CHAPTER 9

Project-Based Learning Progressions: Identifying the Nodes of Learning in a Project-Based Environment

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INTRODUCTION

Discussion and research into learning progressions and project-based learning have been at the forefront of the learning sciences for the better part of the last decade. The initial descriptions of learning progressions arose from developmental psychologists' understanding of how children's understandings in domains change with continued exposure to the content

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of those domains. Learning progressions, by their very nature, are theoretical and require work toward validation and measurement. In addition, while there has been work outlining learning progressions in specific topics within the domains of science, there are currently no studies linking project-based learning, the design process, and learning progressions. Research indicates an ongoing need for the improvement of teaching and learning in science (Gonzales et al. 2008). This is particularly true as one examines the number of new STEM schools opening across the United States and other countries. One possible contribution toward the growth and improvement of teaching and learning in the sciences at the K-12 education level is the utilization of project-based learning.

The purpose of this theoretical chapter is to align project-based learning and learning progressions. A secondary purpose of this chapter is to align the resulting project-based learning progression (PBLP) with International Society for Technology in Education Standards and Next Generation Science Standards. Successful development of domain-specific PBLP would allow educators and researchers to understand and assess student development and learning in this unique context.

This chapter will review relevant literature on learning progressions, project-based learning, and measurement to present a project-based learning progression paradigm that has evolved over the past 15 years. More specifically, the synthesis will discuss the application of the synthesized project-based learning progressions in relation to game-based learning via game development related to STEM fields for students at the K-12 grade level.

Learning Progressions

Learning progressions, in general, are the meaningful sequencing of teaching and student learning expectations accounted for across disciplines, student developmental stages, and grades (Plummer and Maynard 2014). Often characterized by specific content area domains, learning progressions provide a scope and sequence for teachers to develop student knowledge and skills as students progress (Barnhart and van Es 2015). Learning progressions are typically characterized by two traits. The first is standards at each level of development intended to address student abilities, social, emotional, and physiological needs. Second, the standards are sequenced to meet necessary expectancy and actualization. Essentially this means that learning progressions ensure appropriate material that is neither too difficult nor too easy and that the material avoids unintentional repetition.

Building upon the general characteristics of learning progressions, learning progressions in science have been articulated by the National Research Council as providing for empirically grounded, testable hypotheses about learning. In this way, learning progressions provide a link to assessment and help to organize the data-rich environment many teachers experience in the classroom in a meaningful manner. These hypotheses describe the cognitive correlates that students use while understanding fundamental concepts in science, and include how students apply these scientific concepts to problems in science. Learning progressions describe how this practice of applying science concepts progresses over time, and how students are able to become proficient at these essential scientific concepts as they continue to receive adequate instruction (NRC 2007).

Learning progressions also provide a process framework that permits the configuration and alignment of scientific subject matter, methods of instruction, and strategies of assessment that make it possible for students to progress through scientific content domains. Stevens et al. (2010) defined scientific learning progressions as the knowledge that begins on a small basic scale and progresses to more advanced concepts, as well as the application of scientific ideas over a prolonged period. Jin and Anderson (2012) suggested that in order to successfully develop a learning progression in science or engineering, it is important to focus on a specific domain of a scientific concept, or the topic would be too broad to lend itself to the creation of a successful learning progression. We argue that in a project-based environment, the nodes within the project are more important than the content as it allows for the assessment of learning across the project continuum as opposed to the customary score at the project's conclusion.

According to Shavelson (2009), there are two different types of learning progressions; *curriculum and instruction* and *cognition and instruction*. One area of active research is the reconciliation of the types of learning progressions with each other. The *curriculum and instruction* type of learning progression consists of a series of concepts that are based on the empirical evaluation of the comprehensive scientific ideas that function as units in curricula. The *curriculum and instruction* type of learning progression greatly relies on context, which will affect student performance resulting from a specific type of learning progression. Conversely, the *cognition and in*struction type of learning progression plans out a progression that shows how a student arrives at accurate scientific understandings of concepts from their initial conceptions (Shavelson 2009).

