Implementation Strategies for STEM Learning
Using A Computer-Based Simulation

Stella Otoo
New Mexico State University
saotoo@nmsu.edu

Lauren Cifuentes
New Mexico State University
laurenci@nmsu.edu

DOI: 10.13140/RG.2.2.11150.43849/1

Abstract

Educational Computer-based simulations (CBSs) can be applied to provide students with experiences they would not otherwise be able to have, given that realistic scenarios may not be possible due to expense, danger associated, or rare occurrence of the scenario (Smetana & Bell, 2012). Principles of Experiential Learning Theory (ExL) as identified by the National Society of Experiential Learning (NSEE, 1998) include intention, preparedness and planning, authenticity, reflection, orientation and training, monitoring and continuous improvement, assessment and evaluation, and acknowledgment. These principles served as a framework to develop an intervention designed to help teachers effectively implement CBSs. Using a qualitative approach, findings from a pre, post, and post-post survey and participant interviews indicate a shift in teachers' description and perception of effective implementation before and after a professional development and classroom implementation experience. The study also identified instructional strategies for implementing computer-based simulation in the classroom and goes on to describe professional development experiences to support the implementation of simulations.

Keywords: Teacher Education; Technology Integration

Introduction

Historically, simulations have been prevalent for educating students in fields such as healthcare, the military, and nuclear power to mitigate risk. In the 1960s and 1970s, computer-based simulation was restricted to high-performance computing systems. The continuously increasing capacity and reduced cost of desktop computers have made the adoption of simulations across disciplines easier (Beckett & Zalcman, n.d.). Simulations have been characterized as a model (de Jong & van Joolingen, 2008), a process (Durmez et al., 2012), and a technique (Gaba, 2007). This study characterizes a simulation as a computer-based model and experiential.

A good deal of research has been done on the impacts of simulation on students' learning in middle school and higher education. Studies have focused on the extent to which simulations support learning, what students learn from simulations, comparisons of learning from computer simulations versus traditional laboratories, the features of simulations that lead to learning, and implementation strategies (Blikstein et al., 2016; Chen & Howard, 2010; Decker et al., 2008; Kim & Shin, 2016; National Research Council, 2012; Scalise, 2011b).
Simulations offer a constructive approach to learning where students actively interpret the external world and reflect on their interpretations. However, educators must recognize that CBSs are unintelligent and that their effective use to maximize outcomes for all students depends on effective implementation strategies. Implementation of simulations using a simply-follow-the-directions approach does not maximize educational productivity because the approach does not allow for negotiated learning with the technology and/or with others, provide for active construction of meaning, foster critical thinking, or provide for experiences that feel real and relevant to the learner (Lim, et al., 2012). In research conducted by Chen and Howard (2010), teacher presence played a positive role in student learning outcomes. Chen and Howard concluded that students' learning depends not only on how the simulation is designed and developed but also on how instructors implement them. The effective implementation of simulations requires the effort of teachers in a directed instructional manner (Foti & Ring, 2008). Hence, more research identifying effective implementation strategies is needed.

ExL principles framed our systematic literature review of implementation strategies that have been used in CBSs in the past two decades (2000 - 2020). The literature review led us to conclude that an intervention preparing teachers to apply ExL principles when implementing CBS needed to be developed and explored.

**Purpose of the Study and Research Questions**

Teaching approaches have evolved over the years, emphasizing different ways of learning: behavioral, and reflective. Simulations can be mindtools when they support reasoning and engage learners in critical thinking about a phenomenon while scaffolding their thinking process (Jonassen, 1998). In 1984, the constructivist theorist, David Kolb, published his theory of experiential learning, clarifying that knowledge is created through experience transformation. Kolb's theory was influenced by the works of Dewey, Lewin, and Piaget. He proposed that learning occurs when the learner experiences real-life scenarios, makes connections and reflects on those experiences. Learning and assimilation is an intentional and constructive act. The inter-relationship between teachers who are intentional with their teaching and the expectation of students and students who are given freedom is a recipe for dialectical rationality. D'Arcy (2014) claims that such an inter-relationship deploys competence in high-order interpretation of beliefs and actions to prioritize understanding of the world. Informing teachers regarding how to implement simulations effectively in classrooms can produce or improve learning outcomes and positive changes in students' abilities to think critically, computationally, and logically (Roehrig et al., 2007). This study was designed to address the following questions:

- **RQ1:** How do middle school teachers describe effective implementation of computer-based simulation before and after a professional development experience covering the principles of experiential learning; and if descriptions change, in what ways?

