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**AN INVESTIGATION OF THE ARTIFACTS, OUTCOMES, AND PROCESSES OF
CONSTRUCTING COMPUTER GAMES ABOUT ENVIRONMENTAL SCIENCE IN A
FIFTH GRADE SCIENCE CLASSROOM**

A Dissertation in
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by
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ABSTRACT

Among educational researchers and practitioners, there is a growing interest in employing computer games for pedagogical purposes. The present research integrated a technology education class and a science class where 5th graders learned about environmental issues by designing games that involved environmental concepts. The purposes of this study were to investigate how designing computer games affected the development of students' environmental knowledge, programming knowledge, environmental awareness and interest in computers. It also explored the nature of the artifacts developed and the types of knowledge represented therein.

A case study (Yin, 2003) was employed within the context of a 5th grade elementary science classroom. Fifth graders designed computer games about environmental issues to present to 2nd graders by using *Scratch* software. The analysis of this study was based on multiple data sources: students' pre- and post-test scores on environmental awareness, their environmental knowledge, their interest in computer science, and their game design. Included in the analyses were also data from students' computer games, participant observations, and structured interviews.

The results of the study showed that students were able to successfully design functional games that represented their understanding of environment, even though the gain between pre- and post-environmental knowledge test and environmental awareness survey were minimal. The findings indicate that all students were able to use various game characteristics and programming concepts, but their prior experience with the design software affected their representations. The analyses of the interview transcriptions and games show that students improved their programming skills and that they wanted to do similar projects for other subject areas in the

future. Observations showed that game design appeared to lead to knowledge-building, interaction and collaboration among students. This, in turn, encouraged students to test and improve their designs. Sharing the games, it was found, has both positive and negative effects on the students' game design process and the representation of students' understandings of the domain subject.

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CHAPTER 1

INTRODUCTION

Gaming has traditionally been a part of children's everyday life as a method of play. From hide and seek in the backyard and board games indoor to *Atari* and *PacMan* games in arcades to sports simulations on the *Wii* platform in homes, gaming has captured the interest of children, adults, and educators alike. In fact, the prevalence of commercial games that are directed toward young, elementary-aged children has risen in recent years. These include web-based games like *Webkinz World* that extend the play space for purchased animal toys to a virtual space or portable game platforms such as the *Nintendo DS*. More than 3.6 million combined gaming systems were sold in November of 2008, with gaming markets overall experiencing growth of 11 percent in 2008 (npd.com, 2009). The *Wii* and *Nintendo DS*, which were the most purchased, set new hardware sales records.

Given the prominence of such entertainment games for young children, interest has been correspondingly generated in the educational potential of computer games for classroom use (Dickey, 2005; Kafai, 2006). As Squire et al. (2005) stated, new technologies and games are powerful social, cultural, and technological forces that educators cannot ignore. Gee (2005) claimed that games are a hub to combine learning that requires effort includes fun, a characteristic rarely present in education settings. Gaming, it is argued, holds potential for learning as a means to promote the following: (a) engagement of learners, (b) promotion of active learning, (c) enhancement of learning and understanding of complex subject matter, and (d) fostering of collaboration among learners (Ke, 2008).

The implementation of computer games into elementary education, however, is a more nascent area of research and practice in education (Warren, Dondlinger, & Barab, 2008).

Researchers agree that there is a lack of empirically-grounded frameworks for integrating computer games into classrooms (Ke, 2008). In elementary schools, gaming is often limited to either a reward for students' good work or a break time for some teachers. Many educators, not surprisingly, see game-based learning as only an adjunct to educational goals and standards.

As such, educational theory around the use of computer games is still being developed. Two different lines of inquiry seem to have emerged. The first concentrates on the design and effects of educational games on learning or motivation. Such research might involve incorporation of simulations, repurposing of off-the-shelf computer games, or design of computer games to meet specific curricular goals (Warren et al., 2008). Most commercially-developed educational games would fall into this category. Educational games like *Math Blaster* or *Reader Rabbit* allow for repeated drill and practice with nearly immediate feedback. In these types of games, facts are practiced over and over (e.g., addition and subtraction), but often in the context of an imaginary world, narrative, plot, or goal. Lee et al (2004) (cited in Warren et al., 2008) found in their study that this type of game design (i.e., drill and practice) supported children to practice more math facts problems, increasing both their speed and accuracy. Squire et al. (2005) found that students who played the *Civ3* game developed new vocabularies and, while playing the game, the students displayed complex thinking and negotiation skills.

A second area of research on educational gaming centers on teaching children how to design or program educational computer games for the purpose of learning more about a specific topic in the curriculum (Kafai, 2006). The notion of "learning by design" emphasizes constructing artifacts by programming computers or designing games (Kafai, 1998). Computer

game design by students has led to the hope that students may become more interested in computer science. Recent research suggests that students' interest in game designing has increased as opposed to students' interests in pursuing a computer science major (Synder, 2006; Vegso 2005 cited in Rankin, Gooch, Gooch, 2007). Game design has been used as an encouragement for freshmen to enroll in computer science majors. However, it was also found that game design can have both a positive and negative impact on students' attitudes about Computer Science (Rankin, Gooch, Gooch, 2007). Less is known about the educational impact of introducing young children to programming concepts via a game design approach.

The present research followed the latter approach to gaming research and builds off the work of Papert and others (Harel & Papert, 1991; Kafai, 1996b; Kafai, 2006) to investigate the educational impact of children programming their own computer games. In this context, children become "producers" rather than "consumers" of computer games (Kafai, 2006).

Learning by Game Design

Learning-by-design is neither a new concept nor one that is limited to constructing computer games. The idea of "design" represents a broad class of experiences, but a key experience is that of learning by engaging in design-and-build challenges (Kolodner et al., 2003), culminating in the production of an "artifact" that represents underlying understanding (Kafai, 2005). Design projects can include building physical models of artificial lungs (Hmelo et al., 2000), designing and building a parachute or miniature car and its propulsion system (Kolodner et al. 2003), model rocketry (Petrosino, 1995, cited in Barron et al., 1998), designing blueprints for playgrounds (Barron et al) or virtual roller coasters (Land & Hannafin, 1997).

Resnick and Rusk (1996, p. 434) identified several benefits to implementing learning-by-

design:

- Design activities engage youth as *active participants*, giving them a greater sense of control (and responsibility) over the learning process, in contrast to traditional school activities in which teachers aim to "transmit" new information to the students.
- Design activities encourage *creative problem-solving* avoiding the right/wrong dichotomy prevalent in most school math and science activities, suggesting instead that multiple strategies and solutions are possible.
- Design activities can facilitate *personal connections* to knowledge, since designers often develop a special sense of ownership (and caring) for the products (and ideas) that they design.
- Design activities are often *interdisciplinary*, bringing together concepts from the arts, math, and sciences.
- Design activities promote a *sense of audience*, encouraging youth to consider how other people will use and react to the products they create.
- Design activities provide a context for *reflection and discussion*, enabling youth to gain a deeper understanding of the ideas underlying hands-on activities.

Computer game design has become more prevalent among not only K-12 schools but also higher education and summer camps. In school classrooms, game or software design as a method for learning curricular goals has been explored in a variety of domains: programming (Kelleher, 2006 cited in Pepler & Kafai, 2007), computer science (Franke, Ching, & Shih 1998 cited in Pepler & Kafai, 2007), game preferences and characteristics (Kafai, 1996a), nutrition (Baytak, Land, & Smith. 2008), mathematics (Harel & Papert, 1991), and story building (Kindborg & Sökjer, 2007). An early computer programming design project with students took place in the

1960s and aimed to teach 7th graders how to program a simple strategy game with the *NIM* program (Blankinship, 2005). In the 1980's, Seymour Paper began a line of research around student-designed computer programs using the LOGO system (Harel & Papert, 1991) and later LEGO-LOGO (Resnick, 1993). He was instrumental in developing educational theory and pedagogy associated with young children as game or computer programmers, namely that of *constructionism*.

The constructionist perspective encourages knowledge-in-use through developing physical or digital objects (Papert, 1991). This idea was initially explored by asking young children to use Papert's LOGO environment to design math software about fractions to teach to younger children about them (Harel & Papert, 1991). Learning about fractions, it was believed, would be enhanced by supporting kids to represent what they know by making games about them and to learn by teaching. Constructing artifacts by programming software or games presumably helps students reformulate their understanding and express their personal ideas and feelings about not only the subject but also the artifact (Kafai, 2006; Papert, 1980).

By designing games, children take many roles, as users, designers, storylines, designer, programmer, and teacher (Robertson & Howells, 2008). Designing for others presumably improves student learning by encouraging teaching (Rieber, Lunk, & Smith, 1998). Students become active participants and problem solvers by designing their own games (Resnick, 2007), collaborate and self-assess by sharing designs and asking others for help (Kafai 2005), and become empowered in their own learning by choosing what and how to learn the material (Rieber, Lunk, & Smith, 1998). Designing games is a rich task which offers opportunities for children to exercise a wide spectrum of skills such as devising game rules, creating characters and dialogue, visual design, computer programming, (Robertson & Howells, 2008) and problem-

solving skills (Rieber, Lunk & Smith 1998). Tholander et al., (2002) suggested in their study that game design can lead to learning of complex mechanisms, discovering the internal structure of an artifact, and being creative. Other researchers have also used game or animation design, using a simplified, drag-and-drop software program, as a means to encourage creativity and artistic abilities (Resnick, 2007), and to promote use of core programming concepts such as loops, variables, or Boolean logic (Maloney et al., 2008).

Problem Statement

Although the notion of constructionist learning-by-design is not new, it is relatively unexplored in terms of classroom-based research. Kafai notes that far fewer researchers have emphasized “making games for learning instead of playing games for learning” (2006, p. 37). Despite the considerable interest in game design, and the purported theoretical potential for deep engagement in learning, the processes and outcomes of learning in this way are little understood. What is known from related research on project-based learning and artifact development suggests that learners’ processing and goal setting are often poorly matched to the complexity of project-based learning environments (Barron et al., 1998; Land & Greene, 2000). Schank and Cleave (1995) identified this potential paradox: “how can students learn by doing when they do not know how to do what they have to do to learn?” (p. 187). Learning-by-doing requires learners to both develop a viable artifact that reflects their understanding while simultaneously extending their learning of the material. This requires learners to access and apply their understanding to the designed artifact, think about how to plan and represent their thinking, self-assess and revise thinking as needed, and to develop the artifact itself (Barron et al, 1998). One unintended consequence of such complexity is that learners may focus solely on the details of the

“doing” part of the project (Nicaise & Crane, 1999), or to stick with initial designs, rather than self-assessing and revising them as appropriate (Barron et al).

Specific to game design, some researchers have expressed caution about the inherent difficulty of designing games, questioning whether the design activity should be part of learning process (Prensky, 2008; Tiong and Yong (2008). In addition, Repenning and Iannidou (2008) suggest that, usually among girls, computer science and game designs are seen as simply learning how to code with complicated combinations of letters and symbols. Researchers have been developing game design software that is simple to use, even by children, to lessen the burden associated with building a game (Maloney et al. 2008; Overmars, 2004), but how children use this software to express their understanding of school-based concepts remains uncertain.

Although considerable interest has been devoted to increasing high school students and college students’ interest in computer science, less attention has been paid to elementary school students’ interest in this area. Technology education courses are now taught starting in kindergarten. Children start making decisions about their interests and abilities in technology before entering middle school. It would thus be of interest to learn how programming and game design affects elementary school students’ interest in computing and game design more broadly.

Finally, there are critics against using games in formal education settings because of practical, academic, and moral reasons. Teachers and school administrators often lack technical support for computer problems, instructional support for integrating games in the curriculum, and time for integrating a complex system with learning objectives. As Ke (2008) listed, (a) game play may not appeal to every student, (b) students may be distracted by the game itself rather than achieving the learning goals, and (c) students may fail to extract intended knowledge

from a complicated gaming environment. Some researchers argue that no causal relationship between academic performance and the use of computer games has been established (Ke), and that game-based learning may not fit into school culture and external reporting and assessment requirements (Squire et al., 2005). Lastly, some teachers, administrators, and parents do not accept game design or playing as part of an academic curriculum, instead viewing it as appropriate as rewards for finishing homework or entertainment.

Purpose and Research Questions

The goal of this study is to explore how elementary school students design educational games for younger students to learn about environmental awareness and the types of learning processes and outcomes that result. Learning processes focused on *how* students represented their understanding in the context of developing an educational game about environmental awareness and the social and technical influences in the process of developing and revising their games. Learning outcomes documented *what* types of learning gains occurred as a result of designing games. These outcomes were measured with instruments assessing potential gains in environmental and programming knowledge, as well as environmental awareness and interests in computers/game design activities.

Students used the programming environment, *Scratch*, to design their games (Maloney et al. 2008; Peppler & Kafai, 2007). This program was developed by MIT researchers as a way to make programming accessible to young children and is based on the LOGO concept. *Scratch* has been implemented as part of The Computer Clubhouse community project at MIT for more than two years (Maloney et al.2008). The participants, between the ages of 8 and 18, used various computer programs to design computer graphics and animations. Peppler and Kafai (2007)

analyzed how students at The Computer Clubhouse community were interested in *Scratch* among many other computers programs. According to their analysis, scratch was the most popular design software (n=11 926).

Using *Scratch*, students reportedly have designed a wide variety of products, including music animations or video games. *Scratch* is flexible enough to support multiple designs of varying purposes and complexities. A prior study of the Computer Clubhouse showed that students using *Scratch* developed 19 types of different game genres (Pepler & Kafai, 2007) within an informal, unstructured context. In this study, however, the students were asked specifically to design games to teach younger students about environmental science.

Monroy-Hernandez and Resnick (2008) argue that users of web 2.0 are able to produce content easily but not games. With the *Scratch* official website, however, students are able to upload their *Scratch* games or animations. Borrowing from the *YouTube* concept of user-generated content repositories, the *Scratch* website allows children to share their animations or games by clicking on the “Share” button within the software. According to Monroy-Hernandez and Resnick, there were more than 23,000 designs uploaded to this site (as of August 14, 2007), making access and organization of the games challenging. Accordingly, in this study, students uploaded their games to a secure content management site (*MyLingua*) operated by the school, supporting students to more easily play the games online, rate them, and write comments.

This study extended previous work by focusing on how learners develop games that reflect content understanding within an actual science classroom. Other game design studies either took place in after-school club contexts (Monroy-Hernández & Resnick, 2008), or were organized with college students in computer science majors (Cagiltay, 2007; Overmars, 2008) or gifted and talented programs (Almeida, 2008). In this study, the data were based on an extended

(21-day) learning experience that allows examination of game design factors within an authentic, classroom context.

The guiding questions of this research include the following:

- **Research Question 1 (RQ1):** *What game design characteristics and programming concepts do students use as they work with Scratch to program their games?*
- **Research Question 2 (RQ2):** *How did students represent and revise environmental science concepts throughout the design process?*
- **Research Question 3 (RQ3):** *How do students share knowledge, strategies, and projects for game design?*

Definition of Terms

Operational definitions of study terms are provided below.

Computer games refer to any type of game that a user can either download on the computer or play on the internet through computers.

Avatar refers to the main character of the games where most of the control actions are performed on that character.

Game Character refers to sprites in the game world

Design, unless specified another way, refers to the process of conceptualization and making the game. And thus the term **designer** refers to participants who design games.

Testing refers to debugging and/or the process of receiving feedback from others who play one's game that suggests changes are needed.

Sharing refers to the process of showing the games to others face to face or online.

Technology education refers to a general term for K-12 technology education and emphasizing an introduction to computers courses in elementary and middle school level, and computer science courses in high school.

Environment is defined as the total of the surroundings (air, water, soil, vegetation, people, wildlife) influencing each living being's existence, including physical, biological and all other factors; the surroundings of a plant or animal, including other plants or animals, climate and location. (Pennsylvania Academic Standards commission)

Environmental awareness refers to being knowledgeable about how the nature cycle acts, how humans impact that cycle, and how to sustain that cycle.

CHAPTER 2

REVIEW OF LITERATURE

In this chapter, there is a comprehensive review of the literature related to constructionism, learning by design, and the elements of game-design learning environments.

Constructionism

Constructionism is accepted as both a theory of learning and a strategy for learning which has become an important topic in education (Han & Bhattacharya, 2001). Constructionism is the practical materialization of Piaget's constructivism theory, which states that a student is the builder of knowledge and not the receptor of knowledge supplied by the teacher.

Even though the root of Constructionism comes from constructivism, Papert (1991) defined his theory in two steps which make the theory apparent. The first step is internal; an active process where students construct their knowledge from their experiences in the world. The other step is external; which is based on research that suggests that students learn best by making artifacts that can be shared with others. Constructionism takes the notion of individuals constructing knowledge one step further. It argues that individuals learn best when they are constructing an artifact that can be shared with others and reflected upon (Grant, 2002, Harel & Papert, 1991; Kafai & Resnick, 1996). These artifacts can be anything from a poem or an internet posting, to more complex artifacts like an origami, or a video game.

The basis of Constructionism clearly shows that the theory has permanent connection with constructivism. However, Papert, a student of Piaget, drew attention to a characteristic difference in his theory.

“When Piaget describes himself as constructivist, he is referring to a view that knowledge structures are built by the subject rather than transmitted by a teacher. When we describe ourselves as a constructionist we subscribe to this view but add the idea that building knowledge structures (“in the head”) goes especially well when the subject is engaged in building material structures (“in the world”) as children do with construction sets.”
(Papert, 1991 p. xi)

Harel, a student of Papert, adds three important points that makes Papert’s idea unique. Her first argument is that Constructionism is far more involved in cognitive development through the process of learning. Second, constructionist learning environments are also computationally richer than Piaget’s learning environment. Lastly, Papert’s theory is more focused on individual differences (1991, p 27).

Bruckman and Resnick (1995) believe that children learn with particular effectiveness when they are engaged in constructing personally-meaningful projects. Students in a constructionist learning environment are more likely to explore and to make deep "connections" with subject areas (Resnick & Ocho, 1991). Harel (1991) described the nature of the changes in a student’s learning that she observed in a constructionist project: *“Debbie moved back and forth from being attentive to limited and static amounts of information, to considering several aspect of a situation simultaneously; she moved from concrete thought to more formal thought; she moved from rigid thinking that focused to more fluent and dynamic thinking related to several dimensions of her computer programs. She shifted from narrow and rigid actions to more flexible actions...”* (p.115)

As constructivism has many differences with traditional learning, constructionism also distinguishes itself from more traditional instruction. In a constructionist perspective, students

are not passive receptacles of the knowledge that teachers impart (Hay, & Barab, 2001). In his seminal book *Mindstorms*, Papert clarified this argument; “*knowledge built by the learner rather than taught by a teacher does not mean that it is built from nothing. Interestingly children appropriate to their own use materials they find about them, most saliently the models and metaphors suggested by the surrounding culture*” (Papert 1980, p.19). Students in a constructionist learning environment approach their work with a sense of caring and interest that is missing in most school activities (Resnick & Ocho, 1991).

The structure of a constructionist learning environment is well defined by Papert in both his MIT LOGO project and Samba school projects. Different from the traditional learning environment, a constructionist learning environment, aims to design a learning setting where students construct “objects to think with” and collaborate and share artifacts. Papert describes an applicable learning environment in Constructionism as follows:

“I see the classroom as an artificial and inefficient learning environment that society has been forced to invent because its informal environments fail in certain essential learning domains, such as writing or grammar or school math. I believe that the computer[’s]presence will enable us to so modify the learning environment outside the classrooms...” (1980 p. 8-9).

Pinkett and Randal (2000) have suggested that a constructionist learning environment should be based on individual interest. A learning environment should facilitate deeper understanding with the support of a community of learners. In this setting, individuals have interaction with not only other learners but also with their physical and virtual constructions as well. Accordingly, a constructionist learning environment has a primary focus on a learner's individual cognitive development. But at the same time, the community and the surrounding human context have an important effect on enhancing this development.

The MOOSE Crossing environment is an example of a constructionist learning environment. This environment is a text-based virtual reality environment that is designed for children of ages eight to thirteen. Students using MOOSE Crossing learn computer programming and improve their reading and writing by working on self-selected projects in a self-motivated, peer-supported fashion. The approach is soundly constructionist in that learning through designing and constructing personally meaningful projects is the key element. After studying hundreds of adults and children, Bruckman (1998) found that *“the community provides essential support for the children’s learning experiences. The community provides role models; situated, ubiquitous project models; emotional support to overcome technophobia; technical support; and an appreciative audience for completed work”* (p.47).

