 1 Two buildings of the Second Life™ virtual campus used in the distance education program (Left: Main Classroom; right: Small Group Building)

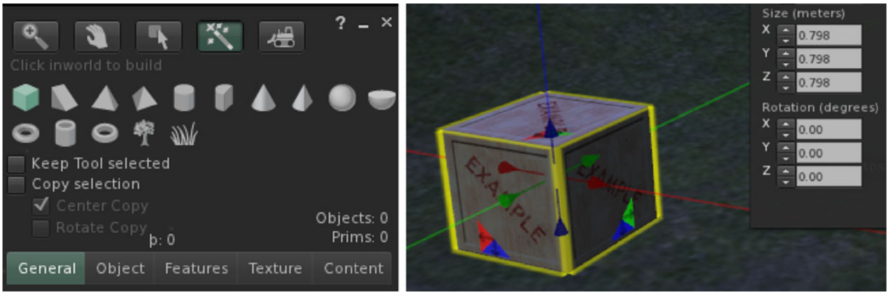

Fig. 2 Left: Selecting a basic 3D shape (prim) in the SL builder. Right: setting two of the attribute values (size and rotation) of the cube prim ("box")

Our informants used the term "box" when they described the tool. The technical term is "default prim" or "cube prim," a primitive object or just "object." Other prim types are named after basic 3D shapes (prism, sphere, cylinder, torus, tube, ring) (Fig. 2, left). Prims are the basic building blocks in SL and can be created, modified and stored with simple commands. Prims are created in a design environment (builder) invoked by Ctrl-B (Fig. 2, left and right). In the builder, objects can be linked to form composite prims or grouped objects to model more complex building parts. The surface texture and other attributes (e.g. size and rotation) of an object can also be edited in the builder (Fig. 2, right). Later (runtime) edits are possible on any object on land with building permit by right clicking on the object and selecting "Edit" from the pop-up menu, referred to as direct activation in the EUD literature (Wulf & Golombek, 2001). All of these features were used in the study reported here.

We adopt a "components approach" to EUD (Bandini & Simone, 2006; Mørch et al., 2004; Mørch & Zhu, 2013; Won, Stiemerling, & Wulf, 2006). The components approach combined with tools for end-user tailoring (Mørch, 1997; Mørch, 2011) differs from the "programming approach" in that end users create and modify software artifacts using high-level (user oriented; domain specific) operations rather than programming operations. However, using the Linden Scripting Language (LSL), boxes can also be modified by writing code. Such modification was not observed in this course, but the professor has used LSL in another course to create a non-player character (NPC) in a roleplay.

Our long-term goal is to use EUD to practice generic (domain general) skills in order to complement the domain-specific concepts and skills taught in classes. The skills and concepts taught in the special education class we report from include: negotiation, conflict resolution, persuasion, and resistance (Caruso et al., 2014; Mørch et al., 2015). On the other hand, generic skills include: learning to learn, academic basics (reading and writing; computational skills), communication, adaptability, personal development, and group effectiveness (Carnevale, 1991; Kearns, 2001). We argue adaptability is the generic skill best matched for EUD and learning. It is defined as follows: (1) The ability to bridge the gap between what is and what ought to be, (2) the ability to produce a novel idea, and then turn it into a practical one (Carnevale, 1991; Kearns, 2001).

The skill most often thought of in conjunction with EUD and learning is computational thinking, i.e., programming and algorithmic problem solving (Grover & Pea, 2013; Repenning, Webb, & Ioannidou, 2010; Wing, 2006) and certain areas of mathematics, such as geometry (Papert, 1980) and vector calculus (El-Nasr & Smith, 2006). The full mastery of EUD in SL requires skills in programming and applied mathematics, but in the work presented here we aim to go beyond computational thinking and use EUD for practicing adaptability in conjunction with preparing for learning domain-specific skills.

We address the following research questions: (1) How do the multiple functionalities of the SL "box" support end-user development, and (2) what is the role of EUD in the learning activity?

The rest of the chapter is organized as follows. The conceptual framework is presented in Sect. 2. The design of the virtual learning environment is described in Sect. 3, and the research methods for data collection and analysis of the case study are given in Sect. 4. Sect. 5 presents five data extracts for exemplification. The findings are discussed in Sect. 6 in terms of the conceptual framework. At the end, we identify some limitations and unresolved issues with our approach and suggest some directions for further research.

2 The Evolving Artifacts Framework (EAF)

We present a conceptual framework for research design and analysis that integrates concepts in EUD and concepts from sociocultural and constructivist learning theories. The three areas of research have developed independently, but have some things in common: learning with the use of tools and application of evolutionary principles and ideas beyond biology. We draw on their similarities to identify a set of concepts and techniques for end-user development as a learning activity (adapt to learn; sense making) and learning as the creation and modification of knowledge (learn to adapt; tool mediation). Researchers in the learning sciences (e.g., Cobb, 1994) have argued for integrating sociocultural and constructivist learning based on complementarity of individual and social processes. In this chapter we propose the complementarity of EUD (tool adaptation) and learning domain-specific concepts (knowledge adaptation).

2.1 Evolving Artifacts in End-User Development: Frameworks, Tools, and Techniques

End-user development is defined as the methods, techniques, and tools that allow users who are acting as non-professional software developers, to create, modify or extend a software artifact (Lieberman, Paterno, & Wulf, 2006). One branch of EUD focuses on enabling and studying these activities in evolutionary application development (Fischer, 1998; Mørch, 2011; Stevens, 2017), i.e. continuous processes of creating and modifying software artifacts that may also involve professional developers and changes made on different time scales (design time vs. use time). Key notions are meta-design, end-user tailoring and appropriation.