Learning Progressions as Guides to Instruction

According to Furtak (2012), ideas that are described via learning progressions are able to assist teachers in identifying and drawing conclusions about evidence that related to student cognitive processing. This evidence can be used to help alter methods of instruction that would benefit students in ways that assist in progressions and advance their learning. Additionally, teachers are able to use learning progressions to understand how students' ideas are able to advance in a domain. Assessment in this manner is a constructive practice for providing a means for educators to examine the formation of ideas, and, more importantly, the sequence of students' thought processes. The author qualitatively examined teachers' views of how learning progressions supported their method of instruction and found that using learning progressions supported teacher instruction and greatly increased student learning. The learning progression examined in this study evaluated how students in a high-school biology class learn the concepts of natural selection. The study then analyzed the responses and interpretations of teachers in regard to these student ideas from the *Natural Selection* learning progression. From the videotapes and interviews conducted with the teachers, it was found that the learning progression served as a rapid approach for teachers to be able to identify student misconceptions about concepts related to natural selection. Teachers also used the learning progression as a logical arrangement to organize the unit that they taught.

Neumann et al. (2013) developed a learning progression to teach energy to students in grades 6, 8, and 10. In this study, the Energy Concept Assessment (ECA) was developed as a measurement tool for the collection of student data from the students understanding of energy concepts as they progressed through the primary learning progression to more advanced components of the learning progression. Results indicated that students developed an understanding of energy concepts, such as energy degradation, energy transfer, and energy transformation. This study detailed methods that offer beneficial support to the teaching and learning of energy concepts for middle-school and high-school students. An explanation was provided of what the primary focus of initial lessons should be and then when and which concepts should be followed, as well as the order in which it is best to teach those specific energy concepts (Neumann et al. 2013).

From each of these examples (Furtak 2012; Neumann et al. 2013) various methods of curriculum reform are proposed. These proposed reforms provide beneficial methods of instruction that would arise because of a learning progression. For example, a natural outgrowth of learning progressions is the inclusion of project-based learning, task-based instruction, and by extension inquiry-based instruction. Schwarz et al. (2009) developed a learning progression for scientific modeling in order to present scientific models as instruments that enable prediction and explanation. This learning progression was used to work with fifth- and sixth-grade students. As they evaluated the students' use of the scientific modeling, Schwarz et al. (2009) found that students were able to successfully progress through the content and develop more advanced views about the explanatory nature of the models using the learning progression. For instance, students were able to explain the essential processes and relationships between various phenomena that they had studied. The students were also able to move beyond explanation and assemble models of these phenomena such as the transition of water particles from the liquid-to-gas phase, and the motion of particles (Schwarz et al. 2009).

Duncan et al. (2009) developed a learning progression to teach genetics to students in fifth through tenth grade. The researchers provided evidence that the use of a learning progression is a more successful approach for teaching important concepts in modern genetics when compared to traditional curricula, in which the sequencing does not account for student development. The results of this study revealed that students do not develop an in-depth understanding of genetic concepts via traditional curricular methods alone. These results were consistent from elementary classrooms to high-school classrooms. Following the implementation of the learning progression, the authors of the study found that there were increases in student understanding related to genetic concepts. According to the study, these concepts should be taught in greater depth. The increased depth informs a suggested science curriculum reform (Duncan et al. 2009).

Gotwals and Songer (2013) conducted a validity study with sixth-grade students, in which student responses to a task were analyzed via think-aloud protocols and item difficulty analyses. These analyses evaluated how assessment tasks serve as evidence for knowledge levels within the progression. In this case, knowledge levels were a combination of information resulting from two learning progressions: one related to fundamental ideas in the field of ecology and a second that provides a mode of scientific practice for the creation of evidence-based explanations. Using the combination of item response and think-aloud protocols, the authors identified tasks that enabled students the opportunities to reveal learning and knowledge about various scientific concepts. The students also demonstrated the ability to develop evidence-based explanations as a result of exposure to the second learning progression (Gotwals and Songer 2013).