Computers in Constructionism

Computers played a very important role in Papert’s Constructionism. Papert’s perspective was that the most appropriate use of computers had nothing to do with the transmission of information; rather, he saw computers as tools to enable children to do things that they could not explore otherwise.

According to Papert (1991), programming helps children express their ideas in an organized output. An example of this implementation started with Papert’s Turtle project at MIT where the computers were used as a mathematically expressive medium. Instead of a traditional approach of teaching math, which was based on using computers as a means of delivery, Papert let the children use computers to design personally meaningful and intellectually coherent artifacts. These artifacts then would help children to reconstruct their mathematical knowledge (Papert, 1980). As a result of this knowledge construction, Turkle and Papert claimed that

computers help children to construct their own personal microworlds (1991). Hay and Barab (2001) also support Papert's idea of the role of computers in a constructionist learning environments. They state that:

“From a constructionist framework, technology is recast: Instead of the metaphors of content delivery for learning, the constructionist metaphor casts technology as a cognitive medium. It becomes a medium for intellectual expression and exploration” (p.283).

The idea of letting the kids lead computers also came up in Turkle's book a few years after Papert's study. Turkle (1984) questioned the results of children's computer use. In her expectation, educators should ask what different kinds of children think about with computers, but should not ask what the computers do for children. Different from the emphasis on tools, Bruckman (1998) also proposed that tools alone are not enough, since they are often misused from the proposed goal. In her perspective, tools can only be effectively constructionist when they are used in a constructionist learning environment.

Role of Teachers and Students in Constructionism

According to Han and Bhattacharya (2001), the role of instructor in a constructionist learning environment classroom is ideally different from the role of instructors in a traditional setting. The instructors in a constructionist classroom are not transmitters of information; instead, they are facilitators and give guidance to the learners along their paths of learning. The teacher's new role as facilitator allows them to assign tasks to students to implement particular instructional goals. According to Rieber, Lunk, and Smith (1998), students do not see teachers as the authority of knowledge, instead a source with more knowledge. The structure of a lesson explained by Han and Bhattacharya is as follows:

“In a learning environment guided by Constructionism, it is important to set lesson/unit goals and expectations at the outset, so that learners understand what they are trying to achieve and the level of that achievement. Explaining multiple strategies allows the learners various ways of solving the problems that they encounter.” (2001 p.2)

Another principle of a constructionist learning is the status of teacher as a mentor.

Teachers act as facilitators; therefore, information for a learner is on demand and not on a script.

However, some researchers (Ionnidou, et al. 2003; Tiong & Yong, 2008) believe that teachers have to be more knowledgeable about the programming and content of the subject area in order to facilitate effectively a constructionist classroom. Nevertheless, by collaboration, students become teachers for each other as well.

The Role of Resources

The term *resource* in constructionism is not limited to textbooks or information sites. With this approach, everything available in the context becomes a resource for students. From a textbook to internet postings, all information can be used by the students. Furthermore, Papert emphasizes how each artifact designed becomes a resource for the designers themselves and for the rest of the community. For, example, a student’s design can inspire other students to add a particular feature to his or her artifact. Kafai (2005) emphasized that the design process ends when artifacts are designed. However, these designed artifacts become resources for yet another new design process. This process, therefore, never ends. Allan Shaw, in his community support study with youth, state that the “*individual developmental cycles are enhanced by shared constructive activity in the social setting, and the social setting is also enhanced by the developmental activity of the individual*” (1996 p.203).

Theoretical Framework for Learning by Game Design

As it was briefly explained above, there are two main components of constructionism: internal and external. Although few scholars have forwarded a detailed learning process framework for constructionist design, Kolodner et al. (2003), Bell and Linn (2000) and Resnick (2007) have generated frameworks that are similar in purpose and are useful for synthesizing a cohesive framework for learning by game design.

The framework for the current study mainly focuses on the external process of constructionism, which emphasizes design and sharing of artifacts. Even though the framework (Figure 2.1) does have internal processes, we refer to these ‘internal activities’ as cognitive processes consistent with Piaget’s view of constructivism. The direction of the learning process in the framework is clockwise. Even though I will give detail explanations for the parts of the framework later, the following is an overview of the learning process in the framework (Figure 2.1):

1. Individuals use their declarative knowledge to plan a design,
2. Then they produce artifacts by using resources and the help of the teacher/facilitators
3. The designed artifacts (games) are shared with other community members
4. Peers, teachers, and other community members provide feedback for the designer
5. The game designer then revises as needed.

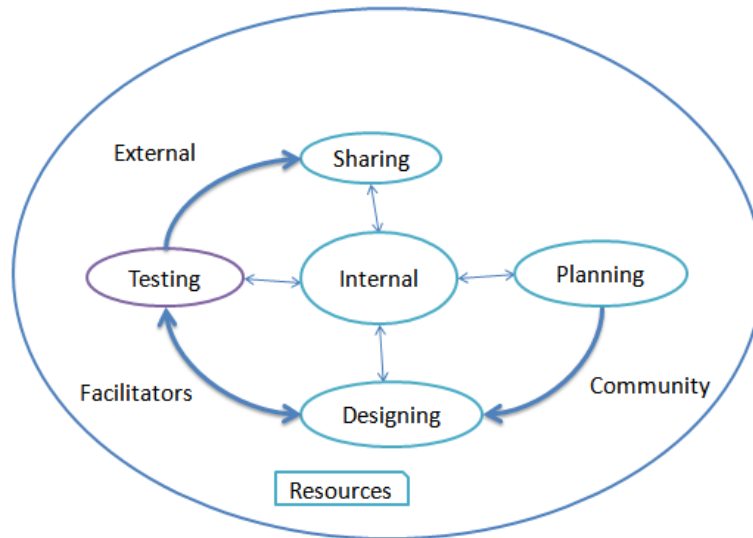


Figure 2.1 A common activity and interaction process in a Constructionist Learning Environment.

Planning

Planning is the initial step in this design setting where learners set goals for their designs. Based on their design ideas, students may have different plans for their design process. Rankin, Gooch, and Gooch (2007) called this step conceptualization in their Waterfall Lifecycle development approach; students conceptualize their understanding of the subject area. Most of this planning process occurs internally, unless students are asked to externalize their planning processes through note taking or journaling (Kafai, 1996b).

Almost every study in constructionism emphasizes that students have to engage in either formal or informal planning to break down a complex programming task and its implementation into more meaningful sub-problems. For example, in Brandes's study (1996), students held brainstorming sessions for planning. Kolodner and her colleagues (2003) required planning sessions and "design diaries" as an explicit element in the curriculum. In a design diary activity, students spend time daily taking notes about their plans for the design before every design

session. The scope of the design diary can cover both planned programming strategies and implementation of the content of the subject.

Kafai (1996a) also used a similar planning strategy in her study where she asked the students to spend five minutes to create “daily journals” before every game session. Kafai, then, compared the students’ projections of game designs in the “daily journals” and interviews with their actual implementations in LOGO. Kafai (2006) used the same strategy in another study and found that students’ contents of planning changed periodically from the demands of the project to focus on design and then to focus on completion.

Artifact Design

One of the most distinguishing features of constructionism is programming or designing artifacts. Designing sharable artifacts that reflect students’ different styles of thinking and learning make that principle of the theory most important. In Papert’s statement, in order for students to gain a deeper understanding of something, students have to create it, construct it and build it (1991). Thus, he uses “objects-to-think-with” for describing objects that embody meaningful and important concepts, enabling learners to make contact with new ideas through their interactions with the objects (Papert, 1991).

Based on the concept of student-designed instructional software, Kafai (2005) claimed that designing the artifacts or programming the software helps students reformulate their understanding and expressions of their personal ideas and feelings about not only the subject but also the artifact. Papert (1980) also sees programming or game making as a construction tool for personal expression and knowledge reformulation, and this tool helps students explore psychological and cultural aspects of learning environments. Bruckman and Resnick (1995) also

stated that learning takes place effectively when students are engaged in constructing personally-meaningful projects.

Wu (2001) stated that designing artifacts and sharing with others as part of learning makes students' ideas concrete and also helps the students establish a personal connection with their designs. Resnick and Ocho (1991) see design activities as extending beyond standard hands-on activities in science classrooms. They claimed that students only recreate knowledge when doing hands-on activities (1991). As an example in their LEGO/Logo project, students formulate their own designs and feel responsible for their designs.

The designed artifacts in constructionist-based research are varied. Harel (1991) asked the study participants to design instructional software for teaching math. In the LifeLong Learning lab, Resnick (1993) also asked the students to program robotic bricks. Hmelo and her colleagues (2000) organized a science-based project where students designed artificial lungs and built partial working models. In other projects, students also designed jewelry (Sylvan, 2005) and origami software (Millner, 2005). Games were used as artifacts in studies by Kafai (2006) and Baytak, Land, & Smith (2008).

When designing these artifacts, students used different strategies. For example, in Harel's (1991) study, students designed math software from scratch. In Kafai's (1998) game design study, students also designed a game from scratch but changed their designs over time. In another study, Baytak, et al., 2008 used a modding strategy in their design phase in addition to designing from scratch. Other common strategies which have been employed in various artifact-design projects include the following:

Using templates: Designing artifacts requiring complex programming is always difficult especially if the program is new to students, because they need time to understand the features

and functions of the program. Thus, a useful strategy is to start with templates and let the students edit them. This helps students become more comfortable with the program codes and functions.

Trial and error: After progressing in programming, students may explore different codes and see the outcomes of those codes in their design. This also helps students discover some features and functions of the program of which they were previously unaware.

Learning from others: Collaboration is another principle of constructionist learning environments in which students share ideas and not only receive feedback, but also gain assistance with programming. Especially with younger children, students tend to work more collaboratively and curiously by checking each others' designs. This helps them to obtain new ideas and new strategies for their own designs. In some situations, some students might already have more programming experience and may be able to help others. For example, in Harel's (1991) Instructional Software Design project, students shared the same room and helped each other with programming in LOGO. Kafai (1996) used a similar setting for her game-design project with elementary school students. Evard (1996) encouraged sharing and collaboration by using an online platform, where students could use time outside of class as well.

Getting help from teachers: The role of teachers in these settings is as facilitator and expert in the domain and the programming software. The teacher or teachers should be available to students for their programming questions.

Using help menu: Although program dependent, help menus are one of the most useful tools for the users to progress independently. Directing students to use help menus more often can be an effective strategy, since the contents of help menus are always available to students. Accessing information on their own may also reduce peer influence on designs.

Moreover, the design phase of this framework works as a whole since students not only design artifacts but also apply their planning for a design session, debug the designed artifacts, and share with classmates before testing.

Testing

There are three types of testing processes in a constructionist learning environment: debugging, peer testing, and audience testing. By testing their own designs frequently, students can check the problems and “bugs” with the artifact. This testing helps the students find problems on their own and redesign with corrections.

With peer-testing, students not only test their own games but they also collaborate. For example, Peppler and Kafai (2007) reported that one student changed some key usages to make his game more user-friendly after observing friends testing his game. Students observe what went wrong in their designs and correct them based on their observations (Cooper, Dann & Pausch, 2000; Robertson & Howells, 2008). In the peer testing process, students engage in a more collaborative way to share ideas about content and design with their peers. In another study by Kafai (1996), fourth-graders designed games, and third grade students as audience tested the games. Kafai believes these testing processes served not only as tests for the educational appropriateness of their games, but also as a platform to build a community of practice.

Feedback

Feedback in constructionism is more than a reflection that is provided as a result of information display. The learners receive two types of feedback from displaying the designed artifacts. First of all, the audiences consider the content information that the designer included in the artifact, and the representation of the designers' knowledge occurring in the artifacts is also available for the audience to evaluate. Most constructionist studies design the study in such a way that someone in the community can judge, try, or evaluate artifacts and content.

Harel (1991) was one of the first researchers in constructionism to apply these feedback mechanisms in her study. She asked the students to design instructional software for younger students from the same school. Younger students, while observed, provided verbal feedback for the designer-students that was used to revisit and modify their software.

Kafai (2005) also used a similar strategy to encourage formative and summative evaluation of the students' designs. In one of her studies, Kafai (1995) used "usability sessions" in which younger students considered the simulation in terms of liking and understanding the software. Students also were able to walk into the classroom for informal peer evaluation and demonstrations for every session. In Kafai's (2005) "Living Laboratory" study, younger students from lower grades become the audience and the evaluators. This model coincides with the settings in the description of Papert's constructionism since this environment provides instant feedback and helps the designers improve their designs after external sharing.

Some other constructionists' research (Hmelo et al., 2000; Gargarian, 1996) emphasizes that designers share particular collections of synthetic and analytical tools and commands for making new ones. This was implemented both as "whole class presentation" and as peer evaluations.

Another unique quality of the feedback in a constructionist learning environment is the involvement of the audience which is defined as sharing in this framework. Different from traditional feedback forms, students generally design the projects for a target group of people. When evaluating the artifact and its content, reflections by this group is not just as judge, but also involves users attempting to benefit from it. This requires designers to consider the all design criteria such as usability, accessibility, etc.

Sharing and Collaboration

Constructionism views learning as an active process where the student constructs knowledge from their experiences in the world. After designing the artifacts, students share these artifacts with community members. Sharing gives the designer an opportunity to obtain feedback, redesign the artifacts and reconstruct his/her knowledge. Bruckman (1998) concluded that constructionism works best when it is situated in a supportive community context. She adds that receiving, offering, and providing help are not simply exchanges of information but social acts that take place in the context of networks of relationships.

Gargarian (1996) also views the community as a micro-world and believes that sharing mobilizes the knowledge of the community to support learning among each of its members. His argument states that a community as a whole is more intelligent than any of its members including its leaders; therefore a community opens new discussions for educational settings. Robertson and Howells (2008) agree that collaboration during sharing is a necessary part of the design process. During the sharing process, peer mentoring and peer scaffolding among its designers can take place (Peppler & Kafai, 2007; Repenning & Iannidou, 2008).

Kolodner and her colleagues (2003) used several different strategies to implement knowledge sharing. For example, students engaged in whole-class discussion around a whiteboard to articulate together what they learned from the previous steps and a class “pin-up session” to collaboratively predict how their designed artifacts would behave. Small group and community “rituals” were incorporated to encourage students to explain, justify, and prepare reports about what they were learning, and poster sessions to present their final products with the entire group. Hmelo and her colleagues (2000) also used similar strategies for their designs, particularly the public whiteboard as a means for sharing ongoing planning, theories, questions, and ideas. Kafai (1996a) asked students to walk into other classes to check each others’ games and discuss modifications. Group discussion strategies were used every day after game design to encourage students reflect and share their game designs, ideas, and difficulties with applying the subject to games.

Based on the idea that on a larger scale, help from a community is impossible for designing artifacts, Bruckman (1998) suggested using computer networks to create and spread constructionist cultures. Her virtual world study, the *MediaMOO* project also represented this argument. Evard’s (1996) *MUD* (Multiuser dungeons) project also provided online collaboration and supported children’s individual interests by providing the users with in-depth information on many topics, connections to other information sources, and ways to construct their own stories. This news-related system was based on the structure that news topics can be shared and discussed among community members for constructing knowledge.

Witherspoon and his colleagues (2004) also developed a course called *Robotics around the World* by using *LEGO Mindstorms Robotics* as the common tool for global exchange. This online course was designed for constructionist teaching and learning. In the study, participants

were able to successfully build an online global community of practice and engage in designing, building, and programming robots collaboratively in an online global classroom.

One of the most broadly-used network communities is *Moodle*, an open source Course Management System (CMS). According to the official Moodle website (Moodle, 2008), over half million registered users speaking 75 languages in 193 countries are involved in this official website. The system is flexibly configured based on the needs of a project. Indeed, the educational philosophy of Moodle centers on providing tools for discussions and sharing.

Gargarian (1996) also supports the structure of constructionist learning environment and add that:

“By sharing a design environment, a learner is not sharing experience directly; rather he is sharing a particular collection of synthetic and analytic tools and commands for making new ones. Because design tools are mind-stretching, sharing design tools promotes cooperative mind-stretching.” (1996 p.140)

Academic Achievement and Assessment

According to constructionist theory, learning occurs when learners construct knowledge and produce sharable artifacts based on their knowledge. Evaluation criteria for academic achievement in a constructionist learning environment vary from subject to subject and design to design. However, commonalities across previous studies exist. Based on review of the literature, the following procedures have been used to measure participants' achievement: pre- and post-tests, pre- and post-interviews, questionnaires, and attitude tests toward the subject area.

Pre- and post-tests or only post-tests are one common measurement approach not only in constructionist learning environments but also in other learning environments. Harel's study (1991) with children using LOGO exemplifies measuring the participants' achievement about

fractions. Kafai (1996b, 2005) similarly used pre- and post-tests to measure students' achievement in science and fractions in a game design project.

Another common measurement is pre- and post-interviews on the subject area. For example, Kafai (1996c) conducted interviews to gather information on students' interest, knowledge, and evaluation of video games. Similarly, Hmelo et al (2000) used pre- and post-interviews to analyze students' understanding of the respiratory system.

In his study with elementary school children, Brandes (1996) examined the students' views of science. He used "general background questionnaires" with ten questions to inquire about students' current likes and dislikes in school and out of school. His "attitudes toward science" and "school science" specifically targeted students' science perspectives.

Assessment is a point of discussion with regards to constructivist learning environments. Some researchers accept that design activities are difficult to assess (Ionnidou, et al. 2003). The positivist perspective's multiple-choice and true-false type tests may be inappropriate to judge the quality of learning that has occurred. Han and Bhattacharya (2001) state that there is no single solution in open-ended and ill-defined learning environments; therefore assessment in constructionist learning environments can be different from learner to learner.

In order to measure students' learning about programming, researchers also used pre- and post- surveys of the students' programming knowledge (Kafai 2005) and pre- and post-tests of programming skills demonstrating students' abilities. Some researchers examined the artifact itself to count the codes or actions in the program to make an evaluation of the programming used by students. For example, with *Scratch* software, scripts of the game characters clearly show evidence of students' programming skills (Maloney et al, 2007).

Researchers also accept the design process is complex and therefore creates challenges that students may encounter when combining and integrating the instructional content, game context, the problem-solving process, and time limitation (Kafai, 1996a). Some researchers argue that portfolios may be appropriate for assessing learning, since representations of the students' learning are the artifacts that they construct (Grant 2002). Tanghanakanond et al (2006) suggested that portfolios can assess individual performance, abilities, capabilities and progress over time.

Interest toward Computer Science

Today's generation might be challenged to conceive of a world without email, Facebook, computer games, and on-line chatting. According to the 2003 census, 69.9% of households have a computer at home and 61.8% of them had internet access. In schools, the goal is one to one computing (Peck, 2005). In other words, the goal is providing every student access to a computer in all subject areas.

Although technology is rapidly developing, there has been a significant drop since the 1960's in computer science majors. Because of this drop, research institutions supported with external funding have evaluated the situation and proposed solutions to increase interest in computer science majors. Despite funding, few practical, applicable educational strategies or approaches have been identified that increase student interest, especially elementary school and middle school students', toward higher education or careers in computer science (Moore, 2008). Since the Internet, there have been rises and falls in enrollments in computer science majors between 1991 and 2002 (Foster, 2005). Yet, Microsoft, the most dominant computer operation system developer in the United States and in the World, announced that they were hiring

computer experts from outside of the United States because of a lack of qualified candidates domestically (Bishop, 2005).

Researchers have since studied why students drop out from these majors, why there is less interest toward programming, and how to increase children's interests toward computer science. Plass et al (2007) noted that females, in particular, exhibit less interest in computer science majors and programming. In her study, Pinkard (2007) found that girls who elected computer science majors had less prior knowledge than boys electing the same majors. More broadly, it has been found that students who enter computer science majors have gaps in their background knowledge and because of these gaps, there is less student engagement and involvement in computer science activities. Consequently, students who indicate a high prior knowledge in operation systems, have limited prior knowledge in programming (Kautz & Kofoed, 2004).

Lin and colleagues (2005) believe that this low prior knowledge (in Taiwan) is due, in part, to the absence of integration of programming in Technology Education Classes, even though there is an increasing awareness of the importance of programming among researchers and educators. Instead, students in these technology classes at elementary and high school levels learn simple Windows applications with word processors, and PowerPoint (Lin, et. al. 2005).