2.1.1 Meta-Design

Meta-design is a conceptual approach for system development with end users that pioneered the adoption of evolutionary ideas in EUD (Fischer, 1998). Through this approach, developers create at *design-time* an environment in which users, as "owners of problems," are empowered during *use-time* with methods and tools to create the solutions themselves and engage actively in the continuous development of systems rather than being restricted to the use of existing systems (Fischer, 2009). More recently, researchers have broadened meta-design to include different application domains, including virtual worlds (Fischer, Fogli, & Piccinno, 2017). Second Life is an example of a meta-design environment (Koehne, Redmiles, & Fischer, 2011). SL provides a set of components (building blocks and tools) for a range of different tasks that define flexible design spaces for end-user developers to create locally adapted solutions and participate in the continuous development of the shared environment (Caruso et al., 2015).

Fischer (1998) refers to two types of system development processes (evolutionary growth and reseeding) inspired by two types of organism evolution, ontogenetic (individual; lifespan) and phylogenetic (species; genes). End user developers are the main contributors during evolutionary growth, whereas seeding and reseeding involves professional system developers. Mørch, Nygård, and Ludvigsen (2009) refer to the two processes as adaptation and generalization, and Andersen and Mørch studied the interdependencies of adaptation and generalization and refer to the overall process as mutual development (Andersen & Mørch, 2009). In the case study we report from here, reseeding or generalization means to maintain the Second Life software and spawn new versions, which is a design-time activity organized by Linden Lab with initial release in 2003 and downloaded by end users during use-time. Evolutionary growth or adaptation is the creation and modification of specific artifacts in SL during use-time by end user developers. Both types of evolution have shaped the SL box tool and other SL artifacts; we have focused our research on end-user developed solutions.

2.1.2 End-User Tailoring and Direct Activation

Researchers in EUD have created instances of meta-design by specific tools and techniques for continuous application development (Cabitza & Simone, 2017; Fogli & Provenza, 2012; Mørch, 1997). Mørch (1997) has suggested tools for tailoring generic applications at three levels – customization, integration and extension. These levels provide a gradual transition into the computational complexity of an application via increased power for each level. Fogli and Provenza (2012) apply a meta-design model to create EUD environment for citizens to take active part in an e-government service in Italy. These tools and environments empower domain expert users to create solutions themselves (Costabile et al., 2008) and learning while doing it (Caruso et al., 2015).

The SL user interface consists of visual components. The notions of direct activation by event handling (Mørch, 1995; Wulf & Golombek, 2001) and components approach (Bandini & Simone, 2006; Mørch et al., 2004; Mørch & Zhu, 2013; Won et al., 2006) support tailorability. It entails that tools for EUD are part of the runtime environment at the granularity of components and invoked by a mouse-keyboard combination. Direct activation supports a "gentle slope to complexity" (Ludwig, Dax, Pipek, & Wulf, 2017), which means that the practice situation indicates to the user when there is need to tailor, e.g., associated with a breakdown or problem. A breakdown triggers the need for "repair," whereby a tailor descends to a lower level of detail to make the necessary changes (Ludwig et al., 2017). Direct activation is supported in Second Life by right clicking on a modifiable 3D object. The edit command in the pop-up menu opens a property sheet for customization, allowing object features, textures and content to be changed (see Fig. 2).

2.1.3 Appropriation

Appropriation of everyday objects will typically not involve actions to "create, modify or extend a software artifact." For example, appropriation is defined in the arts in Wikipedia to use pre-existing objects or artifacts in new ways and combinations with little or no transformation applied to them. On the other hand, both appropriation and EUD can be characterized as continuous processes of evolving artifacts. Software appropriation has been researched in computer supported cooperative work (CSCW) and human computer interaction (HCI) and defined as combining adoption and adaptation: adoption of a specific technology in an organizational context and adaptation of the technology to that context (Dourish, 2003; Tchounikine, 2017).

Pipek (2005) argues that appropriation should be considered in terms of design in use and tailoring. He describes appropriation as "an ongoing design process that end users perform largely without any involvement of professional developers" (Pipek, 2005, p. 5). Based on two long-term empirical studies, he identified advanced user activities with collaboration tools (groupware) in two workplace settings and proposed appropriation support to aid the activities. Pipek characterized this appropriation as "a collaborative effort of end users … to make sense of the software in their work context" (Pipek, 2005, p. 5). The appropriation support combines communication, demonstration, negotiation, and tailoring.

More recently Stevens (2017) has proposed appropriation as a sociotechnical framework (infrastructure) for EUD. He traces the roots of the concept back to German idealism in the works of Hegel and Marx and studies its uptake in 20th century Activity Theory of Leontiev and Engeström, who connect appropriation with expansive learning, thus forming a dialectic of mental and material appropriation activities (Engeström, 1999). The dialects of acting on the external world, as a form of production and reproduction, and changing one's inner nature as a form of learning and self-expression, are elements of Marx' theory that provided later scholars with ideas for new research methods for studying human activity as a dialectic process (Stevens, 2017).

2.2 Evolving Artifacts and Human Learning

EUD and learning from a sociocultural and constructivist perspective share a focus in the use of tools (cultural tools in sociocultural learning; learning through concrete experiences in constructivist learning) and application of evolutionary ideas. However, there are also important differences between the two perspectives, one being that constructivist theory suggests to focus on individual learning motivated by personal interest while sociocultural theory is more concerned with the ways in which learning is culturally dependent and involve social interaction and scaffolding (Scott & Palincsar, 2013). We present two theoretical ideas, Vygotsky's Genetic law of cultural development and Piaget's process of Adaptation, which we integrate with concepts from EUD to define two types of adaptation: technology-adaptation (EUD) and knowledge-adaptation (learning).

2.2.1 The Genetic Law of Cultural Development (Duality of Learning)

Vygotsky's "genetic law of cultural development," referred to here as "duality of learning" to avoid confusion with the contemporary meaning of genetics (genes and DNA), states that "every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first *between* people (*inter-psychological*), and then *inside* the child (*intra psychological*). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relations between human individuals" (Vygotsky, 1934/1978, p. 57, emphasis original).

Wertsch (1991) suggested that the interaction between individual and social processes is not linear but interdependent and that tool-mediated human activity is central to the interdependence. The activities that tools facilitate are the co-construction of knowledge and the internalization of knowledge for the individuals (Säljö, 1999; Wertsch, 1991). Leontiev (1981), a junior colleague of Vygotsky, used the term "appropriation" to characterize this process of internalization to simplify the task of understanding the history of development of specific artifacts that have taken centuries and decades to evolve in order to appropriate such objects into their own system of activity (Newman, Griffin, & Cole, 1989).