A final example of the power of learning progression is illustrated in a learning progression created by Plummer and Krajcik (2010). Developed due to elementary-school students' difficulties around understanding basic concepts related to the motion of the sun, moon, and stars, Plummer and Krajcik's (2010) learning progression assisted students with the learning and explanation of patterns of celestial motion. Difficulty in understanding the motion of the sun, moon, and stars prevents students from developing a more advanced understanding of the domain of astronomy. In this particular study, the authors observed that the learning progression related to celestial motion served as a tool to facilitate discussions between teachers, students, and planetarium directors, leading to the opportunities to better structure and sequence topics for student understanding (Plummer and Krajcik 2010).

Learning Progressions as Methods of Assessment

There are a variety of benefits to learning progressions and how they are used to support classroom learning and teaching practices for both students and teachers. Learning progressions have been used as the foundation for design practices of assessment and curriculum development (Corcoran et al. 2009) and the applications to classroom practice include improving science curricula via empirical feedback as the student progresses, the scaled assessment, and classroom instruction.

Learning progressions are commonly used as a method of formative assessment and growth modeling, which is a process that teachers utilize in order to institute learning goals, determine current knowledge of the students, and consequently offer feedback to students in order to assist students in the progression and advancement of their learning (NRC 2001). Under the growth modeling approach to learning progressions, the progressions represent discreet areas of growth anchoring the students' progress and ultimately their progress toward mastery of the particular progression (Cooper and Klymkowsky 2013). The intention of assessments that accompany learning progressions is to offer analytical information in regard to the intensity and type of student understanding (Steedle and Shavelson 2009). According to Songer et al. (2009), learning progression-guided assessments are able to offer an immense range and the amount of information that can then be used for the purpose of more in-depth analysis to be able to distinguish the various abilities of students, than can be determined via standardized assessments alone. Songer et al. (2009) developed a learning progression for this purpose in relation to teaching and assessing biodiversity content knowledge of sixth-grade students.

Johnson and Tymms (2011) developed and evaluated a learning progression for the instruction of chemistry and the concept of a substance for middle-school students. Using a computer-based assessment instrument in conjunction with video and animation, fixed-response items were developed and data were collected to learn about progressions of various ideas in middle-school chemistry. Data from the learning progressions was shown to fit the Rasch Model, allowing learning progression data to take advantage of the Rasch assumptions and be scaled for task difficulty (Johnson and Tymms 2011). Songer and Gotwals (2012) conducted a study that utilized a learning progression to examine the reasons why elementary-school students have a difficult time formulating scientific explanations. The use of this learning progression enabled researchers to combine traditional content analysis with students' developmental stages to go beyond the use of standardized assessments. Using learning progressions, educators acquire a more in-depth understanding of what areas of learning create the greatest difficulty for elementary students. Combining the learning progression with item response theory (IRT) models such as Rasch, educators can examine and scale the ability of elementary students to devise scientific explanations and track progress over time (Songer and Gotwals 2012).

The goal of learning progressions is to present educators with a framework that could be used to measure a student's level of understanding of a principal concept and then to direct the student to a more complex level of understanding (Neumann et al. 2013). From a study conducted by Mohan et al. (2009), it was concluded that while students may perform successfully on standardized tests, a deeper understanding of various global scientific concepts present in the everyday interactions of our society is obscured due to limited information garnered in standardized tests as a result of test sensitivity.

The identification of the principal concept in understanding biochemical processes was identified via a learning progression that was designed to study how upper elementary through upper high-school students acquire an understanding of essential biochemical processes that transform carbon in socio-ecological systems. For this reason, learning progressions that are empirically validated via Rasch or other methods and whose concepts are logically articulated can serve as a crucial instrument for the development of standards, formative, and summative assessments, and further development of curricular materials (Mohan et al. 2009).