Repenning and Iannidou (2008) claimed that current technology education models do not work in K-12 schooling. These researchers raised another important aspect of the problem that the elective current technology education courses and computer clubs attract and sustain students who are already strongly interested in computer science. In another study on students' attitudes toward programming, Callan (1994) found some practical reasons behind students' declining interest in computer programming. The findings showed that students in the study selected

programming as the least preferred thing to do with computers among many applications. This is believed to be because many software programs are available to use with computers for various purposes. Students also commented that in traditional technology education courses, it takes a long time to transition from basic concepts to interesting projects.

However, a study by Repenning and Iannidou (2008) concluded that it is possible and necessary to find alternative solutions to these curriculum problems in technology education courses. The researchers suggest a shift in focus of existing curricula from programming to design, since programming itself does not attract many students. In order to increase students' interest toward computer science majors, they suggest a scalable game-design approach, which can be used as a means to broaden participation in computer science and to advance design understanding.

This trend in technology education curricula is recognized by the International Society for Technology in Education (ISTE). The National Educational Technology Standards of 1998 emphasized skills such as learning about the ethics involving computers and the use of the computer for communication, “demonstrat[ing] a sound understanding of the nature and operation of technology systems” and “be[ing] proficient in the use of technology” (ISTE, 1998). In its updated 2008 standards, students are now expected to demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology (ISTE, 2008).

In order for students to construct knowledge and develop innovative products, researchers and educators have employed different technological tools in computer classrooms. For instance, Sands, Moukhine, and Blank (2008) implemented *Adobe Flash* as a design-based activity in inner-city middle schools and high schools to engage more students in computer science

activities, while dispelling some misconceptions about computer science and programming. The researchers concluded that the *Flash*-based curriculum worked in attracting and interesting students in computer science.

Engaging students in design activities was also investigated with the *Alice* animation design software. In their empirical study, Moskal, Lurie, and Cooper (2004) examined whether or not using *Alice* programming in computers science courses change students' performance, retention in computer science, or their attitude toward computer science majors. The study results showed that students who worked with the *Alice* program as compared to a control group improved in performance and retention in computer science and displayed more positive attitudes towards computer science. In another study with *Alice* software, Kelleher and Pausch (2006) asked girls to make visual stories with that software. The results showed a potential increase in girls' interest in learning to program.

Although considerable research has been devoted to increasing high-school and college students' interest in computer science majors and technology education courses, less attention has been paid to elementary school students' interest in this phenomenon. Technology education courses are now taught as early as kindergarten across the country. Consequently, students may start to make decisions about their interest in technology and related majors before entering middle school. It is of interest to study how programming and game design affects elementary school students' interest in computing activities.

Computer game design has led to the hope that students may become more interested in computer science majors. According to research, students' interest in game designing has increased as opposed to computer science majors (Synder, 2006; Vegso, 2005 cited in Rankin, Gooch, & Gooch, 2007). In recent years, game design has been used as an encouragement for

freshmen to enroll in computer science majors. However, it was also found that game design can have both a positive and negative impact on students' attitudes about computer science (Rankin, Gooch, & Gooch).

Environmental Education

Recently, there has been a growing interest in environmental issues, and in particular, global climate change. This interest extends not only to researchers and educators in science but also nonprofit organizations (NGO), governments, concerned citizens and advocacy groups who aim to raise awareness on environmental issues. The international community has increasingly paid more attention to the importance of environmental education to environmental protection.

In the literature, the term environmental education (EE) began to be used in the 1960s as an effort “to produce citizens who are knowledgeable about the biophysical environment and its problems, aware of strategies that can be used to deal with those problems, and actively engaged in working toward their solution” (Stapp et al., 1969, cited in Fisman, 2005, p.39). A few years later, The United Nations Education Scientific and Cultural Organization (UNESCO) and United Nations Environment Program (UNEP) announced three major declarations that structured the objectives of environmental education courses.

The first declaration, the Stockholm Declaration, was created in 1972. Three years later, UNESCO and UNEP with representative from 60 countries, announced the Belgrade Charter in former Yugoslavia. According to this charter, the goal of EE is “to develop a world population that is aware of and concerned about the environment, its associated problems, so that the population will have the knowledge, skills, attitudes, motivation and commitment to work individually and collectively towards the solutions of current problems and prevention of new

ones” (1996, p. 94). The Tbilisi declaration, in 1977, by the same international communities, focused on local environmental issues (Fisman, 2005). More recently, former UN Secretary General, Kofi Annan, stated the importance of current environmental problems and how humans are causing these problems. He also called nations and individuals to take action to end thoughtless or deliberate waste and destruction (Annan, 2004, cited in Haigh, 2006).

A US-based international NGO, the Earthwatch Institute, was established by academicians in 2003 “to work together to promote environmental education and the cause of sustainable development” (Haigh, 2006 p.330). With similar goals, there are different organizations such as TEMA in Turkey (2009) and the Worldwatch Institute in the US (2009), companies such as Shell in Malaysia (Said, Yahaya, Ahmadun, 2007) and several worldwide NGOs such as The National Audubon Society, Sierra Club, and GRACE (2009). Recently, Live Earth organization, which is founded by producer Kevin Wall, in partnership with former U.S. Vice President Al Gore, organized a worldwide concert on 07.07.07 called “round the world”. The aim of this event was to increase people’s awareness on environmental issues and global change.

In addition, special days and events focused on the environment are commemorated worldwide, and are often familiar to children in schools: Earth Day on April 22nd of each year and World Environment Day on June 5th of every year. These initiatives are designed to stimulate worldwide awareness of the environment and enhance political attention and action (UNEP, 2009). Tree Planting Day is also organized in different countries such as China, Turkey, Australia, Iran, and Ireland in order to increase awareness of nature among young generations by planting trees.

From a research perspective, studies from the 1960s and 1980s were mainly concerned with the identification, prediction, and the control of variables for environmental behavior (Palmer & Suggate, 2004). In the last decade, however, researchers have examined various perspectives related to the environment such as students' environmental knowledge (Morgil, et al. 2004), environmental awareness and concerns (Sherburn & Devlin 2004; Zimmer et al. 1994), behavior (Negev et al. 2008), and comprehension and participation (Said, Yahaya, Ahmadun, 2007).

As Nicolaou, et al. (2009) stated, environmental problems are complex and ill structured, and these problems involve consideration of values, tradeoffs, social interests, and culture. For instance, Shobeiri, Omidvar, and Prahallada, (2007) found cultural differences between Indian and Iranian students' perceptions of identifying environmental problems in their countries.

Barraza and Walford (2002) found that students have different perceptions about environmental issues in each country. For example, students in Mexico ranked population growth whereas students in England ranked nuclear waste as the most dangerous environmental issues. In another study conducted in China, students listed the quality of water and pollution as the main environmental problem (Jinliang et al, 2004). Similarly, lack of water was identified in a study in Madagascar (Korhonen & Lappalainen, 2004), and air pollution in studies in Israel (Negev et al. 2008) and in Malaysia (Said, Yahaya, Ahmadun, 2007).

Similarly, when examining Chinese students' awareness of global problems and local problems, Duan and Fortner (2005 p.30) say that "It is reasonable that people would determine that an issue is real if they can see or smell it. The most significant issues are the certain ones that can be directly sensed." They suggest further that "educators should choose effective sources

and formats to make more complicated environmental issues tangible and understandable” (p.30). However, none of these studies focused on a diverse classroom environment.

Barraza and Walford, (2002, p.178) stated that “children’s environmental knowledge varies according to the school ethos, the teacher, and their access to information through books, media such as television, computer games, and other social activities. Thus, when children are exposed to situations that involve environmental dilemmas, their reactions vary according to four major factors: (1) culture; (2) experience; (3) affiliation for a particular animal; and (4) school ethos”. Shobeiri, Omidvar, and Prahallada (2007) stated that type of school management, private or public, also has an impact on environmental awareness of students.

Some studies also focused on how people’s environmental knowledge and awareness is structured. According to Palmer and Suggate (2004), “environmental problems are socially constructed in terms of their conceptualized effects on individuals, groups, other living things and systems, [and accordingly,] research based on constructivist principles provides not only a coherent framework in which to theorize about learning, but also a context for understanding socially constructed issues and knowledge” (p. 208).

Students’ perceptions about environmental issues, however, seem mainly influenced by media coverage (Barraza & Walford, 2002; Jinliang et al. 2004). For example, survey results from Jinliang et al (2004) showed that students learned their environmental knowledge from TV (34.259 percent), followed by the press (27.350 percent), teachers (13.746 percent), and only 4.630 percent from the parents.

Even though most prior studies explored students’ environmental knowledge and awareness, there are still concerns about transferring knowledge into action. For instance, in one study, it was found that people were aware of environmental aspects but were not prepared to

transfer their environmental beliefs into consumer behavior (Tuohino, 2003). A similar finding was also reported in the Barraza and Walford study (2002) in Mexico and England where students perceived environmental issues and had a high level of knowledge of environmental issues, but, they were not able to transfer this knowledge into action. Thus, in order to deal with such problems, Nicolaou, et al. (2009 p.49) suggest that “students should be able to reason cause and effects, advantages and disadvantages, and alternative outcomes to the decision making process.”

Since today’s children will be responsible for the remaining natural resources, children’s environmental knowledge, environmental awareness, and attitudes toward environment is important (Korhonen & Lappalainen, 2004). To address that problem, UNESCO has urged educators, institutions, and governments to design environmental education curricula for students that provide learning modules that bring skills, knowledge, reflections, ethics, and values together in a balanced way (Haigh, 2006).

Since the 7-9 age group is at a state where the child’s mind undergoes a developmental change, some researchers specifically examined these students’ environmental awareness (Barraza, Walford, 2002). According to Palmer and Suggate (2004), “the analysis of understanding shows that children as young as 4 years of age are capable of making simple accurate statements about the effects of major environmental change on habitats and living things. Occasionally by the age of 8 and certainly by the age of 10, pupils are capable of appreciating and explaining the complexity of some of the relationships that exist among plants, animals and their habitats, and to provide accurate reasoned explanations of some of the effects of significant changes to global environments” (p. 205).

In order for students to have sustainability, educators start teaching Environmental Education courses either as part of science class, or a separate course. Environmental education as conservation was established in the second half of the 20th century. For example, formal environmental education started in England in the 1950s and in Mexico in the 1980s (Barraza & Walford, 2002). In the US, conservation education started in 1953 and current environmental education started with U.S. Congress Environmental Education Act in 1970 (McCrea, 2006).

In environmental education classes, there have been different programs and activities organized to increase awareness and knowledge of students about environmental issues. Some of them are traditional class lectures, media coverage, camping (Dresner & Gill 1994), or involving students in “the use of facilities, such as botanic or zoological gardens, or museums, as educational resources” and “involvement of the local community in the management of resources” (Evans & Gill, 1996, p. 245). Computer-based instruction is also used for environmental education (Morgil et al. 2004).

Even though environmental issues have an effect on several subject areas, it is rarely integrated with subject areas other than science in formal schooling. Some areas of integration in the research are as follows; math (Jianguo, 2004; Foorest, Schnabel & Williams, 2006), geography, science, moral education, and life skills (Said, Yahaya, Ahmadun, 2007), web-based storytelling (Heo 2004), mobile technologies (Uzunboylu, Cavus & Ercag, 2009), and art (Day, 2004) in order to increase students’ environmental awareness. Day (2004), for instance, designed a study where students created art work to increase their environmental awareness. The results showed that the artwork reached students on an emotional level, affected critical thinking, and assisted memory retention.

Researchers have acknowledged that children's and adolescents' opinions and knowledge concerning the environment have been under-researched (Korhonen & Lappalainen, 2004). In addition, some scholars believe that environmental education should not be restricted to formal education class time since environmental education is a lifelong process (Haigh, 2006). Accordingly, Evans and Gill (1996) suggested having cross-curriculum teaching for environmental education.

Given the growing interest in including more environmental content in education, efforts to increase students' knowledge and awareness of environmental issues are valuable. However, "young people will not act immediately because there is an inevitable time lag before the children or students, who are being educated, are in planning or decision-making roles" (Evans & Gill, 1996, p.245). Likewise, some scholars have criticized the learning strategies employed in environmental education classrooms. Heo (2004), for instance, argued that most classrooms focus solely on learning facts and principles of environment. Others note that studies are focusing solely on local problems (Evans and Gill 1996). Students, therefore, fail to consider environmental issues from a global perspective.

Game play also has been explored as a formal and informal learning environment about environmental issues. For instances, 6th graders were asked to play the game *Second Chance* to increase their environmental awareness (Pacheco, Motloch, & Vann, 2006). In another study, 6th grade students designed games about global warming (Pinkard, 2007). However, this study only focused on girls' engagement in programming. It was found in this study that designers should have clear definition of their responsibility during collaboration.

In sum, many previous studies have focused on educational strategies and tactics to improve students' environmental knowledge and increase their environmental awareness.

However, few studies have investigated the impact of student-designed artifacts around issues in the environment. This study, however, plans to integrate game design with environmental education. With game design, students will have ownership of their learning, be empowered by coming up with their own solutions, design a physical artifact, and collaborate with peers by sharing their games.

The environmental content in this research fulfills school curriculum which is based on Pennsylvania State Academic Standards for Environment and Ecology. If implemented successfully, this research can be a module that effectively educates students on important environmental issues. According to some of these standards (Pennsylvania Department of Education 2002) students will be able to (4.2.4.C) know that some natural resources have limited life spans, (4.2.4. D) identify by-products and their use of natural resources, (4.3.4.A) know that plants, animals and humans are dependent on air and water, (4.3.4.B) identify how human actions affect environmental health, (4.8.4.C) explain how human activities may change the environment and (4.8.4.D) know the importance of natural resources in daily life.

Researcher Beliefs and Biases in This Study

The problems investigated in this study stem from my own college experiences. As a computer science major in college, the first classes I took were on Microsoft© *Office* programs. Word processing was one of the first topics of my computer experience. In that class, the professor taught the software step-by-step starting from the File menu. Since the content was new to me, I lost focus in the second class. The most important and probably easiest topic in computer science became a nightmare for me. I hardly passed the class, and did so without gaining any conceptual or practical knowledge.

Nevertheless, in my second semester I took another class on algorithm from a different professor. This new professor taught the class with a totally different approach. We were assigned to design an algorithmic program to be used by a well known company. Over the semester, we worked on each piece of the whole program and successfully finished the program. I still remember how much I enjoyed the class and how much I learned by designing a product that was designed for actual audiences.

After experiencing two very different educational strategies for learning about computing, I implemented the second approach when I started to teach Technology Education at the school I work for now. I observed the same joy and expression of learning from the students in the class after they learned Office programs by making a car race animation with the PowerPoint program.

Years later, after reading Seymour Papert's book, *Mindstorms* (1980), I realized that I was not the only one with that dilemma. The learning approach we had for the second class I took and the technology education class I taught was based on Papert's constructionism, where students learn by designing sharable artifacts (Papert, 1991). Papert and his colleagues at MIT conducted studies on how students learn math and science while designing educational software (Harel and Papert, 1991).

However, as a researcher, I always wondered what processes I went through while I was programming algorithms for the company, what did I learn about the structure of the company, what my students learned while preparing car race animations on PowerPoint, and how they reflected on their understanding in their designs. In order for me to find a deeper explanation for this marvel of all people's experience, I want to explore this process of constructing artifacts and the learning that takes place during this process.

CHAPTER 3

METHOD

Research Site and Participants

The research site was an elementary and middle charter school located in a college town in the Northeast. Students attending this school are generally middle class children whose parents are largely affiliated with the Pennsylvania State University. According to the mission of the school, technology is one of the key aspects of the curriculum in addition to multiple language learning.

Twelve 5th graders between the ages of 9 and 10 were recruited from their science class to participate in this study. Ten students participated in the study. Only participants providing informed consent were included in the study. The consent which outlined participants' responsibilities and rights under the Pennsylvania State University policy for human subject of research was given to the students for the parent signatures. Students, whose parents accepted their participation, also signed student consent forms with the witness of a school assistant teacher. Ten students participated in the study. The participants ranged in their prior experience with game design using *Scratch*, the programming software to be used in this study. Yet, all students had at least a minimal level of experience and had tried out the software before the study started. Prior knowledge was assessed via interview and survey instruments prior to the study.

Research Design

This research used a multiple-participant case study as the research methodology (Yin, 2003). This methodology is appropriate for investigating complex, contemporary phenomena within its authentic context. Yin defines a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (2003, p. 13). The key questions of this research had driven the design of this study. Questions around “how” or “why” are appropriate for the qualitative case study method (Yin, 2003).

Both qualitative and quantitative data were collected in this study. Observations, game artifacts, documents, and interviews were used as qualitative data sources for this study. By utilizing survey and knowledge tests, quantitative data were linked to this qualitative data to corroborate and extend the primarily qualitative approach (Ke, 2008). The unit of analysis for this case study was the entire classroom learning environment, including all students, teachers, interactions, online postings, and game artifacts.

Class Setting

Since this study was conducted in a joint class of technology education and science, on some days, students went to the science room with laptops and on other days, they went to the computer lab. Both classes were structured loosely in a setting that encouraged students to move around and share knowledge and strategies informally. Students collaborated when sharing information, game ideas, and testing games, but each student was assigned to a computer to work

on his/her design individually. Each student received a computer with a server personal account access through the internet.

The computers that students used were Gateway brand laptops with 1.7 GHz processing and 512 MB RAM. The laptops had CD drives and USB drives which allowed students to upload files into external storages. Since there were extra computers, students were able to use another computer in case of any technical problem with their assigned computers. With the tablet capability, students were able to use the special tablet pen to draw images easily and more professionally.

In this study there were three teachers: a science teacher, a co-teacher, and a Technology Education teacher, with the last being the principle investigator of this research. The science teacher and co-teacher were responsible for classroom management and science content expertise. The technology teacher was primarily responsible for overseeing the study and helping students with game design software assistance.

Game Design Phases

Rooted in the theoretical framework of constructionism, four main phases of game design were implemented in this study (Harel, 1991; Reiber, Luke & Smith, 1998; Kolodner, et al., 2003; Kafai, 2005): planning, designing, testing, and sharing.

Planning

The planning phase was the initial step for students in the game design process. The students planned based on their previous knowledge. The planning phase emphasized student-

directed research on the topic of environmental issues. Consistent with Rankin, Gooch, and Gooch (2007), the students conducted research on a specific environmental problem they chose.

The students specialized in a self-chosen environmental issue since the topic itself was too broad to cover in one game design. After reading more about environmental issues, a student, for example, selected air pollution as her topic, and then engaged in further research to learn more information on air pollution. Similar to the process used by Kafai (1996a) and Kolodner et al (2003), students were asked to take notes on their planning process and post them online. For example, in Kafai's study, students wrote their design plans in their notebook before starting the design process. Students, then, came up with an environmental problem they identified with before starting to design a game about that issue.

Design

The design phase or prototype (Rankin, Gooch, & Gooch, 2007) was the most important phase of the game design process. In this phase, game design was used to mediate students' understanding about not only environmental issues but also the game concept and *Scratch* software.

Students had options to start their game design either from scratch or by modifying the template games that come with *Scratch*. Students were also able to use a modding strategy to build games from available templates which have built-in elements of challenge, curiosity, fantasy, and other properties associated with engaging games (Seif El-Nasr & Smith, 2006).

The design phase took approximately twelve 45-minute class sessions. Students started these design sessions with micro-level planning about what task to do for that specific session. Students kept their planning notes on the *MyLingua* Course Management System which will be explained below.

Students then spent 35 minutes on designing actual games. This design phase included designing sprites, adding actions (using command blocks), and debugging the games. Designing sprites was either with Image Editing on *Scratch* or other available image editing programs such as *Paint* and *GIMP*. Some students uploaded actual environment pictures as well.

Adding actions was the programming aspect of the game design. Students used command blocks to give actions to their sprites and avatars (more detailed information about the technical features of command blocks will be given below). Depending on students' designs, different command blocks were combined for various purposes.

Sharing and Testing

At a micro level, students were able to debug their own games. Testing their own games and learning from errors was an important part of this process (Robertson & Howells, 2008). Within an informal class structure, students also tested each other's games. By debugging their own games and other students' games, students chose to redesign some parts of their games (Kafai, 1998; Kolodner, 2003; Baytak, Land, & Smith, 2008). Testing and sharing are important components of constructionist-based designs. In similar studies, researchers frequently used collaborative settings in their designs so that students can test each other's design and share ideas (Kafai, 2005; Kolodner, et al, 2003; Shaw, 1996).

In this study, it was common in the classroom for students to vocalize their excitement over getting a strategy to work, and then to have several students stop their work to come over and see the new development, since it was a small class with a loose structure. Similar to previous studies, students had a chance to test others' games during any design session. In addition, students were required to spend 20 minutes in the 10th design sessions to walk around the classroom and try out games of their peers.