The connection between appropriation as a form of advanced technology use and the social construction of knowledge has been studied in teacher education research, for example, in examining the appropriation that occurs when learners (teachers in training) adapt information technology in a way that is meaningful to them (Cook, Smagorinsky, Fry, Konopak, & Moore, 2002; Grossman, Smagorinsky, & Valencia, 1999). Appropriation involving modification to software (EUD) has been studied in computer science education research where the aim is to teach computational thinking (Grover & Pea, 2013; Repenning et al., 2010; Wing, 2006) and in CSCW to provide a sociotechnical infrastructure for tool modification (EUD) and flexible use practices (e.g. participatory design, collaborative sense making, and learning) in workplace settings (Stevens, 2017). However, to the best of our knowledge, EUD has been little investigated in research in special education.

2.2.2 Piaget's Adaptation: Assimilation, Accommodation and Equilibration

Constructivism is a theory that puts forward the hypothesis that knowledge is not passively received but actively built on an individual's prior experiences. It also considers the main function of cognition as adaptive in order to organize and make sense of the experiential world (Bruner, 1961; Piaget, 1952; Von Glasersfeld, 1989). Piaget's constructivism suggests that learning happens whereby learners integrate new experiences with prior knowledge through two complementary processes of adaptation, assimilation and accommodation, driven by a tension-laden internal dynamic referred to as equilibration (Piaget, 1952).

In *assimilation*, people take information from the outside world and convert it to fit in with their existing ideas and concepts. These mental categories are known as schemas, and are used to understand the world around them. When people encounter information that is completely new or that challenges their existing ideas, they often have to form a new schema to *accommodate* the information or alter their existing mental categories (Piaget, 1952). The desire for *equilibration* (inner sense of balance of knowing) motivates learners in periods of restless mind (cognitive conflict) to adjust old ideas and imprecise concepts and to learn new and better ones. Piaget's tension-laden process of evolving knowledge artifacts can be compared with and form part of Vygotsky's broader social-individual (outer-inner) dynamic of learning and knowledge development in the context of human activity.

2.2.3 Duality of Adaptation: Technology Versus Knowledge

By synthesizing two sets of ideas on adaptation, we suggest that adaptation takes place in two realms by two processes: in the social realm by technology adaptation, and later, in the individual realm, by knowledge adaptation. This is not a strict linear process, but one that iterates between two sides, where each side draws on the other to cope with own shortcomings (e.g., lack of knowledge to accompany technology-adaptation and lack of stable intermediate forms in knowledge-adaption). Furthermore, knowledge adaptation does not have to be an individual activity;

collaborators can create and adapt knowledge together and conversational data allows researchers to study knowledge adaptation in a semi-naturalistic setting.

In sum: The key concepts of the evolving artifacts frameworks are the following, 1) technology-adaptation: customization, integration, extension, 2) knowledge-adaptation: assimilation, accommodation, 3) complementarity, and 4) bridging concepts (in alphabetical order): cognitive conflict, collaboration, direct activation, externalization, internalization, knowledge refinement, practice iteration, scaffolding, social tension, and tool mediation. These concepts have informed our research design and we have used some of them as sensitizing concepts to classify the data material we report in Sect. 5. We also refer to aspects of meta-design (time scales: design-time vs. use-time) and appropriation (gentle slope; sociotechnical infrastructure) in our discussions in Sect. 6.

2.3 Constructionism

Constructionism developed by Papert and colleagues (Papert & Harel, 1991) is probably the best known theory of knowledge construction in EUD and builds on the constructivist ideas developed by Piaget (self-directed learning involving tangible objects and motivated by personal interest rather than predefined curricular goals) and supported by visual programming environments, pioneered by Logo (Papert, 1980). Several constructionist environments have been created after Logo, such as Boxer (diSessa & Abelson, 1986), Alice (Conway, Audia, Burnette, Cosgrove, & Christiansen, 2000), Agentsheets (Repenning, Ioannidou, & Zola, 2000), Scratch (Maloney, Resnick, Rusk, Silverman, & Eastmond, 2010), and Blockly from Google. The boundary between these environments and the "components approach" is not clear-cut. For example, LEGO WeDo and App Inventor are construction kits that contain a large number of building blocks for composition, programming, and modification, thus combining component-based design and programming. Furthermore, contemporary constructionist environments provide learners with a wealth of scaffolding by online help and instruction, online peer communities, libraries of examples, and video tutorials (Roque, Rusk, & Resnick, 2016), thus bridging the gap between constructionism (self directed) and sociocultural (facilitated) learning theory.

In sum, our approach to EUD (component-based design and modification) and theoretical perspective (Evolving Artifacts) differ from Constructionism in two ways: 1) at the technology level in the same way as Minecraft (and Second Life) differs from Scratch (modification vs. programming; learning domain-oriented concepts vs. computational thinking), and 2) at the theoretical level by a conceptual framework based on evolutionary ideas. However, the two perspectives overlap with respect to the following: end users are learners who actively contribute to own learning through advanced technology use while interacting with fellow learners, facilitators and culture specific scaffolds.

3 Designing the Learning Environment: Buildings & Activities

The third author of this study is the "professor;" who created the learning environment from scratch using Second Life's build feature (a design environment). This was accomplished based on skills acquired through a workshop offered by Sloan Consortium (now called Online Learning Consortium), in which she learned how to build a "box" and how to put content inside of a box. Below we describe two types of functionality that can be built with the SL box as basic building blocks: virtual buildings and learning activities and tools (Caruso et al., 2015).

3.1 Designing Virtual Buildings

After taking the workshop, the professor-as-designer spent time playing in SL to practice making virtual buildings. She built the buildings (two of them are shown in Fig. 1) by creating multiple boxes and linking them together, as shown in Fig. 3: left). There were restrictions on the size of an individual object; therefore, multiple boxes were put together to create a building of the size needed.