Measurement of Learning Progressions

A key challenge in making full use of learning progressions in the classroom is the ability to successfully model resultant relationships that directly link student performance on tasks with the learning progressions themselves. While in theory learning progressions are leveled by individual ability and have tasks at each level clearly defined, this is not always the case in practice. Often, learning progressions and task linkage are inconsistent and subject to error with current statistical models. One recent approach that holds promise is the use of Bayesian networks (statistical models) for educational measurement. Bayesian network modeling is a means to simplify complex interactions in order to better understand and clarify complex causal relationships. An example of a Bayesian network is an artificial neural network used to examine the complex system of student learning (Lamb et al. 2014a, b).

When considering how learning progressions are modeled for assessment purposes, we can examine the probabilistic relationships among the completion of tasks in real-world settings to generate evidence about the students' ability to understand and recall information in a specific domain. Lamb, in a series of papers starting in 2013, outlined a similar process for use during video game design and science learning (Lamb et al. 2014a, b). During the process of designing the game, students completed virtual tasks. Data from each task, such as mouse clicks, interactions, and tool use as completed in the design processes, are analyzed and broken into task cognitive attribute relationships via cognitive diagnostics and item response theory. From these relationships, a rudimentary learning progression was developed based upon the difficulty of the tasks and the cognitive relationships. The progression of tasks was then entered into a Bayesian network and further developed using cognitive diagnostics and a *Q*-matrix. The students' capabilities and cognitive states were assessed using the output of the Bayesian network. Within this model, the different patterns of activations with the Bayesian network provide evidence of item difficulty, student level, and allow the concept to be placed into a progression and mapped over time.

Project-Based Learning

Project-based learning is a systematic instructional method which leads to captivating the interest of students through a desire to acquire knowledge and skills using carefully designed inquiry that employs challenging, in-depth, and authentic questions (Markham et al. 2009). Project-based instruction was originally designed with the intention to assist medical-school students with the problem-solving skills. This movement came about because young physicians would graduate from medical school with in-depth content knowledge but little diagnostic skill. In essence, the new physicians were not able to successfully apply the knowledge due to the lack of practice engaging in critical thinking and problem-solving (Gallagher et al. 1995). Critical thinking and problem-solving are key cognitive attributes when engaging in the application of science (Lamb et al. 2014b) According to Ravitz (2008), there has been growing interest in project-based learning because students are not adequately prepared for success in higher level STEM courses and subsequently the workforce by traditional instruction alone.

Project-based learning is a method of instruction that produces the skills and strengthens the cognitive attributes that are necessary for one to succeed in the twenty-first century (Ravitz, 2008). According to Markham et al. (2009), project-based learning guides students toward a greater level of cognitive development as a result of the student interaction with the thought-provoking and innovative problems. Examples of enhancing processes and skills that students gain as a result of engaging in project-based learning include problem-solving, critical thinking, planning, and communication (Markham, Larmer, & Ravitz).

Project-based learning differs from traditional learning in that it is an active learning method making use of student agency with the intent to transform students into active, rather than passive learners who learn via second-hand knowledge (Thomas 2000). The goal of project-based learning is for the students to understand science content through first-hand experiences, while solving authentic or real-world problems that occur in the context of the project (Thomas 2000). In the project-based learning pedagogy, the role of the teacher is to serve as a facilitator ensuring students' progress appropriately. This pedagogy emphasizes self-learning via a combination of practical activities, interactive discussions, independent operation, and team cooperation (Tseng et al. 2013). According to Lee and Lim (2012), team project-based learning is a suitable method to initiate interactions between students and to inspire knowledge building through collaborative learning processes. Peer evaluation within the Project-Based Learning is shown to be an effective method to lead to active participation of individual students in team projects (Lee and Lim 2012).