More importantly, second graders from the same school came to test the designed games twice, after the second and the third week of the study. Second graders were paired with the game designers. After the second graders tested the games, the game designers surveyed them about their game testing experiences. Please see Appendix A-5 for the survey protocol.

Resources

In the context of this study, students were able to access various resources to design their games. Students' designed artifacts, as Papert highlighted (1991), became resources for the others. In addition to the students' game features, the technical features and the environmental content of a student's game were used as resources for the rest of the class. In addition, students' online postings, face-to-face classroom discussions, and feedback were also valuable resources for other students.

Study Procedures

This research was conducted over 23 consecutive school days. Data were collected during class sessions as well as after-class sessions for interviews. Since all the interviews were done individually, they were held after school time and separate from class time. In addition, there were 18 formal class-time sessions of science and technology education classes. Each class-time was 45 minutes but five minutes of each session was devoted to attendance taking, class preparation, and starting computers.

As Table 3.1 shows, each session was divided into different activities. Starting on the first day of the study during technology education class-time, students took a pre-test on environmental knowledge and a survey on environmental awareness. In the last 15 minutes of this first class, students also took a pre-survey on their interest toward computer science. The

same instruments were given to students again at the end of the study as a reference for comparison.

During the second class session, the study started with a planning phase where students conceptualize the topic and conduct research on that topic before starting their actual game design. At the beginning of that session, student watched a 1.32 minute documentary that emphasizes the importance of environment. After that, students had discussion about the some environmental problems and solutions for these problems for 15 minutes.

Students then chose one of these problems and started researching those specific problems. During the research process, students had a chance to use the textbook, school library, and internet. All the research results were posted on the MyLingua system as a knowledge base and online portfolio. This information was also used as a document for data analysis. This planning phase for the environmental issues was continued in the next science class session as well.

Table 3.1

The summary of the study procedures with detailed time, categorized phases, and collected data.

Date	Activity	Phases	Time Given	Collected Data	Data Source
May 4 th	Environmental Knowledge Test	NA	15 min	Test	Pre-test
	CAQ pre-survey	NA	15 min	Likert scale survey	Pre-Survey
	Interviews	NA	30 min	Interview transcripts	Interview
May 5 th , 6 th	Interviews	NA	30 min	Interview transcripts	Interview
May 8 th	Introducing the project	Planning	5 min	N/A	N/A
	Environmental Awareness Survey	NA	10 min	Likert scale survey	Pre-survey
	Watching Video on Environment	Planning	2 min	N/A	N/A

	Research on their topic	Planning	10 min	Field notes	Observation
	Explaining how to post information in MyLingua	Planning	5 min	N/A	N/A
May 11 th	Research on the their topics	Planning	40 min	Daily journal	Documents
May 11 th (TE time)	Thinking about a 2 nd grade game	Planning	10 min	N/A	N/A
	Students explored different <i>Scratch</i> games	Planning	15 min	Observations	Documents
	Planning for their design	Planning	10 min	Daily journal	Documents
May 12 th 13 th	Planning	Planning	5 min		Documents
	Recording students interactions	NA	40		Observations
	Design games	Designing	40	Scratch Site	Artifacts
May 15 th	Group Discussion	Planning Sharing	20		Observation
May 18 th , 18 th TE, 19 th , 20 th	Planning	Planning	5 min	Daily journal	Documents
	Recording students interactions	NA	40		Observations
	Design games	Designing	40	Scratch Site	Artifacts
May 21 st	Peer-testing	Sharing and Planning	40 min		Observations Documents
May 22 nd	Planning	Planning	5 min	Daily journal	Documents
	Recording students interactions		40		Observations
	Design games	Designing	40	Scratch Site	Artifacts
May 26 th	2 nd graders testing	Sharing	25 min	Interaction and field notes	Observations
	2 nd grade filled the survey	Sharing	5 min	Survey results	Documents
	5 th graders' reflections	Planning	5 min	Daily journal	Documents
May 27 th , 28 th , 29 th , June 1 st	Planning	Planning	5 min	Daily journal	Documents
	Recording students interactions		40		Observations
	Design games	Designing	40	Scratch Site	Artifacts
June 2 nd	2 nd graders testing	Sharing	25 min	Interaction and field notes	Observations
	2 nd grade filled the survey	Sharing	5 min	Survey	Documents

				results	
	5 th graders' reflections	Planning	5 min	Daily journal	Documents
June 2-4	Post-tests and survey	NA	40 min	Test, survey	Post-tests
	Post-interviews	NA		Interview transcripts	Interview

However, before the design session started, the students were asked to think about game ideas by considering their audience, second graders. During this time, students also watched a few environment-related games to get an idea. On the following day, students were given training on how to upload their games online. Then, they continued to collect more information for their game ideas. Next, during two formal class sessions of the study, students designed their games. For every session, students were asked to write a plan for the day and to implement that plan in their game designs. During design sessions, the technology teacher was available for questions. This designing phase took seven class sessions.

After these design sessions, students were divided into two groups based on the environmental problem they chose, and taken to science class for group discussion for the half of the class time. The other group kept designing the games until their turn for the discussion. These discussions were started with the science teacher's prompt questions and they were video recorded. Four design sessions followed that discussion session. The design sessions were in the same design format.

Prior to the first 2nd grade testing session, students were asked to test each other's games, and leave feedback for their peers. This peer testing was planned to be held on May 20th, but it was postponed to May 21st since the students insisted that their games were not ready. For peer testing, students were assigned to four classmates. After they tested the games, they filled

evaluation form for the games they played (see Appendix A-6). These evaluation results and comments from peers were given to the students to make changes on their games.

The third week of the design, after students designed the first prototype of their games, second graders from the same school tested the games. Each 5th grader was assigned to four second graders and the science teacher explained the procedures of this testing process. Assigning students to each other and explaining their responsibility in this process took 5 minutes. In 25 minutes, the second graders tested the games and filled the game evaluation survey (see Appendix A-5). It took approximately 25 minutes for the second graders to test four games. During the last five minutes of the class, the second graders met in the middle of the classroom, in front of the fifth graders, and made comments about the process and what they liked about the games. These responses, as previous literature indicated (Kafai, 2006), helped the fifth graders redesign their games. The fifth graders were also asked to post their reflections on MyLingua.

After this testing process, the fifth graders kept designing their games for four more sessions. Similar to previous sessions, students took their daily plans for the design and posted their games online. The design sessions of this study ended with another testing session with the second graders. The same testing procedures were used.

Within one week of finishing the study, all the students were interviewed individually. During these interviews, students were asked questions about their games, game design experience, and learning.

Game Design Software

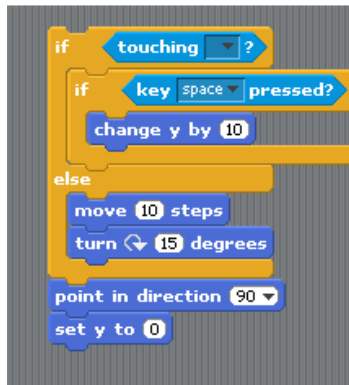
Given the high interest in games, there have been several software programs made available for users to design animation, simulations, and games. Some of them are intended for adult designers whereas others are intended for children. Researchers have used various game programming toolkits such as Stage Cast Creator (Habgood, Ainsworth, & Benford, 2005), Gamemaker (Overmars, 2004; Perciles, 2007; Baytak, et al. 2008), Alice (Kelleher & Pausch, 2006), Neverwinter Nights (Robertson & Good, 2005; Robertson & Howells, 2008), AgentSheet (Ionnidou, et al. 2003), and Scratch (Peppler & Kafai 2007; Maloney et al. 2008).

In order to identify the most appropriate software program for this study, the researcher of this study tested Alice (alice.org), ToonTalk (toontalk.com, MicroWorlds (microworlds.com), Scratch (scratch.mit.edu), GameMaker (gamemaker.nl), StarLogo TNG (education.mit.edu/starlogo/), Stagecast (stagecast.com), and BYOND (byond.com). Among these software programs, the researcher chose *Scratch* for the following reasons:

1. The interface design is user-friendly and coding is visual.
2. The list of command blocks is already provided to the users.
3. *Scratch* blocks simplifies the mechanics of programming by eliminating syntax errors (Maloney et. al, 2008). As shown in Figure 3.1, the users can drag and drop command blocks but they have to type all the letters and symbols, and both codes have similar functions.
4. According to its developers, Peppler and Kafai (2005), *Scratch* was purposely designed for constructionist learning environments. *Scratch* was developed in a university lab and has been funded by the NSF.

5. Since there have been studies already conducted with *Scratch* and specifically with kids (Maloney et. al, 2008; Resnick, 2007), the software and educational theory have been iteratively tested.
6. Different from most other design programs, *Scratch* has clear and visual help for the users. In this program, any time users right click on any command block, they are able to see a description of the command block and an example of its usage in a script.
7. *Scratch* provides object-oriented algorithmic programming. Students do not need to type every single code.
8. The users were able to get advanced help from the forum on the official website of *Scratch* which also allows children to register. On this forum, there are numerous question and suggestion postings from users who introduce themselves as children.
9. When *Scratch* is installed, there are several different types of designs that come with it. These template designs could help beginners of the program to review their scripts.
10. *Scratch* is free of charge to download. Since the study was conducted in a public school with a limited budget, it was reasonable to choose inexpensive tools.
11. Even though the participants in this study were assigned to use *Scratch* on PC, it is noteworthy that *Scratch* works on Mac computers as well.
12. *Scratch* has a “share” feature which allows users to upload their designs to the official *Scratch* website. Furthermore, the participants in this study were able to upload, view and test their own and others’ *Scratch* designs on *MyLingua*, the Course Management System for the school. This allowed for easy viewing of games by others, even from home.

13. Even though it was not used in this study, the developer of *Scratch* has been working on a network-based program called *NetScratch*. When this new program comes out with its promises, future studies can be conducted based on this current study.



Programming on
Scratch

```
if (!$this->rawFieldContent) {
    $result = "";
} elseif ($this->syndicateHtml) {
    $result = "<![CDATA[".$this->rawFieldContent."]]>";
} else {
    if ($this->truncSize and is_int($this->truncSize)) {
        $result = FeedCreator::iTrunc(htmlspecialchars(
            $this->rawFieldContent), $this->truncSize);
    } else {
        $result = htmlspecialchars($this->rawFieldCon
    )
}
return $result;
```

Programming on PHP

Figure 3.1 Similar controlling structures in *Scratch* programming and php programming. (The php code is from Joomla Content Management System).

Scratch is an open-source programming environment written in the Squeak programming language. *Scratch* is developed by the LifeLong Kindergarten Group at MIT (<http://llk.media.mit.edu/>) and Yasmin Kafai at UCLA. This program is designed based on Seymour Papert's LOGO programming and Alan Kay's Etoys which replaces codes with dragging command blocks (Maloney et. al, 2008).

With its colorful and user-friendly interface, *Scratch* gets children's attention. Different from most other design software, the script area on *Scratch* is always visible to the designers and this invites exploration because users can see the stacks in the scripting area highlight as the action unfolds on the stage (Maloney et. al, 2008). In this section, some components of *Scratch*

will be briefly described. Besides a common filing and editing features in the Menu, the other four sections of the program that are not common to other game design programs will be described. As shown in Figure 3.2, there are four main sections on a *Scratch* program; Command blocks, Script area, Stage, and Sprites.

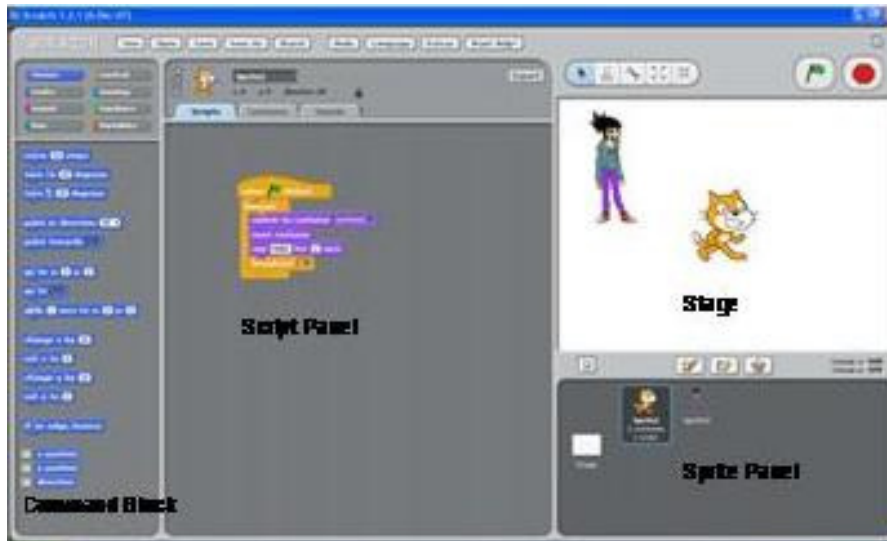


Figure 3.2 A screen from Scratch software.

Command Blocks: Command Block has eight categories and each category has its own command block. These categories are Control, Motion, Looks, Sensing, Sound, Pen, Numbers, and Variables. Under the Control category there are variables and sequences such as if loop, pressing on a key, and repeating and action.

- *Motion* has moving and direction commands. The users are able to set certain coordinates or turn the avatars to a certain degree or set the border for bouncing.
- The command for *Looks* has features to change the costumes of the avatars, hide or show them, change their sizes, or make them speak.

- For *Sensing* there are conditional statements for control commands. The users of *Scratch*, for example, may set collision between avatars or trigger a new action.
- *Sound* has command blocks that allow users add sound to their designs and play them in different tempos. Volume levels also can be controlled with commands in scripts.
- Another unique feature of *Scratch* is supporting arithmetic, comparison, Boolean operations, and negative arguments, and therefore it improves the users understanding of algorithm (Maloney et. al, 2008).
- Under *Number* command block category, users can use different arithmetic and Boolean operations in the design scripts.
- Similar to Papert's Turtle project, *Scratch* also provides a drawing pen feature where an avatar can draw shapes when the commands under *Pen* are used in the design scripts.

Variables allow the user to set live or health type of scoring system in the designs.

Script Area: The users of *Scratch* drag and snap command blocks together to build scripts. In other words, the script area is a coding page for the design. There are four different sections in the script area for coding, costumes for drawing sprites, sounds for recording or importing sound files for the design, and coordinates to set the directions of the selected sprite. By clicking on any of the sprites in this area, the script area will show the properties of that specific sprite. *Scratch* also allows its users to be able to duplicate sprites and scripts.

Sprites area shows the thumbnails of the all sprites in the current design. The users can design their own sprites with the *Scratch* image editing tool, use *Scratch* ready images for the sprites, or export any image to the *Scratch* platform.

Stage is the place where programmed sprites interact. In other words, it is the output for design. However, users are also able to move the sprites onto the stage or take them from the stage.

Designing a Simple Project on Scratch : Designing on *Scratch* is straightforward. By default a new *Scratch* project shows a cat sprite, the symbol for the *Scratch* program, on the stage. The users can replace this sprite with any other sprite(s). Then the users have to choose commands from the Command blocks and set these commands in the Script Area. The users, then, can play the actions by using the control command that was set in the Script Area.

MyLingua

MyLingua is the course management system at the research school site. MyLingua is a Moodle-based course management system, version 1.8.4. The interface of the system is shown on Figure 3.3. The participants of this study had been using this system for seven months prior to the study. The school uses this system for students to access class information, upload assignments, and communicate with the teachers and peers. Although students were experienced with the system, the teachers gave a brief instruction on the procedures to use certain features of MyLingua.

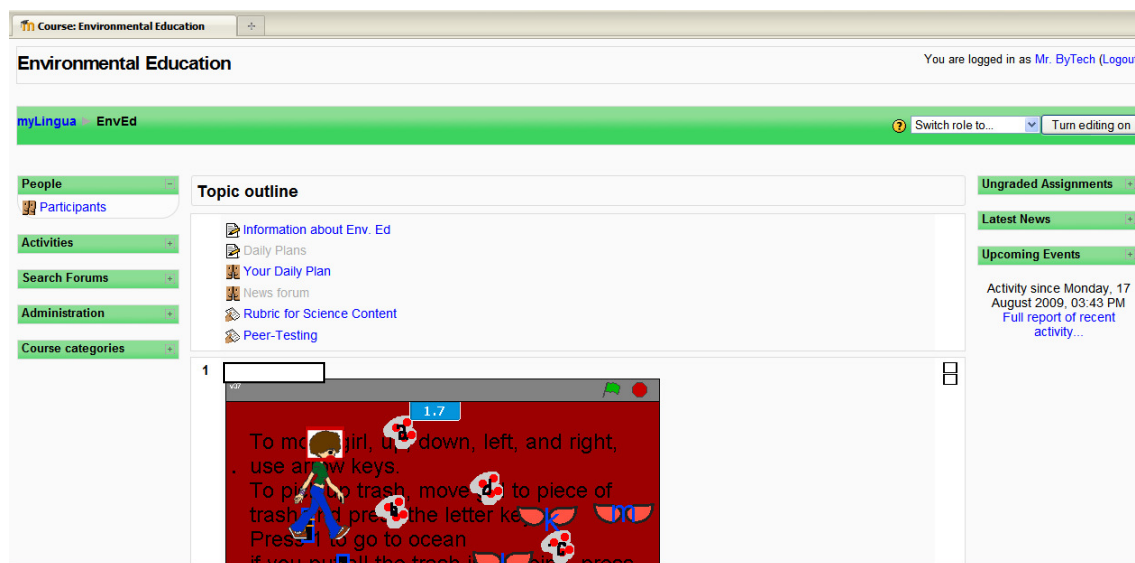


Figure 3.3 A screenshot of MyLingua course management system

In this project, students used MyLingua for multiple purposes. First of all, students took some of the surveys on MyLingua which requires the students to respond to all questions and save their work. Second, students stored their plans and reflections on that system because it saved their postings by date and entry. Third, students uploaded their games on MyLingua which has a filter already installed for *Scratch* games. Uploading games in this system was expected to help students check others' games at any time from anywhere. Uploading games also helped the researcher to archive the games over time.

Data Sources and Instruments

To enhance the quality of the study, the researcher used multiple data sources that are recommended by Yin (2003) and Merriam (1988). The data sources for this study consisted of the following: students' responses for pre-and post-surveys, students' games, interview transcripts, observations and field notes, participant observation, and documentation from

classroom teachers. As shown in Table 3.2, each data source was collected for a certain research question, but some data sources were used for more than one research question.

Interviews: A semi-structured interview protocol was used (see Appendix A). The purpose of interviews were to collect data about students' experience with the game design process (Yin 2003), their interactions with their classmates, their perceptions of programming, and their interpretation of environmental problems. Similar to Ionnidou, et al. (2003), students were also questioned about why they added certain programming features to their game designs. Even though interview questions were open-ended, they were categorized to be consistent and to reduce confusion.

There were two interviews; before game design and after game design. The interviews were conducted outside formal science or technology education class time during free times and during an after-school program. Each interview was recorded on two recorders, and these recordings were saved on two different disks in order to secure the recording process. The students were interviewed individually in a quiet classroom without any other students. Even though classroom doors were closed to avoid interruptions, there were few unexpected and unintended interruptions such as school announcements from paging.

At the beginning of the interviews, each student was told that there is no right answer for my interview questions and they may say anything unless inappropriate. They were also told that what they say did not affect their grades. These reminders helped students be comfortable with their responses. When students were not sure about a question, the researcher gave him/her time to think about it. There were some cases that researcher rephrase the question or gave example to clarify the question. Especially during the post interviews, the students were referred to their games when they were not sure on some questions. At the end of the interviews, all the students

were asked if they had anything to add. This was believed to be helpful for students express other ideas that were not asked.

Students Games: Similar to previous studies, students' games were collected as a rich data source, since artifacts reflect students' understanding and thinking (Harel, 1991; Kafai, 1998). Students' games were saved after each session. Even though all students have personal server accounts and their files were saved automatically on the main server, the students were also asked to 'share' on official *Scratch* website (scratch.mit.edu). Prior to the project, the researcher created a generic username and password for the students to upload their games on this site. When the students uploaded their games, they were asked to name the game files with the date of that day to track differences. Even though the initial plan was to ask the students to upload their games on their MyLingua accounts, some technical problems prevented that. Thus, the researcher uploaded their games on MyLingua after each design session.