Fig. 3 Left: Building a box in Second Life; right: changing the size attributes of a box

In order for the main classroom to appear as one large lecture hall, the interior walls of the boxes were set to “phantom” and made transparent, as shown in the left part of Fig. 3. When an object is set to phantom in SL as opposed to merely “transparent,” one can walk through the object. The main classroom had six boxes linked together in order to create the look and feel the designer wanted. Once the walls were created, faculty built one large floor from a box so that the texture on the floor would look uniform.

After the interior walls were created, the professor changed each “texture” of the exterior of each box to give the objects the appearance of a building. It was the intent to make the buildings look similar to the architectural design of the downtown campus, including vaulted windows (see Fig. 1). The professor built the floor for the foyer by building a box and adjusting the dimensions. She then linked the boxes and the floor together. Several other pieces were also created in a similar manner and finally linked together.

In addition to the main classroom, it was necessary to build small-group buildings for collaborative work. Each group building included a group table with chairs, as well as a lounge area with a sofa and chairs. The group buildings were 60 (virtual) meters apart to avoid sound interference between groups while talking. Combining two boxes and making the interior walls of the boxes transparent and “phantom” created the small group buildings, and the texture of the boxes was changed to account for floors and walls (including windows) without building separate boxes. After the prototype group building had been created, multiple copies were made by duplication of the original; in total, five group rooms per instructor were created.

3.2 Designing Learning Activities and Tools

The learning environment was designed to maximize collaboration and student engagement. When envisioning the main classroom, the online instructors wanted a space where students could meet as a large group ($N = 25$) and engage in interactive lectures. The professor had visited other instructors’ classes in SL and thought that flipping through slides in SL while students sat in a seat and watched was less engaging than students physically moving their avatar to participate, which is more in line with constructivist learning ideals such as active learning (Karagiorgi & Symeou, 2005). Therefore, a decision was made to design the space so that students would walk from display board to display board (Fig. 4, left).

The display boards were used to show lesson content by uploading PowerPoint slides as jpeg textures, and there were individual activities throughout the lesson. After the interactive lecture, students worked in groups for the remainder of the session. During this time, students worked collaboratively to solve problems. In addition to solving problems, students were asked to create a role-play scenario for their classmates to practice skills surrounding one of the topic areas taught in the class (e.g., interpersonal problem solving, effective communication,

Fig. 4 Left: Professor lecturing and walking students through slides; right: a student facilitating a role-playing session using a "box" for information sharing (the box is on the table)

negotiation, persuasion, conflict, resistance). The right-hand side of Fig. 4 shows a group of students engaged in a role-play, using a box attached to a table to share information.

Incorporating role-playing through virtual simulations is grounded in the constructivist notion of learning through concrete experiences and then reflecting upon those experiences (Bruner, 1961; Piaget, 1952). Role-playing scenarios typically encountered in special education training were enacted during class sessions, in order prepare future teachers to experience controlled situations and allow them to rehearse professional responses using effective communication strategies. In addition to participating in role-play creation and play, they were also asked to facilitate their classmates' participation in their role-play, which we show by example in Sect. 5.

As part of this assignment, students had to learn how to build boxes to disseminate their materials, create notecards and put them inside the boxes, and allow their boxes to be "purchased" for zero Linden dollars. These were the same kind of boxes the professor used to create the learning environment, but in this case, the students did not have to connect boxes. Instead, some of the in-service teachers played around with self-created boxes and customized them to personalize it to their collaborative work, serving as a "group identity" (Greenberg, 1991). To add content to their box, they dragged a notecard from their inventory into the Contents section of the Edit window.

4 Methods and Research Design

Thirty-four in-service teachers took part in the study, participating in seven live 2-hour class sessions and nine collaborative group work sessions spanning four weeks. Each class consisted of a combination of teacher-led and student-centered activities, including interactive lectures of theoretical concepts (30 minutes), individual activities (15 minutes), group activities in separate rooms (30 minutes), and role-play activities (10 minutes). Learning was embedded within the activities, and members of the group were assigned roles (leader, facilitator, secretary, time keeper, organizer) during collaborative group work sessions.

We used a qualitative research analysis, combining a case study (Yin, 2003) and virtual ethnography (Boellstorff, Nardi, Pearce, & Taylor, 2012; Hine, 2000). A cases study is a particular instance of something used or analyzed in order to illustrate a thesis or principle. In accordance with virtual ethnography (Boellstorff et al., 2012; Hine, 2000), all sessions were observed at a distance in the virtual world and video-recorded with screen capture software (BSR, Camtasia, SnagIt) by the first two authors (in total 15 hours of raw video data). Afterwards, two interviews were conducted with one student who volunteered, and with the professor, by using chat and voice (headset), in SL.

In order to manage and classify the data material, each session and interview were stored in a separate file and entirely transcribed. We thematically categorized the data (Guest, 2012) in two rounds: first according to an open coding and iterative classification process (data-driven), and then informed by our research questions and by two empirical concepts (technology-adaptation and knowledge-adaptation). We focused on one group's activities as they unfold throughout the collaborative work and roleplay. This group was chosen because its members were the most active in using EUD techniques in their collaborative work. Then we counted the occurrences of domain-specific concepts in the transcripts ("conflict" had 34 instances in the session we report from). Inspired by the interaction analysis method (Jordan & Henderson, 1995) we base our claims on the participants' utterances (chat and voice), verbal interactions, turn taking, and tone of voice ("body language"). We integrate the participants' EUD actions with their verbal and non-verbal data using screen images and comments. We have reproduced five extracts below, which are snapshots of the learning trajectory organized into two themes: technology-adaptation (Extracts 1–3) and knowledge-adaptation (Extracts 4–5).

5 Data Extracts and Findings

Each subsection below is organized as follows: (1) short context description, (2) illustrative example of "raw" data (spoken utterances, set in italics), and (3) brief summary of findings. The transcript notation used in the data presentations includes these symbols: (..) short pause; ((text)) comment by researcher; [..] excluded (not audible) speech; :: interruption of talk by extraneous sources at the participant site.