Often project-based learning and problem-based learning are confused. According to Markham et al. (2009), the functions of problem-based learning is: (a) recognize students' inherent drive to learn, (b) their capability to do important work, (c) their need to be taken seriously by putting them at the center of the learning process, and (d) engage students in the central concepts and principles of the content discipline. The project aspect of the work is central, rather than peripheral, to the curriculum. Highlighting provocative issues or questions that lead students to an in-depth exploration of authentic and important topics develops projects. The in-depth exploration requires the use of tools and skills for learning, self-management, and project management. Cognitively project-based learning leads to increased problem-solving, explains dilemmas, and presents information generated through investigation, research, or reasoning. Students produce multiple products during the development of the project permitting frequent feedback and consistent opportunities for students to learn from experience. Using performance-based formative assessments that communicate high expectations, presents rigorous challenges, and requires a range of skills and knowledge promotes prosocial environments and discourses through either small groups, student-led presentations, or whole-class evaluations of project results.

Project-Based Learning in STEM Fields

Studies have shown that there are numerous positive benefits toward student learning, attitudes, motivation, and cognition as a result of participation in project-based learning environments (Hawan and Chang 2011). In a survey-based research study conducted by Tseng et al. (2013), a significant change occurred in the attitudes of college freshman students toward engineering after participation in a project-based learning using a STEM discipline activity. Results of this study indicated that project-based learning environments integrating STEM discipline content have a positive increase in student attitudes toward STEM careers. This positive change in attitudes leads to meaningful learning due to a desire to achieve success in the career field of interest (Tseng et al. 2013).

Chu et al. (2012) conducted a study in which a novel project-based learning pedagogy was implemented during a laboratory on communications electronics. The idea behind this type of teaching approach is to motivate students in ways that the students can see that the material that they are learning as realistic and useful for applications outside of the classroom. As a result, students become engaged in applications from which they are able to relate. The findings of this study revealed that this project-based learning environment leads to high student motivation and effective learning outcomes (Chu et al. 2012).

Zeren Ozer and Ozkan (2012) evaluated the effects of project-based learning on science process skills of preservice science teachers. In this study, while the project was being created, the goal was to determine if preservice teachers demonstrated deeper learning of science process skills through participation in the project-based curriculum. The experimental group demonstrated more success in terms of science process skill tasks when compared to the control group. The experimental group showed higher scores on tasks such as making observations, designing experiments, and using deduction process skills (Zeren Ozer and Ozkan 2012).

According to Kim et al. (2011), a web-based learning environment was able to provide features that enhance project-based learning experiences and processes. These features included the ability to interact and collaborate with small or large groups not in direct contact with the student, access to large amounts of information and resources, as well as the ability to create, organize, and present digital media thereby reducing cognitive load (Kim et al. 2011). According to Lee and Lim (2012), a blended classroom, team-based e-learning environment made it easier to record both synchronous and asynchronous student interactions on the website. As a result of the ability to record large amounts of formative assessment data students were able to reflect on their performance and teachers were able to more easily track the learning processes and progress of the students.

Griva and Semoglou (2012) conducted a study with second grade students evaluating the effect of student participation in a game-based project and its impact on early foreign language skills. Within the game-based projects, the students participated in various gaming activities such as memory, word games, drawings, constructions, and role-play games. Results revealed that participation of young learners in the game-based project lead to a positive effect on the development of their language skills and motivation level in psychomotor activities (Griva and Semoglou 2012). While this study is not directly related to a STEM field, it illustrates the application of games and e-learning in project-based learning. The use of games in project-based learning has implications for fields in science and technology as well as education.

The final example of a successful project-based learning in a gaming environment is in a study conducted by Cappelleri and Vitoroulis (2013). Within this study, project-based learning labs were incorporated into an introductory robotics course that developed into a semester-long Robotic Decathlon in which students designed robots to complete a series of 10 events over a 14-week period. In this study, the experimental group took part in a hands-on project-based laboratory and an open-ended final project. By contrast, the comparison group consisted of a lecture-only type course. Results of the study indicated that students had greater preference and enjoyment toward the project-based labs and final project when compared to the lecture-only course. Results of the course assessment from this study also revealed that student learning is greatly increased as a result of the project-based labs and final project when compared to the standard lecture/test teaching style.