- **RQ2:** How do middle school teachers' perceptions about the most effective principles of experiential learning change after they experience their classroom implementation of computer-based simulations with middle school students?

- **RQ3:** What perceptions do middle-school teachers have of the influence of applying the principles of experiential learning on student engagement when they implement computer-based simulations?
Method

The study was conducted in five different middle schools in the southwestern state of the USA. We used design-based research methods to explore the impact of an intervention preparing teachers to use the ExL model for implementing CBS in a single-subject case study (McKenney and Reeves, 2019). A single-subject case study uses a few participants to study the influence of a new procedure and participants are introduced to an intervention after baseline data is collected (McMillan, 2015).

The design-based research, Educational Design Research (EDR), consists of three main phases: Analysis and Exploration, Design and Construction, and Evaluation and Reflection. The researchers identified and defined the problem through needs assessment and literature review during the analysis and exploration phase. During the design and construction phase, the researchers explore potential solutions that can constitute an actual representation. The proposed solution to address the need is to design and construct an intervention that prepares teachers to implement CBS while applying the principles of experiential learning. After administering the intervention, in this case, professional development (PD) in ExL, phase three commenced through data collection with teachers before they participated in the professional development, during professional development, and after implementing a computer-based simulation with students.

Participants

Five middle school teachers participated as an ideal number for a qualitative case study (Creswell, 2014). From fifteen teachers who had implemented simulations for at least one semester and had experience with simulating in StarLogo Nova, an online agent-based simulation programming environment, five volunteered to participate. Participants identified as three females and two males. They have middle school teaching experience ranging between six and twenty-five years.

Instrument

Data sources included a Pre-Teacher Perception of Implementation Survey, a Post-Teacher Perception of Implementation Survey, a Post-Post-Teacher Perception of Implementation Survey, researcher observations and reflexive notes in a research journal, and teacher interviews. The surveys were designed and developed by researchers from data gathered during the literature review exploration during the first phase of EDR.

Procedure

Participants decided with the lead researcher that a simulation of ecosystems fit their curriculum. Then the researcher developed the CBS using StarLogoNova (https://www.slnova.org/) for participants to implement with their students. Next, the researcher designed the professional development intervention that embeds a scientific approach in using the simulation to teach ecosystems and the principles of ExL in explaining how to implement the CBS. The professional development administration were in two phases: the first PD supported teachers' understanding of using the simulation to teach ecosystems, and the second PD supported the application of EXL principles whiles using the simulation to teach ecosystems (See Figure 1).

Participants filled out the Pre-Teacher Perception of Implementation Survey, participated in the professional development intervention, filled out the Post-Teacher Perception of
Implementation Survey, implemented the ecosystems simulation with students in their classroom, and then completed the Post-Post-Teacher Perception of Implementation Survey. The lead researcher made notes in her journal about participants' processes as they implemented CBS. Then during participant interviews, the researcher took field notes which were recorded and transcribed for analysis. The researcher used descriptive and content analysis to analyze the survey data, and the framework method (Nicola et al., 2013) for analysis of the interview data and member checked to establish the trustworthiness and authenticity of the findings (Denzin & Lincoln, 2017).

**Figure 1**
Research Procedure

Analysis

Results from the surveys and the researcher's journal were analyzed using descriptive statistics and content analyses. Responses from the pre, post, and post-post TPI surveys were compared, and changes in participants' answers were analyzed. The researcher used the Framework Method to analyze the teacher interviews (Ritchie & Lewis, 2003) using the NVIVO qualitative data analysis software to organize and summarize data into categories and themes.