5.1 Data Extract 1: Creating a Box and Personalize the Learning Activity

In Extract 1, in-service teachers are working in small groups. We follow the group consisting of Heather, Janet, Mandy, and Stacy (fictitious names of participants). After creating a scenario for the role-play activities, they need to write the instructions on a notecard intended for one of the other groups to act out. The notecard is put in a box. When the extract below begins, the group is ready to create their box:

Stacy:	*OK, now we need somebody to make the box.*
Heather:	*Y'all go together and do that. I kind of… can we build it in here? ((A default box appears on the screen in yellow color))*
Stacy:	*I'm not sure if we can or not.*
Heather:	*I think we can build it here ((in their group room)), we just have to put it in our inventory before we leave. I have one (..) started; I'll try to get it so you can see it. ((Typing on keyboard)) (..)*
Janet:	*Exactly. ((chat))*
[14:18] Stacy:	*Ok. ((chat)) (..) ((long pause, then the box' color changes several times))*
Heather:	*That's a fancy box. Is it changing:: the scenery on it or are you changing that? (..)*
Mandy:	*Yeah, can you see it? ((Positive tone of voice))*
Heather:	*Yeah, I can ((laughs)) (..)*
Mandy:	*OK, tell me when you… we get something that you like. ((Happy voice))*

The group attempts to collaboratively create a box for sharing documents with another group, but Stacy is unsure if they can build it in their group room or somewhere else. The box eventually appears in the room in a default state based on Heather's actions ("I have one … started; I'll try to get it so you can see it."), and she believes it can be saved in her inventory (a local storage for each person's items). Then, Mandy modifies the box into the pattern shown in Fig. 5, thus connecting the box with their case.

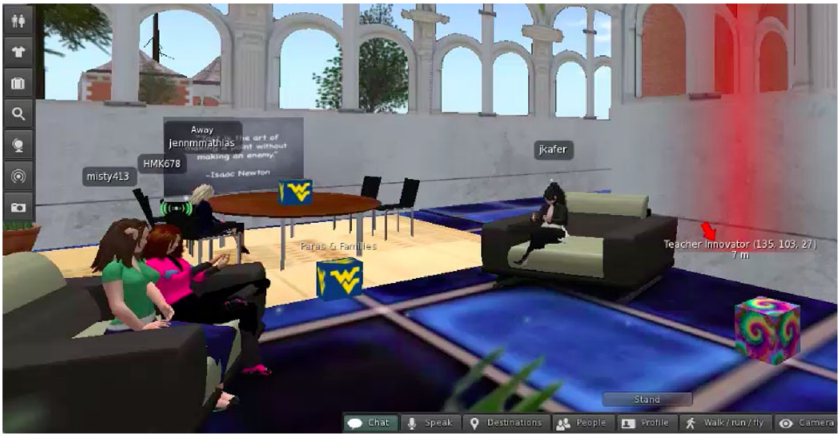

Fig. 5 The participants in the four-person group shown in data extracts 1–4 collaborate to build and customize a box for information sharing (the fancy colored box in the lower right-hand corner). The professor provided the two other boxes for seeding the environment with learning resources

What the in-service teachers build is not rocket science in EUD; they set parameters in the box's property sheet, but they struggle with the physical location and operations on the object (shared view vs. local actions). But when they figure out how to make changes that are visible to them all, it gives them great pleasure. It also gives them a sense of ownership of the box they made, which is evident by the tone of their interactions, as shown in the last four turns.

5.2 Data Extract 2: Customizing the Box for Content Sharing

The content to be put in boxes refers to notecards with instructions for the role-players of another group. To accomplish this, the groups needs to make one more adjustment to the box to allow for content sharing, as shown in Extract 2:

Mandy:	*How do I make the box (..) ahm:: have a price of nothing? What do I…?*
Stacy:	*There should be a spot on there ((in the property sheet)) that says… with a… I think it's down toward the bottom where it says ahm, the price or whatever and you have to set it to zero dollars. Let me see if I can…*
Mandy:	*Oh pay… about object (..) I'll have to make it for sale.*
Stacy:	*Yeah.*
[14:25] Mandy:	*Features, ahm:: (..) I'll have to look it up. I'm trying to build. If you guys want to talk, I'll still listen (..) All right. I did have the note (..) So:: what exactly do we want to put in this box? I'm guessing do we need to put a little snippet of (..) what part of this case we're going to talk about and what skill we want them to practice on?*

Stacy looks at the property sheet for the box after doing an edit command on the object, and suggests an attribute to be set ("the price or whatever"). She struggles at first to understand why they have to set the value to "zero dollars," which was described in the instructions from the professor. Mandy suggests they have to make the object for sale, and goes on modifying the box ("I'm trying to build. If you guys want to talk, I'll still listen"). The other in-service teachers comment on her work, test the box, and report what they see. By setting the value of the content to $0L in the box's property sheet, they allow the content to be shared without payment (a feature inherited from the box' commodity packaging origin). Now, they can start to work on their role-play script to be disseminated to another group and start educational role-playing and concept application.

5.3 Data Extract 3: Exploring Online Scaffolding

The participants we observed were newcomers to SL, and the professor prepared multiple ways of scaffolding the learning activities. She created a "getting started handbook" (Hartley, Ludlow, & Duff, 2016) and several instructional videos for specific situations. The use of the handbook is shown in the following extract:

[14:28] Mandy:	*In our handbook that we have did it say how to put a card in there (..) or was it on-line that the instructions were there?*
Heather:	*I'll see if I can help too. I remember doing it for that activity but let me go play around, see what I can find (..) Mandy, what did you put under ahm:: content permission?*
Heather:	*Go under content and click on permissions and see what you have selected there.*
Mandy:	*It has all checked ahm:: (..) Maybe I need to put share there (..) Anyone (..) ok (..) see if that works and you can buy it now (..)(..)*
Heather:	*How did you pick it up, Mandy? ((a new box appears on their lap))*
Mandy:	*I have no idea. I just started cracking up laughing because I have no idea why it's on my lap ((laughs)).*
Heather:	*Somebody else has it. Janet, you have it on you.*
Janet:	*How do I get it off, it's squashing me! ((the box is on her lap))*
Heather:	*If you right click it'll say drop ((laughs)) (..) It's floating above the window (..) (..) There are two tie-dye boxes floating above the window. ((box is in the air))*
Mandy:	*Yeah, I see them.*