Creating a Project-Based Learning Progression and Measures

Through several funded projects from the United States National Science Foundation, a project-based learning approach has been developed and modified with students from grades 5 to 12. It is important to note that each of the NSF projects studied also investigated learning of various science concepts. For example, the first project explored invasive species and simple machines, the second project looked at renewable and reusable energy, and the third at biotechnology. Within this model of serious educational game (SEG) design and development, distinct nodes of learning were created to aid students in the design process (Annetta 2008). Figure 9.1 illustrates the Serious Educational Game design approach where students were challenged to become the teacher of science content through an SEG.

Each learning node in the progression depicts knowledge and/or skills a student must attain before moving along the learning spectrum. Within each node are subnodes that can actually be considered learning progressions on to themselves all the while the teacher facilitates understanding and conceptual change.

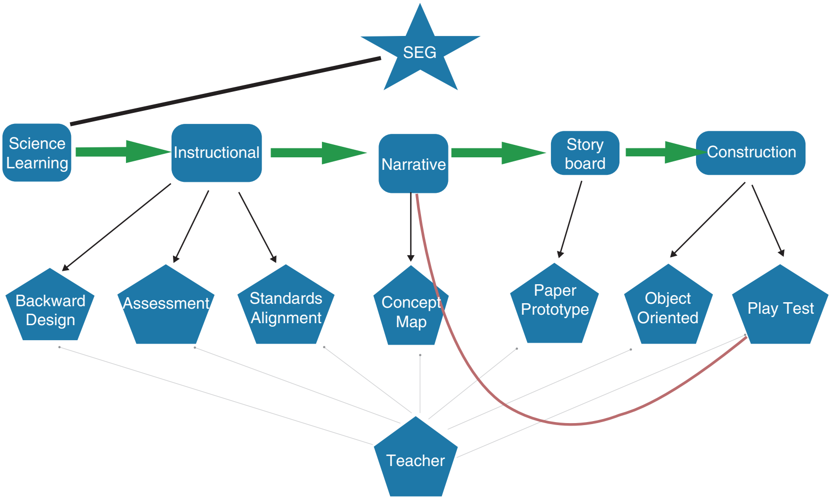

Fig. 9.1 Serious educational game design approach

If we critically look at each node within this example, we can further describe what a student needs to learn before progressing to the next node and how we can measure each node and subnode to accurately study the learning progression in a project-based environment.

NODE Measurement

Additionally, as learning progressions also consist of upper and lower anchors or boundary concepts, they allow for the scaling of tasks within the progression using item response theory measurement techniques and cognitive diagnostics. The upper anchor describes the knowledge that students are expected to acquire and apply toward the conclusion of the learning progression. Conversely, the lower anchor describes the assumptions of the developers about previous knowledge and skills of the students at the beginning and entry phase of the learning progression. In addition, the intermediate steps of learning progressions that occur between the upper and lower anchors, describe the fluctuating levels of achievement of the students as they evolve throughout the learning progression (Duncan and Hmelo-Silver 2009). Lower and upper anchors, when used in conjunction with scaled intermediate tasks, allow for accurate tracking of student understanding, and foster a link between the *cognition and instruction* view of learning progressions and the *curriculum and instruction* view of learning progressions by identifying intermediary concepts between concepts mandated by curriculum, and assisting with teacher creation of scaffolds between those concepts.