Findings

Middle school teachers perceived that by applying principles of ExL when implementing CBS, they felt high levels of organization and comfort in their teaching skills. When teachers were asked to rate their comfort level (1 being very comfortable and 5-Not at all comfortable) in teaching with the simulation before and after the intervention, all participants reported an improvement in their comfort level and teaching skills (See Table 1).
Table 1
Participants' Comfort Level Before and After Intervention

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Pre-Comfort Level</th>
<th>Post-Comfort Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
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<tr>
<td>5</td>
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<td>2</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Pre and post-surveys included a ranking order of statements that spoke to the six principles of ExL. The table below shows the mean ranking for each principle for the pre and post-survey. The results indicate that after participants have gone through the intervention and implemented the simulation with students, their perception of the value of each of the principles changed.

Table 2
Means of Survey Rankings of ExL Principles (N=5)

<table>
<thead>
<tr>
<th>EXL Principle</th>
<th>Pre-Survey Mean Score</th>
<th>Post Survey Mean Score</th>
<th>Diff. (Pre &amp; Post)</th>
<th>SD (Pre &amp; Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intention</td>
<td>3.40</td>
<td>2.57</td>
<td>.83</td>
<td>.94</td>
</tr>
<tr>
<td>Preparedness and Orientation</td>
<td>2.97</td>
<td>2.93</td>
<td>.04</td>
<td>.62</td>
</tr>
<tr>
<td>Authenticity</td>
<td>3.10</td>
<td>3.60</td>
<td>-0.5</td>
<td>1.27</td>
</tr>
<tr>
<td>Reflection and Acknowledgment</td>
<td>3.40</td>
<td>3.70</td>
<td>-0.3</td>
<td>.58</td>
</tr>
<tr>
<td>Monitoring and Continuous Improvement</td>
<td>3.37</td>
<td>3.90</td>
<td>-0.53</td>
<td>1.00</td>
</tr>
<tr>
<td>Assessment and Evaluation</td>
<td>4.77</td>
<td>4.30</td>
<td>0.47</td>
<td>.64</td>
</tr>
</tbody>
</table>

Post-post survey also included a ranking order (in a different order) of statements that spoke to the six principles of ExL. The table below shows the mean ranking for each principle for the post and post-post survey. The results indicate that after participants have gone through the intervention and implemented the simulation with students in the classroom, their perception of the value of each of the principles yet again changed.

Table 3
Means of Survey Rankings of ExL Principles (N=5)

<table>
<thead>
<tr>
<th>EXL Principle</th>
<th>Post Mean Score</th>
<th>Post-Post Mean Score</th>
<th>Diff. (Post &amp; Post-Post Mean Score)</th>
<th>SD (Post &amp; Post-Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intention</td>
<td>2.57</td>
<td>2.87</td>
<td>-0.30</td>
<td>.59</td>
</tr>
</tbody>
</table>
Participants reported observable behaviors indicating students' engagement. They witnessed their participation and self-regulation, that is, their control over their own learning. According to participants, following the teachers' introductions to the simulation and directions, students were immediately engaged using the simulation tool. Teachers identified the principles that influenced and further supported students' engagement as—intention, authenticity, reflection, and monitoring and continuous improvement. They also believed that computer-based simulations by themselves promote student engagement for some students. They believed that introducing a new tool supported and encouraged some students who were technology oriented.

**Other Emergent Findings**

In addition to research findings that meet the objectives of the study, participants interviews revealed findings that are relevant to implementing CBS in the classroom:

- Time is a major barrier to implementing simulations in the classroom.
- Teacher attitudes towards using simulation with the principles of EXL affect classroom implementation practices and processes.
- Student attitude toward simulation affects their engagement. That is, students disengage until they start to connect with the simulation.
- Dual language learners find it hard to express their reflections on their learning, leading to teachers not necessarily realizing what students have learned or not.
- Some students need to overcome an initial barrier to starting the simulation, especially if they feel they might "mess up" the simulation.