Extract 3 shows the necessity of giving the participants some examples and instructions for scaffolding their activities. When the professor incorporates an online handbook and short video instructions, she ensures that in-service teachers feel more confident with the virtual environment. They refer to the online handbook to set permission for sharing documents, and as a result they make changes to some attribute values in the property sheet of the box. It is worth noticing that the work to do this takes some time and is partly done individually according to own time preferences. For examples Heather needs to "play around," and Mandy asks, "if that works," after setting a value in the property sheet. It is clear from the tone of their voice that they enjoy the activity, which gives them time to reflect on and learn to understand what it means to create and modify boxes.

5.4 Data Extract 4: Using Domain-Specific Concepts in Planning a Roleplay

The pre-service teachers were asked to create a role-play scenario for their classmates to practice one or more interpersonal problem solving skills during the role-play activity. In addition, each member was assigned a specific role in coordinating the activities: leader, organizer, timekeeper, secretary, and facilitator. In Extract 4 the group of students are planning the role-play activity (note: Franklin is a child described in the scenario and the role players argue for best placement for him using the concepts taught in class):

Stacy:	*Is our situation going to be like Franklin and other – and other teachers or is it going to be like teachers talking about Franklin or:: (…) what? You know, what kind of scenario? I think we've got to think of what kind of scenario first and then think of what kind of skill we should practice.*
[14:14] Janet:	*True ((chat))*
Janet:	*I think that we could do something like ahm:: the teachers talking about what they can do to help him, like what is the best help. I mean, because that's kind of what we've struggled on too, what is the best help for Franklin? Do we try and seek counseling for him, do we just punish him for making dirty pictures and making shanks at home, like what is the best for Franklin?*
[14:14] Stacy:	*Ok, that sounds good ((chat))*
Stacy:	*So do you think that might fall under negotiation? (…) Because they're… teachers are kind of negotiating with each other about (…) what would be best for him.*
[14:15] Janet:	*I think that or conflict ((chat))*

By planning the role-play activities in collaboration, in-service teachers were highly motivated to take part in the group discussions, thus making sense of the theoretical concepts taught in the course. This is in the beginning of planning the role-play and they are raising the issue of what should be the key concepts to be taught, and considers negotiation and conflict. The extract also illustrates how the role-play in Second Life provided the pre-service teachers with a significant level of immersion and realism, since they interpreted their roles by practicing real collaboration skills and exploring learning situations more safely than in the real world.

5.5 Data Extract 5: Using Domain-Specific Concepts in Skills Practice

In Extract 5, reproduced below, we are at the end of a debrief session of a roleplay facilitated by one of members in the group shown above (Heather). This session occurs one week after the session reported in Extracts 1–4. The debrief starts immediately after time is up for role-playing. The students are no longer playing scripted roles, and we get an idea of what they learned from it:

Heather:	*Okay, do you guys have any, um, we need to head back to class, you guys were doing, like, amazing, but is there anything, real quickly, you would say, um, about (..) You kind of talked about different persuasion strategies which could work, um, what the cause of conflict is, just real quickly, about why the team members cannot reach an agreement, from page two-ninety-seven to two-ninety-nine. Then we can head back to class, 'cause I know the other group is finished already.*
Jenny:	*((long pause)) I think some of it was [passed]*

(continued)

(continued)

Andy:	*::I was gonna say with individuals, if not conflict between individuals with the same goals, because we all have the same goal (..) and we all have different opinions of what's best for this student.*
Peter:	*Yeah, I'd mean, I agree, I think it's – it's conflicts (..) it could probably easily be considered like you said, conflict with the same goal, 'cause everyone's looking out for the student, but one side, they're lookin' out, okay, what's best for the student, is it to remove him from my ((emphasized)) classroom and everyone else wants the best for him, but it- it's the same goal, but they (..) still using different placements.*
Heather:	*Awesome! ((Chat))*

The in-service teachers show evidence of knowing about the skills associated with persuasion and conflict, in two ways: Referring to the pages in the text book where it was presented (Heather), and used when reflecting upon their application of the concepts in the role play. The reflection is about what kind of conflict, if any, did this persuasion strategy lead to and what was the cause of it. The three participants (Jenny, Andy, Peter) elaborate on each other's answer ("I think some of it was" → "conflict between individuals with the same goals" → "it's the same goal, but they still using different placements"), which is acknowledged as "awesome" and "I agree" by the facilitator at the end of the in-group debrief.

5.6 Summary of Findings

The results of the study indicate that the learning we observed in Second Life was highly motivating for the in-service teachers. They took part in collaborative and role-play activities and were deeply engaged; they applied the theoretical concepts taught by the professor in lecture, which in turn aided the participants' learning of key concepts in the subject domain through skills practice. The collaborative activities included advanced technology use, such as modification of 3D boxes for information sharing in Second Life. We focused our analysis of two situations of collaboration and learning, technology adaptation and knowledge adaptation.

The situations revealed two trajectories of evolving artifacts, which were not directly connected but we suggest they are complementary, in the following manner. Technology adaptation required mastery of adaptability skills (i.e., "the ability to bridge the gap between what is and what ought to be" in terms of modifying an SL box from a generic one toward one that is personalized to a group of learners), but it did not involve domain specific concepts or skills to serve as a kind of design rationale for the adapted box. On the other side, knowledge adaptation by which in-service teachers learned domain-specific concepts and skills in special education in an iterative, incremental, three-step fashion (i.e., interacting with professor during theory presentation; collaborative planning of roleplay involving theoretical concepts and skills practice; practicing required skills doing role playing) did not provide any means for practicing adaptability hands-on to ensure deep learning. We hypothesize these "shortcomings" of either side are "off loaded" to the other. At this stage our findings are tentative and must be further explored, as this is the first application of a new conceptual framework for learning with computer tools. We elaborate our findings in the next section.