Observations: As one of the main data sources of the case study (Yin, 2003), students' activities during the study were observed. Observations were based on field notes and video recording during design activities. However, video recordings were limited to students whose consent forms included their agreement to be recorded. In their consent forms, all the students except one, agreed to be recorded. Besides a data source for the analysis, these observations were used as sources to build interview questions. It was observed that students got used to the video recording after the few design sessions. They rarely paid attention to camcorder which was set in the corner of the classroom focusing on the interaction of four students.

Participant Observation: The data collected included the researcher's observations and interactions. The researcher's role, as a technology coordinator and technology education teacher at the research site, inherently brings prior experiences and background information to the study.

The researchers observed students in class and out-of-class behaviors related to this study. The students' participation at the school technology-related activities and the students' uses of the programming concept in other classes were also observed during after school program.

Journal Entries: As part of the study design, the students were asked to make daily plans for their designs prior to each design session and after testing sessions. The daily plans were structured with prompt questions that students responded to online. This journal taking was done on MyLingua system to keep students' entries permanent and organized. Prior to the study, the researcher explained the process of keeping an online journal. Journals entries, students' planning and reflection notes, provided an indication of the thoughts, intentions, and goals of the students. These notes provided further basis for interview questions.

Programming Knowledge Test: Students programming knowledge, i.e. programming using *Scratch* software, were assessed during the pre-interview. This test measured students' prior knowledge about *Scratch* software. This test was done face-to-face as a semi structured survey (see Appendix A for the questions). The results are presented in Chapter 4 as Students' Computing and Programming Background.

Interest in Computer Science Survey: The survey was consisted of excerpts from the Computer Attitude Questionnaire (CAQ) (Knezek, Christensen, & Miyashita, 1998). The CAQ is a 65-item Likert Instrument for measuring middle school students' attitudes on all Young Children's Computer Inventory subscales, plus computer anxiety. Part 1 of this instrument was used for this study, which focuses specifically on computer enjoyment and computer importance. These scales have established reliability scores of .82. Part 2 of this instrument is adapted from Bonanno and Kommers (2008) to look at game design issues specifically.

The survey did not only shape the case study interview questions, but also provided a wider context within which to nest the findings from the cases. The participants took the survey on MyLingua system which is password protected. The responses were copied to word file for backups (see Appendix B). The survey consists of 23 questions. The survey was done as pre- and post-survey.

Environment Knowledge Test: Students' pre- and post-test knowledge about environmental content was measured with a multiple choice question test. The test questions were generated from the class science textbooks (McDougal Littell, 1993; Holts, Rnehart, & Winston, 2005) dealing with basic information about environmental content such as environmental terms and the origin of environmental problems (see Appendix C). The validity of the questions for this assessment was established by vetting of the content of the questions by the science teacher. The same questions were used as pre- and post-test.

Environment Awareness Survey: Students' awareness of environmental issues was measured by a survey administrated both before and after the study. The questions were selected from an existing survey developed by Musser and Malkus (1994). Reliability scores for this assessment are .68 (see Appendix D). The same questions were used as pre- and post-test.

Data Analysis

Based on (Yin, 2003), the pattern-matching technique was employed to analyze most of the collected data. Pattern-matching logic is the specific technique used for within-case and across-case analysis. Pattern-matching compares a theoretical-based pattern with an empirically based pattern (Yin, 2003). However, because of the variety of data sources and research

questions, there were different techniques used based on the literature review. For each research question, multiple data sources were used.

A case study (Yin, 2003) was employed within the context of a 5th grade elementary science classroom. Among eleven students, ten students completed the study. Fifth graders designed design computer games about environmental issues to present to 2nd graders by using *Scratch* software. During 18 design sessions, there were three game-testing sessions, assessments, and a variety of data collected. All the students took pre- and post-tests and surveys. All the participants were also interviewed before and after the study. Students' computers games were stored daily on two different locations.

The researcher transcribed all interviews with *InqScribe* software. With this software, the interviews were verbalized by words. The researcher read the transcript more than three times to find themes and patterns. The transcripts then transferred to *Weft QDA* software, an open source data analysis software, to code the students' responses.

RQ1: *What game design characteristics and programming concepts do students use as they work with Scratch to program their games?*

This research question looked qualitatively and quantitatively at what game characteristics are apparent in the students' game designs. Linked to previous studies, students' games were classified based on Kafai's (2005) and Wood et al. (2004) categorization; game world, game genre, sound, duration of the game, control options, feedback, interactions, winning and losing features, and graphics and character development. The data sources for this research question were comprised mainly from students' physical games. However, students' verbalization from interview transcripts also supported that data. During the interview, students clarified some vague functions of the game.

Designing games on *Scratch* is more than simple collections of actions. Since students designed the games based on programming with command blocks, students were expected to use complex programming concepts in their games. For this question, the researcher also quantified and described the types of programming concepts or commands that are used in the students' games. The scheme used by Malan and Leitner (2007) and Maloney et al. (2007) was used as a starting point for the analysis.

RQ2: *How did students represent and revise environmental science concepts throughout the design process?*

The data sources for environmental knowledge and awareness were based on pre- and post-test differences. A paired t-test statistical analysis was used to test the effectiveness of game design on students' awareness about environmental issues and the test was run on the SPSS statistical computer program version 10.

This research question also looked qualitatively at students' representations and reflections on the artifacts they designed. For this question, the researcher examined the conceptions of environmental issues that were evident in the students' games. Based on analyses of children's games and interview data, students' conceptions of environmental content were analyzed.

RQ3: *How do students share knowledge, strategies, and projects for game design?*

For this question, the researcher documented the types of verbalizations and interactions that took place both within the classroom and online that appeared relevant to the initial design, testing, sharing, and revision process.

The video-recordings of the study were analyzed based Erickson's (2006) Type I approaches which focuses on whole-to-part and interaction process. Consistent with this approach, the researcher followed the six steps of video-recording analysis. In the first step, the researcher reviewed the whole videos without stopping the playback. During this step, some main themes were noted. As a second step, the researcher watched the entire recordings again, but paused or replayed, if necessary, to note participant interaction changes on time line. During the third step, the researcher chose a single strip within an episode of interest that reflected the pattern of the interaction. These strips were then transcribed. As a last step, determined instances were analyzed.

Thus, the researcher explored the process of these collaborations, specifically how peers interacted and collaborated during the game development process, how they shared games, environmental knowledge, and design strategies, and how these collaborations affected the students' designs. Data sources included students pre- and post-interviews, video observations, class observations, and game artifacts. The interview transcripts were analyzed based on Miles and Huberman (1994), and the video observations were analyzed based on Erickson (2006). During the transcription process, as Miles and Hubermann (1994) explained, irrelevant conversations were excluded from the transcriptions. The conversations or acts that collaboration and sharing happened were transcribed.

Table 3.2
The summary of data analysis

Research Questions	Analyze Techniques	Data Source	Task/Materials/Instruments
<i>RQ1: What game design characteristics and programming concepts do students use as they work with Scratch to program their games?</i>	<ul style="list-style-type: none"> • game characteristics by (Kafai, 1996a; Wood, et al., 2004) • programming concepts by (Malan & Leitner, 2007; Maloney et al, 2007) 	<ul style="list-style-type: none"> • students' game contents • verbalization from students' interview transcripts • documents • scripts in the students' games 	<ul style="list-style-type: none"> • games saved in each session • post-interview • field notes • journal entries
<i>RQ2: How did students represent and revise environmental science concepts throughout the design process?</i>	<ul style="list-style-type: none"> • paired t-test • pattern matching based on (Kafai et al. 1998; Spitunilk, et al. 1998) 	<ul style="list-style-type: none"> • test results • game content • verbalizations of students interview transcripts 	<ul style="list-style-type: none"> • pre- and post-test on environmental knowledge and environmental awareness • pre- and post-survey on interest toward computer and game design • documents • games
<i>RQ3: How do students share knowledge, strategies, and projects for game design?</i>	<ul style="list-style-type: none"> • pattern matching 	<ul style="list-style-type: none"> • observation notes • video recording observation notes • journal entries • verbalization from students' interview transcripts 	<ul style="list-style-type: none"> • post-interviews • video recording • observations • participant observations

CHAPTER 4

RESULTS

Introduction

The main purpose of this study was to explore how elementary school students design educational games for younger students to learn about environment, and the types of learning processes and outcomes that result. Learning processes focused on *how* students represented their understanding in the context of developing an educational game about environmental awareness and the social and technical influences in the process of developing and revising their games. Learning outcomes documented *what* types of achievement may have occurred as a result of designing games. These outcomes were measured with instruments assessing whether or not students met the state and institution standards in environmental and programming knowledge, as well as environmental awareness and interests in computers/game design activities.

The study examined the following research questions; (1) what game design characteristics and programming concepts do students use as they work with *Scratch* to program their games? (2) How did students represent and revise environmental science concepts throughout the design process? (3) How do peers share projects, knowledge, and strategies for game design during class or online? Before giving the results of the study for each research question, background information about the participants and their computing and gaming experiences are presented.

I. Overview of the participants and overall game characteristics

Among 11 study participants who provided informed consent to participate in the study, the data from ten students were analyzed, since one student did not complete the testing process. There were 6 girls and 4 boys who participated. The majority of the students were of middle class socio economic status. Most of the students' parents were university affiliated with at least a college degree. According to the survey done by the school, all participants had a computer at home with an internet connection.

It was documented that students had a high presence rate in their attendance. Most of the students did not miss any session during the entire study. Three students; Eli, Megan, and Larry were absent for four sessions since they had to be out of town for a school competition. Megan was also sick and could not make the class for two more sessions. All students came to class on time when they were present for the sessions.

Students Computing and Gaming Background

One purpose of this study was to examine whether students at younger grades are able to design computer games for an educational purpose and if they do, what are the computational and programming concepts that appear during this game design process. In order to respond to this research question specifically, the following data were analyzed: students' designed games, field notes, pre- and post-interview transcripts.

The data analysis for this research question was adapted from Maloney, et al. (2007) and Kafai (1996). In their study, Maloney et al. documented students' use of *Scratch* commands and categorized those most frequently used by the students at different levels. Kafai coded games for

gender differences based on their preferences of game world and interfaces. This study drew from these prior methodologies when analyzing the characteristics of the students' games.

Based on the analysis of field notes and interview conversations, the participants reported a diverse background of experience with computing and gaming. As part of the school requirement for fifth grade, all the participants had to take a Technology Education course which has been offered once a week for 45 minutes. Students used technology equipment in other classes such as Language Arts, Social Studies and Science.

In the Technology Education course, students learned keyboarding, imaging software, Word Processors and PowerPoint. The students were taught these concepts with a Project-Based Learning approach. Students, for example, had a PowerPoint project in their Technology Education course where they had to prepare a presentation to teach kindergarten some basics of Spanish language. Since the school provided a sufficient number of computers for the students (the ratio of computers and students for last year was 4/7), the computers were being used for other subject areas as well. In other classes, such as Social Studies and Language Arts, students had to prepare reports with Word and animations with PowerPoint.

The school also offers technology clubs during after-school programs. Since clubs are optional, not all participants of this study attended during the school year. Genders were almost equally represented in this technology club. The following participants attended this year's technology clubs; Eli, Megan, Tanya, Kyle, and Larry. In last year tech clubs, the students learned to use Pivot software to make animations. Table 4.1 summarizes students' computing and gaming backgrounds prior to the study.

Table 4.1

The participants' background experiences with technology and game play.

Student Name	Stay for Tech Club	How often play games	What types of computer game plays*	Design games with any software
Kyle	√	½ h. a day	Sports, strategy, adventure,	√
Larry	√	2 h. a day	Adventure	X
Amber	X	4 h. a week	Arcade, math games,	X
Isabella	X	½ h. a day	Maze, arcade	X
Lacy	X	2 h. a week	Webkinz, DS	X
Nick	X	½ h. a day	Adventure	X
Tanya	√	1 h. a day	Puzzle, maze, arcade, RPG	X
Adria	X	1 h. a week	adventure, Wii games,	X
Megan	√	1 h. a day	MORPG	X
Eli	√	2 h. a week	RPG	√

*: Listed from played mostly to played less

√: Yes

X: No

The students' game play experience was varied, but, on average, boys (5.6 hours a week) spent more time on game play than girls (4.2 hours a week). During the pre-interview, students were asked how often they played games. Table 4.1 shows the average time students reportedly spent on game play. Most of the participants stressed that they played less on weekdays but played more on weekends. Even though Eli reported that he played rarely at that time, he also pointed out that he used to play a lot until recently (Eli had been attending science and math Olympiads during this study). Lacy also reported that she rarely plays desktop computer games, but she has a DS game console and often plays these games.

During the pre-interview and post-interview, students were also asked what type of game they play. Their responses are presented in Table 4.1. Adventure and online arcade games were the most common games that students reportedly played. Megan reported that she mostly played Massively Multiplayer Role-playing Games (MMORPG) and Eli also reported that he plays Role-playing games (RPG).

More importantly, students were asked to report the extent of their computer programming and game design experience prior to the study. Most of the participants did not seem to understand the term “programming”. For example, Tanya said that she never heard that term before. Lacy thought that programming meant “putting things on a hard drive”.

Researcher: *“What comes to your mind when I talk about computer programming?”*

Nick: *“I imagine a computer screen with bunch of complicated codes on that.”*

Larry: *“like fixing a computer is the first thing that comes to mind just I think of programming a computer.”*

Megan: *“I think MIT.”*

Researcher: *“Why do you think programming is something related to MIT.”*

Megan: *“That’s what you learned I guess.”*

Researcher: *“Any example?”*

Megan: *“It is sort of because you can program what you want ... it is sort of ... do you like this place you want to install this program manually? And then you press enter but that's like back computer programming. I don't know.”*

According to pre-interview transcripts, only three students, Eli, Kyle, and Larry, had game design experiences. Larry and Kyle acknowledged that they had made simple games and they did not feel confident to make advanced games. These two students mentioned that they learned to make games from Eli. Indeed, Eli mentioned that he had game and animation design experience in class and out of class.

Researcher: *“Have you designed any games?”*

Eli: *“A few.”*

Researcher: *“What did you use?”*

Eli: “*Scratch and Gamemaker.*”

Researcher: “*What else did you use?*”

Eli: “*I did little turtle like you give direction ' forward 90 and forward' (student meant MIT Turtle project) yeah.*”

Researcher: “*Do you think it was hard to make games?*”

Eli: “*No I think it is pretty easy.*”

Students’ Prior Experience with *Scratch* and Games

One of the goals of this study was to explore elementary school students’ computer programming experience by designing games with *Scratch* software. Thus, this study examined in depth what computational or programming concepts these elementary school students used as they worked with *Scratch* to program their games.

Since there was not a scalable and valid instrument to measure students’ prior experience with *Scratch* programming, the researcher developed open-ended questions about *Scratch* and programming experience and asked these questions during the pre-interview. These interview questions were generated specifically to measure students’ knowledge about different features of *Scratch*. Since it could be overwhelming to test students on more than 200 *Scratch* software icons and features, four question areas that assess students’ knowledge about *Statements*, *Conditions* and *Loops*, *Threads*, and *Variables* were asked during the interview. Students were interviewed in front of the computer, and they had to show these tools on the *Scratch* program. Since the questions asked during the interview were open-ended, the researcher followed up where appropriate with clarification questions.

The findings showed that most of the students had already known some basic features of *Scratch* software since they had used *Scratch* a few times in another class for a project. Table 4.2 shows students' knowledge prior to the study.

Table 4.2
Students' responses for some *Scratch* commands.

Student Name	Editing	Statements	Condition, loop, Boolean Expression	Variables	Design any animation or game with <i>Scratch</i>
Kyle	√	√	X	X	X
Larry	√	√	√	√	√
Amber	X	√	√	√	X
Isabella	√	√	√	X	X
Lacy	√	√	√	√	X
Nick	√	√	√	√	√
Tanya	√	√	X	X	X
Adria	√	√	√	X	X
Megan	√	√	√	√	√
Eli	√	√	√	√	√

√: Yes

X: No

According to the results displayed on Table 4.2, all students, except Amber, were able to use the image editing function of the *Scratch* program. With this skill, students are able to either draw their own images, use images from the *Scratch* image library, or import their own images and edit any of these images. *Statements* are the widely used programming concept in *Scratch*. The commands in *Statement* concept allow designers to make actions such as move, play, change color, and so on. During the pre-interview, all the students were able to show and place a simple 'move' statement on scripts panel of *Scratch*.

The students were also asked which function they would use to make some actions repeat forever under some circumstances. By asking this question, students' prior knowledge of *Loops*, *Conditions*, and *Boolean expressions* were assessed. Other than Tanya and Kyle, all the students were able to show examples of that script on *Scratch*. The students were also asked whether or

not they knew how to set scoring on *Scratch* as it is commonly used. As shown on Table 4.2, almost half did not know about scoring (variables column) on *Scratch*.

Besides students' prior knowledge about *Scratch* facts, the researcher also looked at how students were able to apply what they knew into *Scratch* to create games or animations. All the boys except Kyle had already designed some animations (but not games) with *Scratch*. However, none of the girls except Megan had completed a design with *Scratch*. Eli also reported during the pre-interview that he had already designed some simple games with *Scratch* and other game design programs.

II. Research Question 1: What game design characteristics and programming concepts do students use as they work with Scratch to program their games?

This research question explored the design and programming concepts used in the students' games. For the ten major design sessions, all the games were classified individually for game characteristics and the programming concepts. Where relevant, the data are presented in ways that compare and contrast gender differences and levels of experiences with game design. In addition, this question examined if the learning-by-game design process increased students' game design interest, computer importance, and computer enjoyment as measured by two different questionnaires.

Game Characteristics

Despite the short time period of the study, all the students were able to successfully design playable games. These games were aimed to teach 2nd graders about environmental problems and solutions. In order to give some background information about the games that

students designed, the games were analyzed based on the following game characteristics, adapted from the previous studies (Kafai, 1996a; Wood, Griffiths, Chappell & Davies, 2004): game world, game genre, sound, duration of the game, control options, feedback, interactions, winning and losing features, and graphics and character development.

In order to classify these game characteristics, 16 different games and more than 80 different versions of these games were analyzed. During the analysis process, each of the students' games was opened with *Scratch* software, played, and examined for the codes day by day. Since *Scratch* provides the codes of the design on the left script panel of the screen, it was helpful to look at the students' scripts for the detailed classifications. There were many cases where some features of the game would not be recognized without exploring the design scripts. Thus, the students' games were analyzed in depth with scripts that affected the interface and interaction of the game. As it is shown in Figure 4.1, the students' actual games are shown on the right top of the screen (the screen size can be adjusted any time) and the scripts for each game and sprites (on the right bottom of the screen) are on the left column. During this analysis process, all of the students' games were analyzed and the findings are mainly based on the students' final versions of their games.

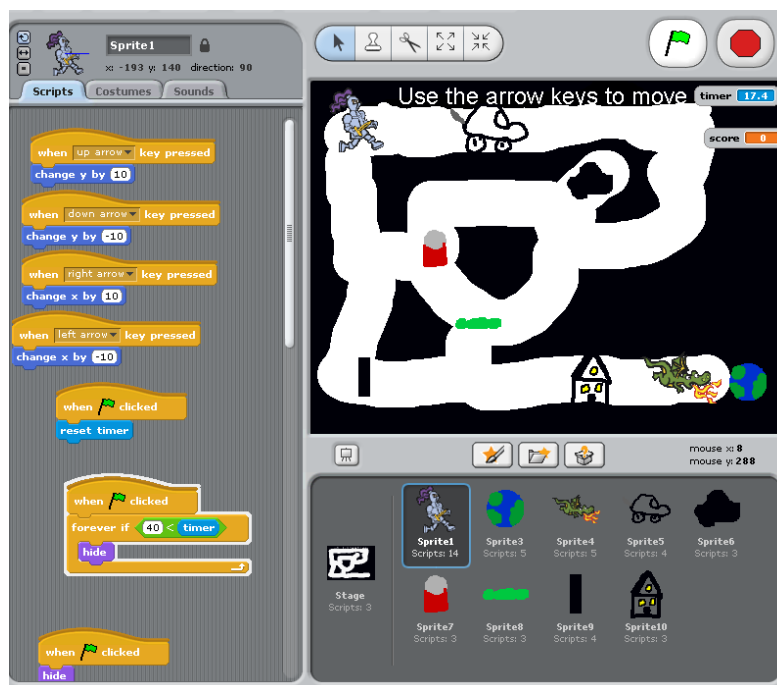


Figure 4.1 A sample student game with different game characteristics

Game World

Since the students used *Scratch* software, all of their games are web browser-based games. In other words, their games do not require any software installation. Players can access the games online, but some web browsers may require having java script or certain plug-ins in order to play the games. The analysis of the students' games showed that students designed a variety of game worlds and game genres.