**Discussion and Conclusion**

The potential for using computer-based simulation in the classroom is substantial. One way to ensure the successful use of CBS is for teachers to apply implementation strategies that have been demonstrated to be effective. Teachers require both technological and pedagogical knowledge to support students as they infuse CBS with their content to meet standards while improving students' learning and engagement.

Each of the teachers expressed that all experiential learning principles are essential. However, the ranking of each principle according to the level of importance changed following professional development experiences and again following actual experience implementing the simulation with students in the classroom (See Figure 2). The teachers' survey responses before the instruction on EXL principles reflected teachers' perception that their preparedness and provision of orientation for students were most important. This is not surprising as activities related to the preparation and being experts in teacher content areas align with what is commonly

<table>
<thead>
<tr>
<th>Preparedness and Orientation</th>
<th>2.93</th>
<th>3.90</th>
<th>-0.97</th>
<th>.90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authenticity</td>
<td>3.60</td>
<td>2.83</td>
<td>0.77</td>
<td>.99</td>
</tr>
<tr>
<td>Reflection and Acknowledgment</td>
<td>3.70</td>
<td>3.17</td>
<td>0.53</td>
<td>.70</td>
</tr>
<tr>
<td>Monitoring and Continuous Improvement</td>
<td>3.90</td>
<td>3.73</td>
<td>0.17</td>
<td>1.76</td>
</tr>
<tr>
<td>Assessment and Evaluation</td>
<td>4.30</td>
<td>4.50</td>
<td>-0.20</td>
<td>1.45</td>
</tr>
</tbody>
</table>
emphasized in teacher preparation instruction and student teaching. Following the instruction on the principles of experiential learning, teachers identified the most important principle as having an intention. This was a dramatic shift from the fourth most important to the most important principle of experiential learning. Although having an intention also has to do with setting instructional methods that prepare the teacher for the classroom, intention and activities supporting intentions are more student-centered.

In addition to setting an intention for effective implementation, teacher interviews provided insight into other considerations. To sustain the adoption of simulations in their classrooms, teachers recommended early and continuous adoption of the simulation tool, scaffolding students' abilities to use the software, content mapping of concepts in the simulations, core standard integration, and adopting authentic simulations. Topics regarding simulation as content scaffolds have been extensively studied and addressed (Renken et al., 2016). In addition, scaffolding was relevant not only in the context of content but in learning the simulation itself. Learners need to be introduced to the simulation tool in simple incremental steps. The lack of a simplified and directed instructional manner can present an obstacle to learning and engagement.

While not declaring them as unimportant, teachers ranked assessing and evaluating students as the least important principle before and after the professional development experiences and after implementing the simulation in their classrooms. This finding is not surprising as others have also found that assessment and evaluation are frequently secondary concerns for teachers. This is also true for teachers, who conduct simulations in their classrooms (Raymond & Usherwood, 2013).

Figure 2
The teachers' shifting rankings of EXL principles based on their experiences

According to the teachers, the principles that best-supported engagement was Intention, Authenticity, and Monitoring and Continuous Improvement. They regarded the principles of Monitoring and Continuous Improvement, Reflection, Preparedness and Orientation, and Assessment and Evaluation as helpful when supporting students' learning using simulations (See Figure 3). Observable behaviors, emotional aspects, cognitive engagement, and self-regulation
define student engagement (Fredricks et al., 2011) and teachers are an excellent judge of what engages their students in learning (Harris et al., 2022).

Figure 3

*Teachers' Perceptions of EXL Principles that Best Support Learning and Engagement*

This study revealed that the professional development and classroom implementation experiences resulted in a change in the teachers' views of the EXL principles as they apply to the implementation of simulations. Experiences are central to a transformative learning process for learners. However, discovering strategies that make experiences profound is difficult due to the holistic nature of learning. What we know from this study is that teachers' professional development experiences should include formal strategy or process such as EXL facilitating successful implementation in the classroom.

The study involved a small number of participants, limited time in classroom implementation, and does not explore students' perspectives on their engagement. We recommend future studies to replicate this study with a larger sample for a generalizable qualitative result, extend the research to include students' perspectives with assessments that can determine student learning and engagement, and extend the study for at least an academic year to explore the impact of the results.

References