6 Discussion

Drawing on the findings reported in the previous section and using the conceptual framework presented in Sect. 2, we discuss the research questions raised in Sect. 1.

6.1 How Do the Multiple Functionalities of the SL "Box" Support End-User Development?

A specific building block in the SL environment, the "box," became the focus for our study as it supported end-user development in Second Life in two different ways: (1) building the learning environment with boxes as building blocks and (2) collaboratively adapting boxes for information sharing with other groups. We discuss our findings in terms of the evolving artifacts framework (and in some areas supplemented by and compared with meta-design and appropriation).

The findings show that professional educators (a professor of education and a class of in-service teachers) are able to design and appropriate advanced 3D objects through an engaging process of collaboration in the 3D virtual environment Second Life, despite little knowledge of computer science. This was possible by an environment created according to principles of meta-design, which according to Fischer (2009) include that "owners of problems" act as designers. In our case the owners of problems are a professor and the in-service teachers, who act in their capacity as domain-expert users (Costabile et al., 2008). The in-service teachers created notecards for preparing learning activities such as role-play scenarios, and they used and sometimes customized boxes for sharing the notecards with peers (Extract 1–2).

The basic building block used by the professor to create the learning environment is the "box tool" (Mørch, 2016), allowing both buildings and learning resources to be created (see Sect. 3). Buildings required connecting boxes (a form of tailoring by integration) whereas modifying them required tailoring by customization (Mørch, 1997). The generic nature of the box tool did not prevent in-service teachers from taking part in EUD. The boxes were also specific enough and provided a "gentle slope" to complexity (Ludwig et al., 2017) so that in-service teachers could further adapt them by customization, which was an enjoyable activity that gave the in-service teachers a sense of ownership of their case (Extract 1), connection with their learning activity (Extract 2), and means to reflect on their learning activity (Extract 3).

In some instances customizing the box tool gave the users some unforeseen challenges (as shown in Extracts 2–3). We firmly believe that this form of appropriation was beneficial for them in terms of self-confidence in accomplishing an online learning activity in real time (this is evident in that they had a lot of fun and were able to "play around," see Extract 3). The professor created scaffolding structures using video and signposts in the virtual world to explain that in some places objects cannot be modified (inventory) and in other locations they can (when attached to modifiable building units or land with building permitted, or in a sandbox).

The notions of direct activation (Mørch, 1995; Wulf & Golombek, 2001) and the components approach to EUD (Bandini & Simone, 2006; Mørch et al., 2004; Mørch & Zhu, 2013; Won et al., 2006) suggest that tools for EUD should be available where the need for tailoring occurs in order to minimize interruption of the ongoing activity and to enter a new activity. Our data indicates that the participants understood these notions. Direct activation is supported in SL by right clicking on an editable 3D object and selecting the edit command (or by keyboard shortcut Ctrl-3). The edit command opens a property sheet for basic operations (move, resize, rotate, modify texture, etc.). The group consisting of Heather, Janet, Mandy, and Stacy (Extracts 1–2) were able to customize their own notecard-sharing box in their group room and enjoyed the activity. Further research ought to investigate ways to stimulate engagment in deeper complexity and increased flexibility in technology adaptation in Second Life, and to compare two conditions of object modification (direct activation vs. sandbox) in order to determine the optimal balance of ease of use and space for experimentation without unanticipated consequences.

6.2 *What Is the Role of EUD in the Learning Activity?*

The evolving artifacts framework presented in this chapter takes inspiration from meta-design, appropriation, and constructionism (Sect. 2). In this section we compare appropriation and evolving artifacts as conceptual frameworks for addressing RQ2.

6.2.1 Appropriation Versus Evolving Artifacts

One of the aims of writing this chapter was to develop a new framework for EUD and learning. Appropriation is one possible way to start because it encompasses sociotechnical development (Dourish, 2003; Pipek, 2005; Stevens, 2017; Tchounikine, 2017) and learning (Billet, 1998; Grossman, 1999; Newman et al., 1989; Wertsch, 1998). Dourish (2003) defined appropriation in the field of computer supported cooperative work (CSCW) as the process by which people adopt and adapt technologies, fitting them into their working practices. Dourish (2003) also says "it is similar to customization, but concerns the adoption patterns of technology and the transformation of practice at a deeper level." Wertsch defined appropriation as learning from a socio-cultural perspective as "the process of taking something that belongs to others and make it one's own" (Wertsch, 1998, p. 53). Implied by this perspective is the idea that knowledge is constructed during appropriation, and that students play an active role in the process (Cook et al., 2002; Grossman et al., 1999). The process of constructing knowledge originates in social and cultural sources, and then it is integrated into one's prior knowledge (Billet, 1998).

The gaps bridged by appropriation by the scholars cited are technology adaptation and social organization on one hand (CSCW), and cultural development and learning on the other (sociocultural perspective). The problem with appropriation as an overarching framework is when it attempts to integrate two types of development activities that operate on different time scales (short term vs. long term; specific vs. general; ontogeny vs. phylogeny) with the risk of aligning incompatible activities (Billet, 1998). This problem is articulated by Newman et al. (1989) in terms of sociocultural learning as follows: "task of understanding the history of development of specific artifacts that have taken millennia to evolve in order to appropriate such objects into their own system of activity."

Arguable it is easier to bridge two forms of ontogeny, tool adaptation and knowledge adaptation, in the activities of a small group of learners as we have attempted with our case study, despite shortcomings associated with weak connections between the two sets of actions and interactions (complementarity rather than subsumption). Two premises of the evolving artifacts framework that should be considered before it is put to further use are as follows: (1) knowledge adaptation is enhanced by hands-on adaptability experience, i.e., learning to bridge prior and new (taught) knowledge by end-user development, thus making learning concrete, and (2) technology adaptation (in the broadest sense of the term, not limited to computers) is a fundamental human activity (design) that gives rise to joy, meaning, and knowledge by accounting for the choices made during the activity. The latter corresponds to a type of design rationale referred to in CSCW as "accountable artifacts" (e.g., Dourish, 2003; Stevens, 2017).