To summarize the value of learning progressions for measurement: learning progressions have learning targets, or nodes, that are defined by societal aspirations and analysis of the central concepts in science. According to the National Research Council (2007), there are five important elements of science learning progressions: (1) Themes in domains that are progress variables identifying the critical dimensions of understanding and skills that are being developed over time. (2) Levels of achievement or stages of progress that define significant intermediate steps in conceptual/skill development that most children might be expected to pass through on the path to attaining the desired proficiency. (3) Learning performances that are the operational definitions of children's understanding and skills. (4) Stages of progress that provide the specifications for the development of assessments and activities that locate where students are in their progress. (5) Assessments that measure student understandings of the key concepts or practices tracking student development over time.

NODE Description (Science Learning) Science learning can be accounted for through any of the currently published science learning progressions. There are clear progressions through this process although in the aforementioned funded projects, students learn science in different ways. Science was often taught in a traditional classroom but science was also learned in non-formal settings as well. We had students interact in science museums, zoos, and working with and shadowing scientist mentors working in their respective field.

NODE Description (Instructional) We subscribe to the notion that the best way to learn is by having to teach the content to someone else. To this end, we required students to become the teacher and overlaid instructional design in the game design criteria. With the aid of the science teacher, we taught students the basic pedagogy of backward design, to set and assess learning objectives and how those objectives should align with state and/or national standards. As previously mentioned, the subnodes of backward design, assessment, and aligning standards could be learning progressions unto themselves.

NODE Description (Narrative) Our game design projects are not only educational but fall under and action-adventure story-driven genre. Students must learn the parts of a story and create an interactive narrative where characters and nonplayer characters interact with the virtual world to teach about a given topic. One might remember the *Choose Your Own Adventure* books and how engaging they were for the learner. The same approach is taken in our projects where once a student learns the science and creates a learning scenario, he then must develop a story to articulate the lesson through a cause and effect manner and essentially become the author of his own *Choose Your Own Adventure*. By concept mapping or creating flowcharts of the player decision process, students must consider how to scaffold instruction to the game player if they do not master a content or skill, so that the player can progress in the game that the student is designing.

NODE Description (Storyboard) Like most narrative driven game designers and movie producers, we teach and expect our students to create storyboards that illustrate the critical junctures of their story. Once the story is complete, students then paper prototype the scenes and critical elements of the game. Paper prototyping allows the student game designer to test the interface and see potential pitfalls in his design. This allows the student to critically reflect on the previous nodes and fix any major errors before proceeding the final node of the project.

NODE Description (Construction) The final node allows the student to take all previous nodes and build a virtual space that is rich in content, pedagogy, and story. Our interface provides an object-oriented programming platform so students do not need to know code-based programming, 3D art or animation, or any other skill a commercial game design studio might require to build a game. The final and critical subnode is to play test the SEG. Play testing allows others to interact with the semifinished project and provides the student designers with feedback on whether or not the learning objectives were met.

PROJECT-BASED LEARNING PROGRESSIONS AND THE NGSS

The Next Generation Science Standards, with their focus on science and engineering practices as well as a spiraling K-12 curriculum, lend themselves well to the use of project-based learning progressions (NGSS Lead States 2013).

The use of project-based learning, as discussed above, fosters the development of science and engineering practices including making observations, making determinations regarding data, and the construction of explanations and arguments. Likewise, well-identified learning progressions would prove useful not only in creating the deeper conceptual understandings that the NGSS purports to target but in vertical planning for the spiraling aspects of the content in the standards. For example, in the grant work described above, participants demonstrated deeper understandings of content than their peers in the comparison groups, coupled with improvements in associated cognitive skills such as visuospatial reasoning and computational thinking.

Conclusion

There are numerous teaching and learning benefits from both learning progressions and project-based learning in STEM fields for the K-12 grade levels. There is evidence to suggest that learning progressions occur through project-based learning paradigms. In particular, this appears when students are engaged in a project-based learning environment, such as gaming or more specifically when participating in the development of a game. Although this project-based model revolved around SEG design, we believe it can be used for any project-based approach with distinctive nodes along the learning spectrum that can be measured and analyzed before a learner progresses to the next node, and effectively employed to foster the science and engineering practices and deeper understandings targeted by the NGSS.

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