Most of the students' game worlds are real-world scenarios. Amber and Isabella, who sat next to each other, used similar game worlds that resembled realistic situations but also had some unrealistic features. Amber for example, selected the ocean as her game world, but some of the game characters were only representations such as the gray shapes for trash or starfish collecting the trash icons. Isabella used air pollution with a similar concept of a bird collecting gray air

smoke icons with a shiny background to represent day, and dark background to represent night (see Table 4.3).

Tanya also used the ocean as her game world where a scuba diver collects oil spills. Even though the main game world was portraying real-world image, she used characters that make her game an imaginary world. Megan also used a real-world scenario of a kitchen where there were several different kinds of apparatus using energy and water. Similar to daily life activity, her game asks its players to turn off switches and water at certain times to conserve energy. Adria's game world, however, was different since it was the only one that did not have a real-world scenario. Nevertheless, she created a maze game where each environmental issue was shown with a representative icon.

The game worlds in the boys' designs were not substantially different from the girls' designs. Kyle, for example, created a New York City and river background in his final game, as he believed that big cities have water pollution which causes bacteria. Larry used a real-world scenario where the player collects trash on a street view environment. Nick's game world was a demonstration of an ocean view in which the player evaporates oil, and the oil grows similarly to a real world case. Eli, however, made a puzzle type of game that portrayed coral bleaching. His background was a sea shore but he used chemical element shapes to show different chemicals for undoing the bleaching of the coral.

Game Genre

Game world and game genre were parallel in the students' games. Given the limited time of the study and student skills with *Scratch*, students' game genres were similar to other sample *Scratch* games available as templates. Other than those designed by Megan and Eli, all of the

games had some feature of platform games even though the games did not explicitly have a jumping function, the main characteristics of a platform game genre.

In addition, some students', especially girls' games included some action game features. One of the main features that make a game an action game is requiring players to use quick reflexes and timing to overcome obstacles. In most of the girls' games, players had to collect trash or pollution in a limited time, and the player won or lost the game based on play speed. In Isabella's game, for instance, the players had to collect ten air-pollution spots in 15 seconds in order to move into the next level. This similar function appeared in Amber's and Adria's games. Likewise, the players of Adria's game had to touch (solve) the shapes (each representing an environmental problem) in a short time before the dragon (the heat, as a cause of the problems that affect the earth) blows up the earth. Lacy and Tanya eventually designed similar games that also required their game players to use quick reflexes to overcome some environmental problems in the games. The players of their games have to press certain letters, which each represent different types of trash (in Lacy's game) and oil spills (in Tanya's game), in a short time. It was also found in Tanya's game that the oil spill (the enemy) was asking whether the scuba diver (the player main character) would dare to fight. When the player destroys some oil spills, the character then tells the oil spill that it is his turn to fight.

The game designed by Kyle also required some quick reflexes, but there was no time limit for the player. In his game, the player has to move into different directions quickly to stay away from the randomly moving dots (representing bacteria) in order to stay alive. Nick's game is similar to Kyle's game, but has more actions that the player should run against time. In his game, the player is required to evaporate the oil spill, which keeps growing over time, by touching it with the main character. The player also has to use quick reflexes to stay away from

oil spills that randomly move around the game screen. Larry had a platform game that asked the players to collect trash, but there was no feature that required running against barriers within a certain time.

On the other hand, there were solid educational genre features that appeared in a few students' games. Even though most of the students' games aimed to teach an educational concept (environmental problems and solutions) their game genres were not explicitly educational, in terms of explicit content presentation. Eli used a simple interface, yet a complex script in his game that required students to solve the environmental problem, coral bleaching, by balancing the chemicals in the water. In his game the students practiced this concept over time. A similar approach also appeared in Megan's game where the player had to practice daily life actions to win the game (turning off switches).

In sum, the results showed that all of the girls had some characteristics of the action game genre in their games, but only two boys portrayed that genre in their games. It was also found that most of the players used some feature of the platform game genre.

Graphics and Character Development

Graphics and the character are one of the most important visual factors in a good game. The appearance of the game itself affects attractiveness of the game. Even though the participants of this study are not professional game designers or graphic designers, most of the graphics in the students' games were appealing. In this section, the following graphics characteristics were examined: the development of graphics and characters, type of characters, and gender representations.

The graphics and character design was usually the first step in the game design process. Most of the students with a clear game design plan finished drawing their game graphics and

characters before working on the programming part of the game. Since *Scratch* comes with various types of images, students were able to use these images for their graphics and characters. However, most of the students decided to draw their own images in addition to *Scratch* ready-images.

Based on their final games, all the girls who used an avatar, or main character, in their games imported the images from the *Scratch* image library, but other supporting characters such as enemies or decorations were mostly girls' original drawings. On the other hand, Nick and Larry drew their own avatar and most of their supporting characters. Kyle, however, used a *Scratch* image as his game avatar. The students who drew their own images for the games used special tablet pens (the computers had tablet capability). Using tablet pens helped students draw images that matched their games since not all images in the *Scratch* image library were suitable for their purpose.

Even though most of these images were drawn during the first design sessions, there were some minor changes on the graphics and characters over time. Besides the students who started a new game, some students who kept working on their same game also changed some of their characters over time. Lacy, for example, initially used a girl avatar who was under water in her game, but after few sessions she decided to draw a diving mask for her avatar. Tanya also drew her own images at the first game session, but over time started to use some commercial game images in the second level of her game.

As Kyle and Isabella emphasized during a design session conversation, they selected their avatars because they were "cute and fun". Students commonly used images that appealed to them. Lacy, Adria and Tanya used a human being image to represent their avatars. Adria's avatar was a knight fighting with a dragon (the enemy which was heating the earth). Isabella and

Amber used animals as their game avatars. Amber mentioned during the interview that she was planning to use a scuba diver (her game was about water pollution), but she could not make it. Isabella also said that she was planning to use a human being character for her avatar, but she thought it might not make sense for a human being to fly (in her game a bird avatar is collecting gray smoke in the air). In Kyle's game, the avatar was a ghost and other supporting characters were fishes. Larry drew his own stickman figure that represented a person recycling trash. Nick's main character did not represent a live creature, rather, it was a gun type of shape that evaporates the oil.

The researcher also looked at whether the characters in the games represent any gender. Among all the games that students designed over time, only Lacy always used female characters in her games. In her first game she had two female characters discuss solutions to help the Earth, and in her second and final games she also had a female character. Larry had two stickman characters in his game, but they could not be categorized according to gender. Other students used human characters, but the genders were not specified.

Control Options

Computer games require some type of control options for the game player to use. The designers usually decide what the player should use to control the avatar of the game. In this study, students mainly used arrow keys for moving their game avatar. Tanya, Lacy, Adria, and Amber used arrow keys to move their avatars and Kyle and Larry also used arrow keys for the same purpose. Isabella and Nick, however, made their avatar move according to mouse direction. Megan asked players to mouse click on certain characters in her game, and Kyle also provided environmental information when the players clicked on the character. Some students required the

player to use other keys on the keyboard to do certain actions in order to win the game. In Larry's game, for example, players are required to press letter 'n' to go to the next level.

Interaction

As Kafai (1996a) categorized, two types of interaction modes typically appear in students' games: guided interaction mode and manipulation mode. In guided interaction mode, players are requested to perform specific actions that the designer has already preprogrammed. However, in manipulation mode, the player uses the main character to move to get a target. The participants of this study used both guided and manipulated techniques in their games.

Guided interaction was clearly observed in Eli's game. His game is designed in a way that the player is required to use certain colors to win the game. Megan also asked her game players to turn off switches she mounted on certain spots. The players had to find these on the screen and click on them.

The students who used manipulated interaction mainly asked their game players to use the control keys and touch the targets. In Amber and Isabella's games, the players have to use arrow keys and find the trash or smoke and touch them to get points. Larry also asks his player to find the trash pieces in the game in order to go to the next level. Adria's game requires similar exploration, but it is more structured, and there is a certain path that the player has to follow. Thus, her game has both guided and manipulated interactions. Similarly, characters of Lacy and Tanya's games also walked around to collect things. On the other hand, these players were also required to follow the keys that the students already assigned in the games.

The students, especially after the first 2nd grade testing session, added instructions to their games to guide their players. Some students used simple instructions that only explained the control options, whereas other students gave detailed information and described the goal of their

games. Most of the students provided these instructions either as startup dialog or a background text message. Kyle, however, made the player click on each game character to get information about them. Larry did not use any instructions in his game. Some of the provided instructions in the games were as follows:

Amber: *“all you do is use the arrow keys to move the star fish to pick up the trash! The trash is the gray spots. be careful if the star fish [touches] sharks you die!”*

Noami: *“Use the mouse to move the bird, because the bird goes where the mouse goes. Collect all the gray spots before the timer reaches 10 seconds. GOOD LUCK!”*

Lacy: *“To move girl, up, down, left, and right, use arrow keys. To pick up trash, move girl to piece of trash and press the letter key. Press 1 to go to ocean if you put all the trash in the bins, press w. To restart, press the green flag” “We need you to help us clean the ocean. All the trash will pollute the ocean. hurry!”*

Megan: *“Click some switches...save the earth! But be careful! You only have 10 seconds!!”*

Eli: *“Press the first letter of that color to add that potion to the pot. Make the pot equal to a coral number and it will c[h]ange a color”.*

Nick: *“Oh no! A giant ship just spilled oil all over the ocean! We need to get rid of it because it's harming the sea life. Use the mouse to move me. Avoid the moving oil. [T]he current is carrying it all over the place. Press the spacebar to fire at the oil and evaporate it so it won't hurt more fish.”*

Over time in the design sessions, the instructions for the game got shorter or longer. In Nick's 9th game, for example, there were detailed instructions: *“Oil spills clog up the gills of fish*

that get close to it. [L]arge oil spills can cause extinction.” However this instruction was removed in his final game.

Feedback

All students provided some type of feedback in their games. This feedback was either positive or negative to reinforce their players. Most of the students used some type of feedback for the end of the game, and some students also provided feedback during the game. Amber, Lacy, Adria, and Isabella, for example, had a scoring panel that showed the increase in students' score after collecting each trash piece. These girls also used a timer to count down the time.

Positive and negative feedback appeared differently in boys' games. Instead of a direct message saying the player lost the game, they instead showed a change in variable either positively or negatively. In Kyle's game, for example, the avatar changed color; it turned to red and then white as negative feedback, and it turned back to its startup color, brown, as positive feedback after getting medicine. This change in variable appeared in Nick and Eli's games as well. In Nick's game, the oil piece increased or decreased based on players' success. Likewise, Eli's game showed a number change as feedback. Overall, students' use of feedback was mainly instant. Based on the types of their game world, they provided positive and negative feedback in different forms. It appears that girls gave more direct feedback whereas boys' feedback did not use a direct text format.

Table 4.3

A summary of design characteristics of the students' games

Student Name	Game world	Game Genre	Graphics and Character Development	Control Options	Interaction	Feedback	Winning and Losing Features	Duration of the game	Sound
Kyle	Real world	Platform	A fantasy game character, no gender specified	Arrow keys and mouse clicks	Manipulation	Positive and negative (score and color change)	Fail	1 level with lives	No sound
Larry	Real world	Platform	Stick man, gender is not clear	Arrow keys and shortcut keys	Manipulation	Positive (text message and change in score)	Win/fail	3 levels	No sound
Amber	Real world Demonstration	Platform, Action	Star fish, no gender specified	Arrow keys	Manipulation	Positive and negative (text message and change in score and timer)	Win/fail	1 level	No sound
Isabella	Real world Demonstration	Platform, action	Bird, no gender specified	Mouse move	Manipulation	Positive and negative (text message and change in score and timer)	Win/fail	2 levels	No sound
Lacy	Real world	Platform, action	A girl, female character	Arrow keys and some keys	Manipulation/ Guided	Positive and negative (text message and change in score and timer)	Win/fail	1 level	No sound
Nick	Real world	Action, action	Boat, no gender specified	Mouse move and some keys	Manipulation/ Guided	Positive and negative (change in oil size and live)	Win/fail	1 level with lives	No sound
Tanya	Real world	Platform, action	Scuba diver, no gender specified	Arrow keys and some keys	Manipulation/ Guided	Positive (characters disappear)	Win	3 levels	No sound
Adria	Fantasy World	Platform, maze, Action	Knight, no gender specified	Arrow keys	Manipulation	Positive and negative (text message and change in score and timer)	Win/Fail	1 level in a certain time	Win/Fail Music
Megan	Real world	Educational, Action	X	Mouse clicks	Guided	Positive and negative (text message and change in timer)	Win/fail	1 level	No music
Eli	Real World- Demonstration	Educational	X	Some keys	Guided	Positive (text message and change in number)	Win	1 level	Background music

Winning and Losing Features

Commercial games typically center on winning the game. In this study, besides instant feedback during the game, most of the students also added winning and losing features. The goal in most of the games was getting rid of the enemies (oil spills, trash, wasting energy).

For example, in Isabella's, Amber's, Adria's, Tanya's, Lacy's, and Larry's games, the player has to collect all the enemies to win the game. However, not all these students provided fail features in their games. It was interesting to note that all the girls' games ended when the players won or lost the game. Tanya's game had this plan but the programming did not work properly to realize those goals. However, none of the boys' games had that feature. Eli's game for example never ends until you win. In Kyle's game, the avatar changes color to white when they player loses 'health' but the game still runs and the player can get medicine to change the color of the avatar again. Larry has a "fail message" as a sprite but this was not implemented in the game and there was no timer or script to make the avatar lose the game. In Nick's game, the player loses the game if the player's three given 'lives' reach zero. However, the game still runs and there was no fail message to the player.

It appeared in all girls' games that the player received a message in green indicating that the player saved the earth. Except for Larry, all of the boys provided a 'You Win' type of generic end of game message. The following are some of the end of the game message used by the participants:

Larry's game: Losing message: "*game is over, the environment is dead. Sad.*"

Amber's game: Winning message: *"you did it!!!"* ; Losing message: *"you failed to help the Earth"*

Isabella's game: Winning message: *"Congratulations. You were able to help save our earth from global warming (for now). I hope that you will continue to help in real life. GOOD JOB!"*; Losing message: *"you failed to help our Earth"*

Lacy's game: Winning message: *"You collected all of the trash, you did not fail!!!!!"*; Losing message: *"you failed"*

Megan's game Winning message: *"Yay! You did it"*; Losing message: *"OH NO! GLOBAL WARMING HAS CAUSED THE ICE CAPS TO MELT, THE WATER FLOODS INTO YOUR KITCHEN, YOU FLAIL TOWARD THE CEILING, BUT THE WATER FLOODS YOUR WHOLE HOUSE...NEEDLESS TO SAY, YOU DIDN'T MAKE IT! SO WANNA TRY AGAIN TO SAVE THE EARTH... AND OURSELF?!"*

In summary, most students provided informative and contextually-relevant feedback in their games.

Duration of the game

Students' games had different duration periods. Some students' games contained multiple levels whereas other students' games contained only one level. Isabella, Tanya, and Larry added different levels to their games to challenge their game players. After the second graders formatively evaluated the game, Isabella decided that she needed to add another level. In her second level she kept the timer shorter to challenge the player. Other students used only one level in their games. However, during the post-interview, Megan

reported that she would add more levels if she had more time (she was absent half the study).

Besides game levels, some students set certain amounts of life or health to their avatars. In Nick's game, for example, the player's avatar starts with three lives and after touching each oil piece, the player loses a point. The game ends when the avatar's lives are lost. In contrast, even though Kyle's game is one level, his game never ends. The avatar loses health when it touches the 'bad' bacteria, but it gains health when it touches the medicine. This cycle may go on until the player closes the game.

Sound

Because of the short period of design time for the participants, the researcher did not expect students to use advanced level gaming characteristics, such as adding sound. However, Adria, who had low prior experience with *Scratch*, was able to add sound to her game. In her game, sad music plays when the player loses the game, and happy music plays when the player wins the game. Amber reported during the post interview that she was trying to learn from Adria about how to add sound in her game, but there was not enough time. Eli, surprisingly, composed his own notes into *Scratch* and made his own background music. This music played during the entire play time. The rest of the students did not use any sound in their games.

In sum, as it is listed in Table 4.1, most of the participants did not have any game design experience prior to this study, yet they were able to design games that incorporated important gaming elements and characteristics. Overall, the use of different game characteristics varied based on individual games, goals, and level of experience.

Using these characteristics made the students' games more professional. However, there were small technical glitches that, if fixed, would make students' games more professional. For example, at the beginning of the study most of the students were missing instructions for play. It was also found that some of the students implemented certain features to their games, which a player would not be aware of without seeing the code. For example, Larry used 'press a' to make the sprite go to the start position. Without pressing "a" accidentally or looking the code, a player would not know that command. Similar limitations appeared in other students' games as well.

Programming Concepts in the Students' Games

Scratch was created for the purpose of supporting young novice programmers to learn programming concepts with easy-to-use command blocks. In this study, as it was indicated before (see Table 4.2), most of the students did not have experience with programming. To analyze programming concepts used, the students' game were analyzed based on Maloney et al. (2007) and Malan and Leitner (2007) who classified each *Scratch* command as different programming concepts. These studies categorized command blocks of *Scratch* and counted how many times the students used these commands in their designs. The *Scratch* programming concepts were classified in Malan and Leitner's work as the following: *statements*, *Boolean expressions*, *conditions*, *loops*, *variables*, *threads*, and *events*. The overall classification of these commands are shown in Figure 4.2.

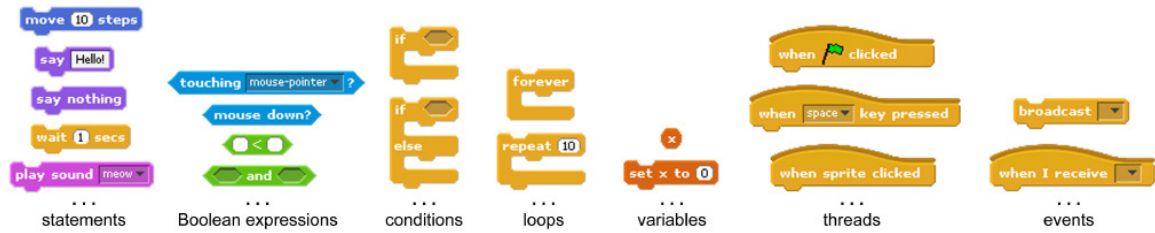


Figure 4.2 The classification of *Scratch* programming concepts by Malan and Leitner (2007).

As shown in Figure 4.3, students used a variety of sprites and commands in their games. In this example, the commands that Nick used for the selected sprite are in the middle of the screen, scripts panel (Figure 4.3). The right bottom of the screen shows how many sprites the student used in the game. Table 4.4 gives a detailed counting of the programming concepts that students used in their final games.

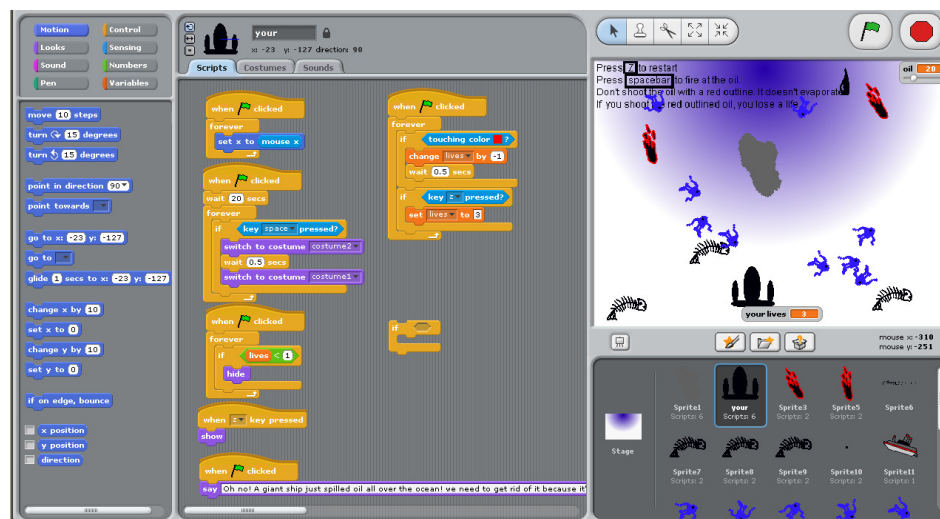


Figure 4.3. A sample script panel from a student's game (Nick's game)

The screenshot seen in Figure 4.3 is an example from Nick's last game. Similarly, each student's games were recorded for ten design sessions. Thus, there were around 100 versions of the games analyzed (16 of these were new games, and more than 80 were different versions of these games). The frequency counts of programming concepts were counted for each session's game by counting commands in this programming concept. There were more than 12 thousand commands in total.