6.2.2 The SL Box as Evolving Artifact

The Box became an evolving artifact for the participants in several situations, starting with the basic box tool as shown in Fig. 2, used by the professor for creating building units and information sharing containers (Figs. 1 and 3). Some of those information-sharing containers (Figs. 4: right and 5) served as models for in-service teachers to create their own personalized containers (Fig. 5). The actual time span during which in-service teachers were engaged in box adaptation was about 10–15 minutes, a short and intense activity, which is captured by Extracts 1–3.

The trajectory of the conversation in these extracts starts with a focus on Second Life idiosyncrasies (build, boxes, inventory, property sheet) in Extract 1, followed by adopting the vocabulary of real-life metaphors built into SL and extending to other application domains (price of nothing, make it for sale, zero dollars) in Extract 2, and in Extract 3 the participants are more comfortable and use also experimental and humorous phrases such as "play around," "it's squashing me," and "floating above the window." Once the technology and metaphors had been appropriated, the students' conversation switched almost instantaneously into the terminology of the skills practice and boxes as artifacts were put in the background for the rest of the session (Caruso et al., 2014; Mørch et al., 2015).

6.2.3 Domain-Specific Skills Practice as Evolving Artifact

Our data captures conversations between the professor and in-service teachers and among in-service teachers in their group work. Their conversation is "public" in the sense that it does not directly represent the thoughts of individual learners but meaning making at the group level, i.e., collaborative learning. The professor applied multiple strategies to support collaborative learning: combing theory and practice, repeating the activities, and providing "before" and "after" methods with the role-play (Mørch et al., 2015). Theoretical concepts such as persuasion and conflict were first taught in interactive lectures, then in-service teachers became engaged in collaborative group work to create a role-play scenario (Extract 4), and finally applied in role-playing, which ends with a debrief (Extract 5). The debrief takes place in two rounds: within the group organized by a peer group (Extract 5), and for the whole class organized by the professor. This combination of abstract and concrete learning activities, application of skills in several rounds and debriefing (skills practice iteration) provides for multiple ways of prior knowledge to surface in the learners' conversations. It also gives the learners multiple opportunities to interact with flexible technology and to refine their knowledge over time.

During the group collaboration activity, the in-service teachers went through a process of making sense of the theoretical concepts presented by the professor (Extract 4). This indicates that the concepts were "assimilated" among the contributing members of the group. We did not observe "accommodation," i.e. that learners adjust old ideas and imprecise concepts in order to create better ones, with the methods we used. However, in the final extract (Extract 5) the participants in the roleplay show evidence of knowing about the skills associated with "conflict" in their discussions as they elaborate on each other's answer in response to the facilitator's question in the debrief session, and in a sense the participants build on each other's experiences of the whole situation, the participants' roles, the rules of the game, and the interactions among the role-players (revealed in our video data by tone of voice, temper, and position).

7 Conclusions, Shortcomings, and Directions for Further Research

This study shows that the "box," a specific and flexible (multipurpose) tool in Second Life is used in three different ways: (1) the environment developer (the professor) created the learning environment by combining boxes to create the virtual campus with buildings and learning resources (tailoring by integration) and editing the user interface of the boxes (customization), (2) active users (more technically inclined in-service teachers) modified boxes by customization, and (3) ordinary users (in-service teachers) used the boxes for information sharing without any modifications. There are two interesting findings, one that can be read out of our data and another which is indicative at this stage and requires more work to establish: (1) The modification of boxes allowed in-service teachers to personalize their learning activity, which engaged them in the learning process, and (2) by off-loading those aspects of knowledge adaptation that individuals cannot be consciously aware of, EUD makes the whole learning process more transparent and meaningful to the participants and observers. Furthermore, modification of boxes is simplified by direct activation of a builder (design environment) and editor (property sheet) by right clicking on modifiable 3D objects. The boxes can be modified over an extended period of time by storing them in a repository connected with their copy of the SL software, thus making the modifications be persistent across all sessions in this environment.

This empirical study is primarily descriptive and adopts a qualitative approach to data collection and analysis, focusing on giving empirical evidence for claims through the voices of the participants, and by giving concrete examples of possibilities and limitations of the technology in a real context (outside a usability laboratory). The overarching theoretical perspective is the evolving artifacts framework (EAF), which entails that humans learn by evolving artifacts in two realms (outer and inner; social and individual; technology and knowledge). We have explored the role of end-user development in the "outer realm," and found that it increases engagement in the learning activity, and we hypothesize that EUD complements the more abstract knowledge adaptation by concrete (hands on) activity and experimentation.

7.1 Theoretical and Methodological Shortcomings

Further work should integrate insights from contemporary theories of collaborative learning to enrich the conceptual framework for knowledge adaptation. We have used Piaget's notions of assimilation and accommodation that focus on knowledge adaptation at the individual level, but our data and methods for knowledge adaptation are discursive and focus on situations of collaborative learning. These two shortcomings can be addressed in the following ways: (1) extend the theoretical framework with concepts and models for knowledge adaptation as a social process (e.g. collaborative inquiry models; from ontogenetic to sociogenetic development), and (2) extend the researchers' toolbox with methods for capturing knowledge adaptation at the individual level, such as to identify students' prior knowledge and differences in prior and new knowledge as a result of flexible tool mediation (EUD) and instructor's facilitation (e.g. pre and posttests; treatment and control groups).

7.2 Technology Improvements

(1) Compare two conditions of object modification (in-place and sandbox) in order to determine the optimal balance of ease of use and space for experimentation

without unanticipated consequences, (2) identify the pros and cons of the various ways to support (or not support) direct activation of tailoring tools in EUD-enabled learning environments, (3) compare the "components approach" and the "programming approach" to EUD to identify their respective strengths and weaknesses to (fail to) support constructivist ideals and design principles, and (4) identify the key characteristics of computer tools to support active learning, and (5) compare EUD with other computational approaches toward that end.

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