Table 4.4 categorized students' use of different programming concepts in their games. The numbers of programming concepts in Table 4.4 represent the average that students used in their games over time. For example, Kyle, did not have any change in his game during the ninth game design session. There were a few similar cases where students did not make any change or did not like the changes and saved the previous game. For these cases, the researcher used the students' previous game and counted the programming concepts from these games for that session.

Table 4.4

Students' average use of different *Scratch* programming concepts.

Students	Number	Statements	Boolean Expression	Conditions	Loops	Variables	Treads	Events
Kyle	10.2	50.5	11.7	7.1	13.8	0.6	18	0.1
Larry	14.9	57.7	13.2	13.6	2.1	1.4	34.3	0
Nick	7.7	26.4	7.8	9.4	12.1	4.6	17.5	0
Eli	17	20	7	4.8	3	4.6	18.2	0
Male Average	20.75	64.4	16.5	14.5	12.9	4.67	36.7	0.04
Tanya	25.8	127	16.3	16.3	19.9	1.6	41.8	3.4
Amber	18.8	31.8	26.1	15.8	16.9	3.5	30.5	0
Isabella	14	42	13.9	11.8	12	1.2	15.4	10.6
Lacy	14.8	33.1	2.5	0.2	0.5	0.2	19.5	0.3
Adria	10.3	56.6	19.9	19.4	19.4	4.5	49	0
Megan	11.2	41.8	10.1	5.3	7.2	1.9	20.4	13.5
Female	26.36	92.4	24.7	19.1	21.1	3.58	49.1	7.72

Average								
Class average	23.56	78.4	20.6	16.8	17	4.13	42.9	3.88

The second column in Table 4.4 shows how many sprites each student used on average in their games over time. The next column shows use of *statements* which commonly contain move, change direction, say, and other simple action commands. *Boolean expressions* were surprisingly used even by students with less programming experience. Based on Malan and Leitner (2007) categorization, the collisions, the act when game avatars touch another game character, were also counted as Boolean expressions. Some common use of collisions were touching other sprites or touching a color (this was usually a color of background, for example, in Nick's game).

Gender Differences in Use of Programming Commands

The researcher expected that there would not be gender differences in the advanced use of programming concepts if the students' prior experiences with programming were equal. The findings show that regardless of gender or prior experience, all students used different numbers of *Scratch* concepts. However, as Table 4.5 shows, the total number of concepts used on average in the boy's game was 188 and 207 for girls. The results also show that boys on average used more statements (82.5) and conditions (19.5) than girls (80) and (18.8), but those differences were small. However, girls used more loop, variables, and events in their games.

As Maloney et al. (2007) indicated, students could use fewer commands to have the same function in their games. Nevertheless, the increased use of complex commands such as *variables* and *events* show that they were able to use advanced programming

concepts in *Scratch*. It was interesting that boys rarely used the *broadcasting* feature which is an advanced feature of *Scratch* (Broadcasting is categorized under *Events* by Malan and Leitner). Yet, most of the girls, after getting help from the teacher, included many broadcasting commands in their games. With this broadcasting function, the students were able to make new game levels.

Most girls used the ‘forever if’ command block which repeats the actions forever under certain circumstances. On the other hand, most of the boys used the same function by using the ‘forever’ command block and embedding an ‘if’ command block into that. Technically, these two approaches do the same function, but using ‘forever’ and ‘if’ command blocks may be more helpful for advanced programming. It was surprising that even students with low prior experience used a large number of commands, even though they were not required to have a minimum number of sprites or scripts. The types of commands used varied for each student’s games.

Students’ Use of Programming Concepts Over Time

As mentioned previously, the students’ games were recorded daily. Changes in these daily artifacts were analyzed using approaches adapted from Spitulnik, Zembal-Saul, and Krajcik (1998) and Maloney et al (2008). The *Scratch* commands were counted for each game within the categorization of Malan and Leitner (2007). During this analysis, students’ games were saved for ten design sessions since some design sessions were used for peer-testing, discussion, or sharing. There were a few sessions where some students did not make any changes to their games. Since some students missed some of the design sessions, their previous games were used for the command counts for these

missing days. As it will be explained later, some students decided to start a new game, and therefore their use of commands changed, which could make interpretation challenging without this information. These changes are indicated in Figure 4.4.

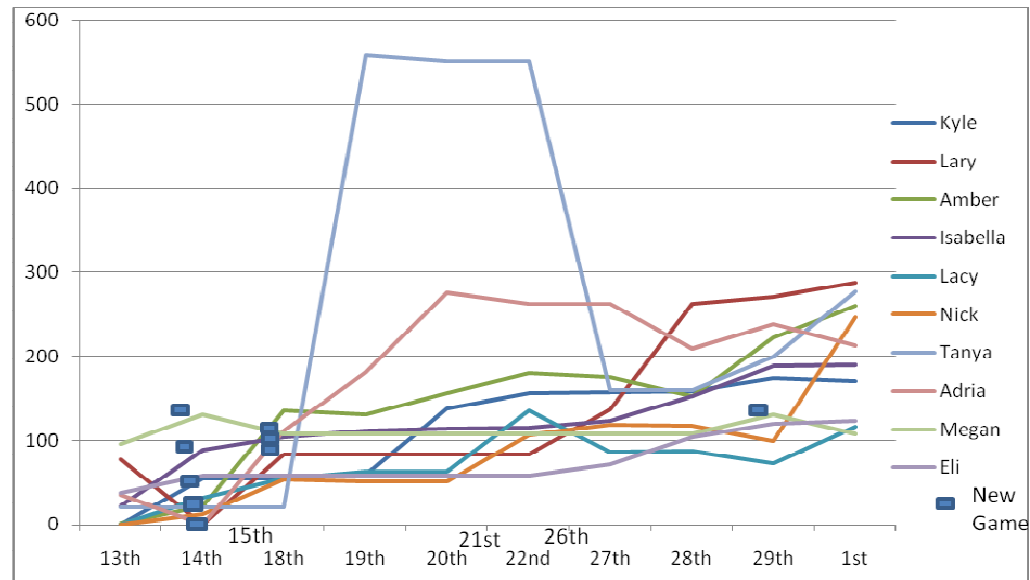


Figure 4.4 The change in total programming concepts use by the students all design sessions.

As the graph shows (Figure 4.4), each student used different numbers of commands during each design session. During the design process, the researcher expected that the number of the commands used by students would increase in small increments over time. However, it was found that each student used different numbers of commands for each design sessions. Although the study has a small sample size, it was examined whether various interventions during the design process affected students' change in use of commands over time.

During the study, there were some major and minor interventions and activities that might have affected the students' use and number of different programming commands. As it was described in study procedures, the design sessions were also supported with group discussion, peer testing, and 2nd grade testing sessions. Group discussion was the first main activity and took place after the students designed initial prototypes. Similar to previous studies, such as Hmelo et al. (2003) and Kolodner et al. (2000), the students were divided into two groups to discuss their games and the content of their games. These discussions were facilitated by the science teacher and were partly recorded. During a twenty-minute discussion, the students shared their design ideas and listed what they already accomplished and what they were planning to add. The rest of the students then suggested some ideas for each student. This discussion was held on May 15th and the next design session was on May 18th. As shown on the graph, there was only a periodic increase in students' use of programming concepts. However, there was a big increase in the number of the commands that Tanya used. It was found, after a specific analysis of her game, that Tanya kept working on the same game, but she added many new characters to her game with scripts.

Peer-testing is another activity that presumably could affect changes in students' games. This activity was held on May 21st after six design sessions. In this activity, the students were assigned to other classmates, and they tested each others' games. After testing the game, the students were then asked to fill out an evaluation form for each game. This testing process was also aimed at helping students revise their games prior to the 2nd grade formative testing which took place two sessions later. Since the testing activity was done earlier in the study, most of the students had negative feedback for the

games and assigned low points for each evaluation item. All evaluation questions and responses are listed in Appendix F. Even though the mean number of commands used on May 22nd (a design session after peer-testing) is larger than the mean number of commands used on the 20th (a design session before the peer-testing), there was no significant difference in use of commands. ($t_{(1,10)}=.105$, $p >.05$). Thus, peer-testing did not make a significant change in the students' decision to use more commands.

One activity expected to prompt changes in students' games was the first 2nd grade testing session which served as formative assessment. Based on the procedures of previous studies by Harel and Papert (1991) and Kafai (1996b), younger students, the target users of the games, were invited to the class to test the games. This formative testing process was expected to help the game designer fix errors, redesign their games, or improve the games based on feedback from the 2nd graders. The second graders tested at least three games in a 45-minute design session. After game testing, each second grader filled out evaluation forms for each game they played. All students' evaluations are attached in Appendix E.

After 2nd grade testing, there was no significant change in the boys' games but there were significant changes in the girls' games. As shown in Table 4.5, there were periodic increases in the average number of programming concepts that both the girls and boys used. Before this formative testing, on average, both girls' and boys' use of programming concepts increased at a similar trajectory. The girls, however, showed a significance decrease in the number of commands used, after the 2nd grade testing session. Their mean number of commands was 28.20 before the 2nd grade testing session,

which dropped to 19.08 after the testing ($t_{(1,10)}=.043$, $p<.050$). On the other hand, boys' average increased from 12.62 to 15.15 after the 2nd grade testing ($t_{(1,10)}=.041$, $p<.050$).

Table 4.5

Gender differences in use of programming concepts over time.

	13th	14th	18th	19th	20th	22nd	27th	28th	29 th	1st
Female										
Average	35	58.6	107	231	254	271	183	174	210.6	232.8
Male										
Average	28.75	31	62.3	63	82.8	101	121	161	165.8	207

As it can be concluded from the graph (Figure 4.4), the change in the boys' use of commands follows a normal distribution when comparing their progress over time. Yet, most of the girls made significant changes to their games after the 2nd grade testing, and this caused a sharp drop in their use of commands. It was also observed in the classroom that most of the girls took off some of the characters in their games during the next two design sessions (May 27th and May 28th). The graph also shows that all boys and girls kept adding new sprites and commands in the last two design sessions (May 29th and June 1st).

In addition to these main activities, there were some minor activities that might cause changes in the students' use of different commands in their games. Some of these activities were teacher comments on the games, classmate testing and commenting on the games, and making a new game. Even though these activities did influence the students to change their games, these changes were observed individually. Some of these changes were limited to certain programming commands. Besides daily comments and suggestions for students' games characteristics and programming commands, the

technology teacher also gave more detailed feedback to the students about their games on May 28th. After these suggestions, some changes in programming concepts were observed in the individuals' games. Peer feedback also affected some students' use of different programming commands. For example, during the design session on May 28th, Amber had many Boolean expressions in her game, but these expressions were replaced with another programming concept combination. When asked, she replied that a classmate suggested using a simpler script which did the same function that her previous scripts did. As colored in the blue rectangle shape on the progress graph (Figure 4.4), some students decided to start a new game in the beginning session of the study. Switching to a new game required the students to start a new game from zero commands. But as the graph shows, most of these new games were done quickly and the students added as many as commands as they had before.

Game Design Interests and Computer Enjoyment

The researcher examined if the students' interest in game design and computers changed throughout the course of the study. For that purpose, the students took pre- and post-questionnaires for the following categories: game design interest, computer enjoyment and computer importance. Computer enjoyment and importance was measured using the Computer Attitude Questionnaire (CAQ) (Knezek, Christensen, & Miyashita, 1998), which was designed for middle-school students. Game design interest was adapted from a questionnaire used by Bonanno and Kommers (2008). It was found that some students increased their scores in post-questionnaires comparing with the pre-

survey. Yet, overall there was not a significant increase in students' game interest, computer interest, and computer enjoyment. For the game design interest survey, the students' mean for the pre- and post-survey were the same, 23.6 . For the computer importance survey, students' scores improved in their post-survey and the mean for pre-survey was 18.9 with std. deviation 2.4 and mean for the post survey was 19.6 with the std. deviation 2.5. For the pre-survey on computer enjoyment, students had 16.9 mean with std. deviation .76 and for the post-survey students has 16.3 mean with std. deviation .59.

Based on findings from the existing literature, the data were analyzed post hoc to examine if gender differences appeared in game design interest (GDI), computer importance (CI), and computer enjoyment (CE) after the game design project. The results showed that boys started the study with a high game-design interest, with an average score of 28 out of a maximum of 32 (see Table 4.6). In the same questionnaire, girls' average was 20.7. However, the post-questionnaire showed that boys' scores decreased by 1.5 for their game design interest, whereas girls increased their interest by 1. Overall, after the game design projects, there was no significant difference in students' game design interest, computer importance and computer enjoyment.

Table 4.6

Gender differences in game design interest, computer importance and computer enjoyment.

Gender	Pr_GDI	Po_GDI	Pr_CI	Po_CI	Pr_CE	Po_CE
Male						
Average	28	26.5	19.5	21.3	17	16.8
Female						
Average	20.7	21.7	18.5	18.5	16.8	16

The data also showed that both girls and boys had closer scores in computer importance attitude in the pre questionnaire. After the game design project, boys increased their average score from 19.5 to 21.3 out of 24. The girls however, kept the same score for the both pre-and post questionnaire (see Table 4.6). It was interesting that both girls and boys decreased their scores on the Computer enjoyment post-questionnaire. As shown in Table 4.6, boys had an average score of 17 for the pre-questionnaire which dropped to 16.8 out of 20. Similarly, girls' scores also decreased from 16.8 to 16.

Nevertheless, students expressed that they enjoyed the project and wanted to do something similar again at another time. The lower scores in the post-questionnaires can possibly be explained by the following reasons; (1) the students took the post-questionnaires on the last day of school which was mostly scheduled for end of year school events (2) most of the students already had very high scores in the pre-questionnaire (regression toward the mean) (3) the students might have perceived game design as primarily a "fun" activity prior to the activity, and later realized that it is hard work and not as fun as anticipated. This could also possibly be due to the fact that academic content and expectations were applied to the game design activity, which might have reduced the perceived enjoyment.

Adria, who scored lowest on the pre-questionnaire increased her score by 50% after the game design. She stated before the game-design project that she thought she would have difficulty designing games. Yet, at the end of the project, she had designed a functional game. She also expressed that she had fun designing games and wanted to keep designing games over the summer at home. Perhaps students who start a game-design project with some anxiety or limited experience have the most to gain from an enjoyment perspective.

Most of the students reported during the post-interview that they wanted to try the same project next year, even though the game design was challenging. Almost all students reported in the post-interview that they enjoyed the experience. There were two students, Lacy and Larry, who said they did not like the project. It was observed that Lacy finished a simple game in the first few design sessions. Her comments during the post interview explain her comments.

Researcher: *“Did you enjoy the game design project?”*

Lacy: *“Not the whole time.”*

Researcher: *“When did you enjoy it and when didn't you?”*

Lacy: *“At the beginning. Toward to end it got harder.”*

Researcher: *“Which part was that?”*

Lacy: *“When we first started the game it was easy and fun but now it is not.”*

Researcher: *“Why?”*

Lacy: *“Well we have done it every day, so it kind of got [less] fun.”*

Larry also reported he did not enjoy the project. Larry was asked to change his game content in an early session, as his topic was fantasy-oriented, and not scientific (His game was about human beings trying to get to Mars as a way to solve overpopulation, and they had to fight Martians). After some detailed questions and class observations, it was found that he was not happy with being asked to change the game to a more environmentally-valid scenario. He was also absent for four design sessions due to other conflicts. He reported the following:

Researcher: *“Did you enjoy the game design project.”*

Larry: *“No ...”*

Researcher: *“Why”*

Larry: *“I had to redesign it.”*

Researcher: *“How about at the beginning, the mars thing?”*

Larry: *“No, I still did not like it.”*

Researcher: *“Why not.”*

Larry: *“It just was not fun.”*

In both cases, it is possible that the students did not enjoy the game because of the expectations for them to represent the academic content of environmental awareness, which was perceived as either more difficult, boring, or not as fun as designing a more entertainment-oriented game.

III. Research Question 2: How did students represent and revise environmental science concepts throughout the design process?

This question examined how student learning of the environmental science domain was affected by the pedagogical intervention of learning by game design, and how this influence manifested itself in the individual learning trajectory of each participant. Thus, this section includes evidence of this influence and the students' representations of environmental knowledge within the games. The researcher also analyzed how these representations changed during the game design phases. As was expected, some students had difficulty merging their environmental content understanding with game design ideas. Thus, the last part of this section will unveil some of the practical barriers of these difficulties and will present other evidence of classroom learning that occurred besides the domain subject.

Achievement in Environmental Knowledge and Environmental Awareness

The researcher expected that the students would score higher on a post-test of environmental knowledge compared to a pre-test after designing environmental games. Prior to the study, the students took a pre-test of 14 multiple-choice questions on environmental knowledge which was generated by the class teachers from the science textbook. The mean score for pre environmental knowledge test was 10.3 and was 10.7 for the post test, indicating no gain in factual knowledge scores after the game design experience.

To further address the question of what type of domain knowledge was learned, students were also assessed on their levels of environmental awareness (see Appendix D for the survey). In this survey, awareness was defined broadly as students knowing the cause of current environmental issues and personal actions for these issues. Students' pre- and post-survey scores were nearly identical at 84.2% correct.

Most of the students already had high scores on the pre-tests of environmental knowledge and environmental awareness. For example, except for Amber and Tanya, all students scored above 70% on the environmental knowledge pre-test. All students but Lacy also scored above 80% on the environmental awareness survey (pre-test). Some students scored 100% scores on the pre-test. With respect to these two pre-post measures, the findings suggest no gains in environmental knowledge based on the assessments. These findings can possibly be explained by the following: (1) the sample size was too small to detect such knowledge gains; (2) since the topic itself was broad (i.e., students chose which environmental topic to pursue), these general assessments did not measure students' individual progress in their specific area; and (3) the post-test was taken on the last day of school, which could have affected student attention to the test. Because there was no control group, the researcher was not able to compare the results with other groups having different instruction. Moreover, detecting pre-post differences on multiple-choice tests in constructionist environments can be difficult to achieve. Indeed, other researchers studying similar environments acknowledge this assessment challenge (Ioannidou et al., 2003; Tanghanakanond et al. 2006).

Because of schooling requirements, students' achievement was measured in multiple ways to show progress in science class and state standards. For that purpose, a

portfolio-based approach was used (Tanghanakanond et al., 2006), where teachers assessed the student artifacts throughout the duration of the project. The researcher requested that the teachers would evaluate students' environmental knowledge during the game design project. Both science teacher and co-teacher used a rubric (Table 4.7) twice: once in middle of the study and once at the end of the study to grade students' work in the science class. The teachers also reviewed students' daily entries and games for evidence of environmental concept development.

Table 4.7

The students grading based on the teacher rubric and criteria for the rubric.

	First Evaluation		Second Evaluation	
	Q1	Q2	Q1	Q2
Kyle	4	4	4	4
Larry	3	3	3	3
Amber	2	3	3	3
Isabella	4	3	4	3
Lacy	4	3	4	4
Nick	4	3	4	4
Tanya	4	4	4	4
Adria	4	4	4	4
Megan	2	3	3	4
Eli	4	3	4	4

Rubric

Accuracy of Environmental Content	Richness of the Environmental Content
The content in the game is not realistic or scientific.	There is not enough content in the design
The content is somewhat realistic but doesn't have enough scientific value.	The students has only one or two few points about cause or effect of the environmental problem
The content contains is relevant to the environmental problem and most of it is accurate	The content has some cause and effects of the environmental problem

The content is relevant to the environmental problem. It is accurate and realistic. It provides creative solutions to the environmental problem

It has rich content about the cause and effects of the environmental problem.

The teachers used standard school measurements keys: (1) below the standard, (2) meets the standard, and (3) exceeds the standard. The teachers reviewed the games to assess whether the students achieved state standards. After the project, students were expected to (4.2.4.C) know that some natural resources have limited life spans, (4.2.4. D) identify by-products and their use of natural resources, (4.3.4.A) know that plants, animals and humans are dependent on air and water, (4.3.4.B) identify how human actions affect environmental health, (4.8.4.C) explain how human activities may change the environment and (4.8.4.D) know the importance of natural resources in daily life. According to the teachers' grading, all the students were able to exceed or at least meet more than three state standards for environmental education. Since these standards were broad and some students selected a specific topic, they could not portray all standards in their games.

In addition to state standard-based grading, the teachers evaluated how each student represented environmental concepts in the games. In this evaluation, two classroom teachers reviewed each student's final game for the evidence of environmental science concepts. For each student, the teacher wrote an evaluation report which described how the student addressed the environmental problem in the games and how the concepts were portrayed using different images. The teachers also listed if a student misrepresented an environmental concept. The report shows that all students successfully

achieved science class objectives for the unit of life science at the fifth grade level. The following paragraph is an example of the evaluation report for Nick.

“This game addresses oil spill as the environmental problem. Nick portrays the oil spill as a scientific fact by showing the oil spill spreading and expanding over [a] period of time if it’s not cleaned up quickly. Nick provides accurate information about oil spills in the game. By playing the game I can see that if the oil spill is not cleaned, it will damage the sea life. For example, as the creature comes in touch with the oil spill, it dies.”

How Students’ Representations Changed Over Time

Learning by game design offers a range of activities to help students move their knowledge from an internal to external process (Papert, 1991). In other words, the steps that students go through during game design help them represent their understanding through a sharable artifact. Some of the main steps in this project were planning, game design and prompts, testing games, and sharing games. During this process, the students’ environmental knowledge development was followed from the pre-interview to daily journal entries and post-interviews. The analysis of these data was based on Kafai, Franke, Ching and Shih’s (1998) approach to the integration of content into artifacts and Spitulnik, Zembal-Saul, & Krajcik’s (1998) approach to reviewing representation change over time. In order to clearly understand the students’ representations of environmental

concepts and issues, it is necessary to review what the students already knew prior to the study.

As mentioned previously, most of the students already had high scores on the pre-test of environmental knowledge. The researcher asked the students what environmental problems and concepts they were aware of. There were two main environmental concepts that appeared during the students' interviews sustainability and biodiversity. In their pre-interviews, the students primarily reported environmental issues of water pollution, air pollution and global warming. These findings support previous studies that show that children are usually aware of problems that are issues in their area or that are commonly reported in the media (Duan & Fortner, 2005; Jinliang et al., 2004). Megan and Isabella gave examples from documentaries about how polar bears can get stuck on melting ice. Tanya also mentioned that she saw on a cartoon that oil was leaking from a ship (her game was about oil spills). This media impression affected some student's solutions to environmental problems in their games. Larry's solution for overpopulation was, for example, sending human beings to Mars which he said he saw on a movie. A summary of student responses about environmental issues they were aware of follows:

Larry: *"There are many environmental problems, like industrial things like factories and mainly cars and transportation, rockets and that stuff."*

Tanya: *"Littering like, that is the only one."*

Isabella: *"Global warming, well there is like a lot of ... recycle ...thrown away paper and stuff."*

Eli: *"More trash and everything and eventually if we don't stop it either become way too hot and do global warming or way too cold and going to an ice age ..."*

Megan: *“Green house gasses. That is mostly everywhere. Or bears. People are cutting down trees....”*

Adria: *“Global warming... sometimes you see trash in water, litter, like trees cut down.”*

Lacy: *“Littering. Technology really does not affect it because you are plugged in. So, you are not using oil or gas or anything. Air pollution usually comes from factories because of ... smoke towers.”*

Amber: *“Global warming, extinction for animals, cutting down trees for animals”*

Kyle: *“...I just think that in big cities like NY that try to ... make people like to stop growing litter all over the place and that you should try to go to green and recycling like reusing something as much as possible until it runs out, then you can recycle it.”*

The students were also asked in the pre-interview why protecting the environment is important. Overall, students mainly mentioned current environmental issues and the effects of these problems on the Earth. A common environmental issue that appeared in the students' responses was global warming, likely since they watched more about it from the media. However, the students rarely mentioned any issues related to sustainability and individuals' responsible actions as environmental concepts. Evidence of these environmental concepts did not appear in the students' planning journals during the planning phase of the study design either.

Planning Phase

The planning phase of the study aimed to provide time for the students to collect information and conceptualize their understandings of the content. In this phase, the students were given three sessions to research environmental issues, explore *Scratch* software, think about a game, and consider 2nd graders as the audience of the game. The students were also asked to post their findings and design plans on MyLingua. The review of these postings showed that most of the students reported environmental issues that they already mentioned in the pre-interview and some details about the effects of these issues on the Earth. Some students specified a topic area and collected data about that. The following note was an example from a student during the planning phase.

GLOBAL WARMING: Global warming is one big problem. We need to solve it because if we don't we could end up dying. [G]lobal warming is caused by factory smoke, cars, and other air pollution. [T]hese air pollutions are very bad for our environment. It is melting the arctic ice and making it hard for animals like polar bears to survive. [B]ecause of the ice melting, polar bears are drowning from lack of resting spots while they are hunting for food or just going for a swim. (From Isabella's journal entry.)

In their collected notes, it appeared that the students tried to find information about their environmental issue and what caused the issue. Except Lacy, none of the student mentioned individuals' responsible actions. It also appeared that the conceptualization was limited to environmental content or the game design idea, but not an integration of the two. Most of the students mentioned in the post-interview that they decided the game design first and then they started embedding environmental issues in

their game design idea. However, Eli and Megan, who had previous experience with *Scratch*, emphasized that they thought about the environmental idea first and then they decided a game based on the topic. The game analyses also showed that these two students generated game ideas that are not commonly found in commercial, non-educational games. For other students, however, the games had some similarities with commercial games. These students embedded environmental content into the games after starting the games. In other words, some students such as Larry, Adria, and Isabella mentioned that that they started with an idea about how to make a certain type of game first, and then they thought about how to add environmental content into these games. Thus, some of these students were challenged to implement their actual environmental ideas into the games.

Design Phase

The game design phase was a rich activity for the students to conceptualize their ideas and to consider how to integrate both their game ideas and the environmental topic. Based on game analyses and observations, the students' representations of their understanding changed from knowing basic causes and effects of the problems to responsible actions for the problems. In other words, the students' pre-interview transcripts and journal postings showed that students mainly were aware of the issues and how scientifically these issues occur. However, with the game design, the students' representation changed from 'knowing' to 'acting'. During the planning phase, the students talked about how an environmental problem occurred and how this problem may

affect others locally or globally. This understanding also came up in the students' daily journal. In their game designs, the students gave a 'responsibility' role to their players.

Three types of responsibility roles were represented in the students' games for the game players: global, local and individual responsibility. Some students assigned a role to their players to solve some environmental problems globally. In her first game, for example, Megan tried to depict global warming, and she designed a game where the player's goal was to make the Earth cooler (in the pre-interview and journal entries, she mentioned that the Earth is getting too hot and that is causing global warming). In her game, the main idea was that the quicker the player used the arrow keys, the longer the earth would survive. A few other students such as Adria and Isabella also gave a global responsibility role to their players.

The students who gave local responsibility roles to their players used some common environmental issues and required their game players to solve the issues. In their games, the students provided a problem for their players and asked their players to help the community resolve these environmental problems by acting directly. In his game, for instances, Larry required his player to collect all the trash to recycle. After the player collected the different types of trash from different locations, the game provide the following feedback; "*you won and saved the earth*". In the games by Amber and Lacy, the players are given a general role to collect trash under water. Even though an individual may not be able to do that task, these game designers mentioned that they wanted to teach second graders to not pollute water. A similar local responsibility role appeared in Tanya and Nick's games as well. These students designed their games based on a scenario that a ship spilled oil in the water, and the oil needed to be cleaned before

all the sea species died. In the post interview, Tanya was asked why she decided to make an oil spill game. She responded that she saw some oil spills cases in the media, and she felt sad. Thus, she wanted to make a game to teach the second graders to act responsibly against oil spills and sea creatures.

Individual actions against environmental problems appeared in Kyle and Megan's second games. The role that these students gave to their players shows how an individual should act in the real world to help the Earth. In her second game, for example, Megan required her game players to turn off electric switches to protect natural resources. Individual responsible action appeared in Kyle's game slightly differently. In his game, the player, which represents a human being, should stay away from 'bad bacteria'. The student also showed a solution for the player when the avatar got sick after touching the 'bad bacteria'.

The design phase was dynamic in that the game-design process inherently prompted reflection on and revision of design decisions. The nature of game design prompted students to search for new information and think critically, especially as they added new features to their games. Thus, the students continually re-conceptualized their ideas throughout the design process. For example, it was observed that Kyle had some shapes roaming around in the game without any purpose. When the co-teacher asked what those were, he said they were bacteria that came from polluted water which were bad for people. The teacher then asked him if all bacteria are bad for people. Kyle paused for a while and replied that not all. He then decided to search for more information. It was later observed that Kyle had two types of bacteria shapes with different purposes. After the change, one type of bacteria would not affect the players' game life whereas the

other type of bacteria took game lives of the player when it was touched. A similar example happened for Kyle's game when he decided to make the player look sick. The teacher then asked him what happens in real life, and he listed some real life cases. The teacher asked him how that could be done in the game, and he mentioned that the player could change color after getting sick. Similarly, Nick had oil spills in his game, but there were no clues for the 2nd graders to understand how that oil spilled into the water. When questioned by the researcher about this, Nick did more research online and found out that sometimes big ships or factories spill oil into the water and that causes environmental problems. Finding out this information helped him to conceptualize components of the oil spill issue and how it could be portrayed visually and realistically. These examples show the reflection-in-action process that results from efforts to represent the content domain into the gaming experience and how that process changes based on the intention-action-processing cycle.

Even small decisions such as which icons to use in their games often prompted deeper reflection and revisions to the game. For example, Lacy decided to create a water pollution game. She required her game players to collect trash from the water and put it into a bin. The researcher asked her if there could be a better solution than putting all the trash in one trash bin. She then decided to make three separated bins: bottles, trash, and sun glasses (in her game, she placed sun glasses everywhere in water). When the players collect (touch) the bottle shapes, they appear in the bottle bin.

Game design encouraged the students to come up with different solutions. Larry, for example, identified overpopulation as his environmental issue, emphasizing population increases over time. However, his game was a common fighting game. After

the teacher questioned the environmental perspective of the game, he mentioned that his solution for the overpopulation was sending people to Mars. He imagined there would be Martians and human beings fighting. He was asked how it would be possible to live on Mars. He replied that humans can design big buildings that replicate the conditions of Earth.

As these cases show, the teacher played a significant role in the learning-by-design process by prompting students to think about new ideas or justify their ideas represented in their games. These conversations were essential for sparking reflection, which led to new actions that showed a more comprehensive representation of the problem under study.

Testing

Not all reflection was due to prompting by the instructors. Testing or debugging games was another common process in game design. It was observed that the students had to test their games several times not only for debugging but for trying out and enjoying their own games. Most of the game improvements or content changes were tried after these testings, seemingly in response to a “need to know” that emerged from trying out and wanting to make improvements to their games. For example, Tanya was observed testing her game, and she asked how she could add a new feature to her game where other sea creatures were affected after touching the oil spills. This question prompted a discussion and led her to search for what happens to sea creatures in real life when there is oil in water. The students also realized that testing their own games helped them to learn better.

Sharing

In the last phase of this constructionist learning experience, the students were asked to design a game that would teach 2nd graders about the environment. It was believed that designing games for other audiences would help the students set some design goals for their games. By sharing their games, the researcher expected that students would redesign their games based on feedback from the game testers. In this study, there were two types of sharing: sharing with peers and sharing with 2nd graders. Since the sharing process with peers will be explained later under research question 3 of this chapter, this section will only focus on how students' sharing with 2nd graders was effective for learning the content and how that sharing influenced students' representations over time.

The post-interview transcripts showed that most of the students were trying to teach the students how to act responsibly about the environment. None of the students mentioned whether or not they were trying teach any environmental content to the 2nd graders. It seems that using a much younger age group impacted the complexity of the environmental knowledge represented in the game. For instance, Adria mentioned that she didn't want to make the game too educational, since the 2nd graders will want to have fun. Nick also shared a similar focus in his post interview;

Researcher: "... *do you think your game was representing your solution?*"

Nick: "*No.*"

Researcher: "*Why not?*"

Nick: "*Just because [it wasn't realistic] because you can't really evaporate oil.*"

Researcher: “*Did you think about this? Why didn’t you make something realistic, then?*”

Nick: “*Well, I did not know any ways to clean up oil spills that 2nd graders will understand.*”

Researcher: “*So, you thought of them first. That is why you made it this way?*”

Nick: “*Yes.*”

Hence, some students seemed to limit how deeply or accurately they represented the content domain, based on an assumption that the second graders would be unable to conceptually understand it.

The Influence of Prior Scratch Programming Experience

As was explained at beginning of this chapter, the participants had different levels of expertise with *Scratch*. In this study, it appeared that level of experience with *Scratch* interacted with the general stability of the ideas explored during the game design. Similar to Malan and Leitner (2007), students were categorized into two groups: students with low prior experience and high prior experience with *Scratch* programming. It seems students experienced with *Scratch* did not significantly change their environmental idea over the course of the project, but the other students did make such changes. Based on the post-interview transcripts, some students with low *Scratch* prior experience such as Adria, Amber, and Lacy reported that they thought of a basic game idea before thinking about an environmental game idea. They then decided to embed environmental concepts into their games.

It was observed that some students decided to change their environmental content or even topic, since they felt they could not design a game with that environmental issue. For example, Adria decided to create a game that teaches students to protect the rain forest. In the first design session, she waited for 15 minutes and said she could not do anything. After the teacher guided her on *Scratch* design, she started to make sprites for her game. However, in the next design session, she said she decided to make a new game since she thought it was too hard to make a rain forest destruction game. She then decided to create a recycling game and started to make some sprites for that game as well, but she stopped working on that game in the next design session. She ended up having a maze game after seeing a classmate making a similar game. She spent other design sessions on that game and was able to successfully make a functional game by the end of the study.

Isabella also reported during the post-interview that she was planning to make a maze game with global warming as the environmental issue. But after working on that game for two design sessions, she decided to make a different game. In her other game she changed her environmental topic as well. Similar technical experience levels affected other students' ideas as well. Lacy, another student with low *Scratch* prior experience, also changed her idea over the study. When she was asked why she changed her idea, she said that "it was easier to make a water pollution [game] than to do one on air pollution".

On the other hand, there were a few cases where the content and the image that the students used led second graders to misunderstand the environmental concepts. Some of these misuses were either because of a lack of technical skills or student's design choices. For example, Amber designed a starfish collecting trash from the ocean, since

she said she could not make the scuba diver work. Another example appeared in Isabella's game. One of the second graders who tested her game was confused that the bird (the main character that was collecting 'air pollution shapes') can get so close to the Sun. Isabella designed the Sun as part of her game background, but that was misunderstood by the young students.

A similar issue appeared in Nick's game where the players of his game evaporate the oil shapes in the water. During the post-interview, Nick reported that he was aware that evaporating could mislead the second graders, and he wanted to change it but did not find a proper solution. If more time was available, he said he would do more research to find out how professionals vacuum oil from water. In general, a tension exists between what a student can both conceptualize and implement in a game design project. Having some higher level of experience with the technology seemed to be able to compensate for the limited content knowledge, making the design process more additive and stable. In contrast, when students had little experience with both the technology and the content area, more topic drifting and less integration were common.

Learning Extensions

As was found and reported in other constructionist studies, the students' learning in this study was not limited to the target domain subject. Participating in the game design process and sharing these designed games may have also helped students in (1) social development, (2) study and presentation skills, (3) learning about design, and (4) other subject areas.

Students' social development is an important part of the elementary school curriculum. Even though this study did not aim to teach or measure social development of the students, the nature of game design may have promoted this development. Based on class observations and classroom teachers' feedback, most of the students performed well in this area of social development. It was observed that the students showed good attention spans during the game design project. During the design sessions, most of the students focused on the task for the entire class time, which is less commonly observed for other classes. The students demonstrated effective skills when they interacted with peers, teachers, and young students. Even though it was not requested most of the time, the students participated in group discussions and sought help from one another. While designing these games, the students demonstrated care and responsibility toward the computers and other materials. The students also showed evidence of learning how to learn. In other words, the students demonstrate self-directed learning by searching or requesting for the information they needed to know. From the initial idea to end product, the game design process required the students to make their own decision for their own learning. It was observed during the two discussion sessions that each student was able to justify his or her game decisions and receive criticism and suggestions for improvement.

Although not directly measured or set as learning objectives, observations showed students learned about other subject areas. For instance, students had to apply math skills during the game design process. Character move was one of the first actions that the students added to their games. In order to add these actions, the students commonly used the structure on Figure 4.5 which requires students to know coordinates and negative

numbers, even though the students had not learned these mathematic concepts prior to the study.



Figure 4.5 A sample moving scripts from Amber’s game

Especially students with low *Scratch* prior knowledge asked how to move the character, and Isabella was the first one who wanted to add that action to her game. After the researcher demonstrated the “move” script (see Figure 4.5), she was able to then show that script to Adria and Amber. For Kyle, the teacher showed him only how to move a character toward (-x), the direction for going left on screen. When the teacher asked him how to move the character to down, the student successfully added (-y) coordinates move to his game script. In addition, the game that Eli designed had embedded calculation systems with three digit numbers.

IV. Research Question 3: How do students share knowledge, strategies, and projects for game design?

Papert (1991) highlighted how the external process of constructing artifacts differentiates this theory from constructivism. The students learn and reflect on their own learning after designing artifacts that can be shared with others. This external process is not limited to presenting a product with others; knowledge sharing can also occur while working on individual tasks, as students informally share knowledge, game features, and strategies. In this study, social interaction and collaboration occurred in different ways. In some cases, students were asked to present their environmental concepts and how they integrated them into their games to classmates. Students also interacted informally with each other during game design. Social interactions also occurred during game sharing with the peers and 2nd graders.

This section describes specifically how peers interacted and collaborated during the game development process, how they shared these games, environmental knowledge, and design strategies, and how these instances of collaboration and sharing affected the students' designs. To do so, the researcher used a broad range of data sources: students' pre- and post-interviews, video observations, class observations, and game artifacts. The conversations or acts where collaboration and sharing happened were transcribed and analyzed. The interview transcripts were analyzed based on Miles and Huberman (1994), and the video observations were analyzed based on Erickson (2006).

Structured Collaboration

Similar to previous studies (Harel & Papert, 1991; Hmelo et al. 2003; Kolodner et al. 2000), there were two discussion sessions in which the students shared their ideas about their environmental topic and games. The discussions involved students presenting and defending their ideas. These discussion sessions were held before starting the game design and after the fifth design session.

The second discussion was held after the 4th design session, and most students already had a game started. The students were divided into two groups based on their environmental topic. To do this, 6 students were sent to the science class for discussion and the rest of the students kept designing their games. After 20 minutes the groups switched rooms, and the students who had discussion came to the computer lab to work on their designs. The group discussion was structured with the following guided questions: What environmental issue they had explored? How did they merge this issue into the game design? and How would their games teach others how to protect the environment? Since the students already selected their topic and researched it, they confidently presented their ideas. To illustrate, one student took on the role of an anchorman during the discussion and asked, “*Why do you have to care about pollution?*” Next, each student responded with a few sentences explaining why pollution presents a danger.

The video observations showed that the students asked questions about the environmental content to each other when presenting the topic. For example in the second group, Eli was presenting his environmental topic and game idea, which was about coral

bleaching. Students appeared to have a hard time understanding the topic since they were not aware of what coral bleaching was:

Eli: *"My game is about coral bleaching."*

Adria: *"Is about what?"*

Eli: *"It is about coral bleaching."*

Larry: *"Oh, corinn bleaching?"*

Eli: *"Coral bleaching!"*

Larry: *"Yeah. Coral bleaching."*

Adria: *"What is that?"*

Eli: *"Bleaching the corals."*

Adria: *"Ok. What is that?"*

Eli: *"You coral the bleaches."*

Adria: *"Ok. Whatever it is, just tell us about your game."*

Eli: *"When you press on letters, and if it is white and it dies."*

Adria: *"And how do they do that?"*

Eli: *"With potions."*

Kyle: *"And how you get potions?"*

Larry: *"You are just coloring to save the earth?"*

Eli: *"You are using letters to change colors."*

Kyle: *"What are these random letters?"* (As is shown in Figure 4.6, in Eli's game one presses a letter on the game to add elements to change the whitening of corals.)

Eli: *"They are on earth."* (He is referring to the chemical elements but he is not clear.)

Adria: “Ok. We are moving on. He doesn’t seem to be putting in information, ...”

(Adria was leading the group discussion for that group.)

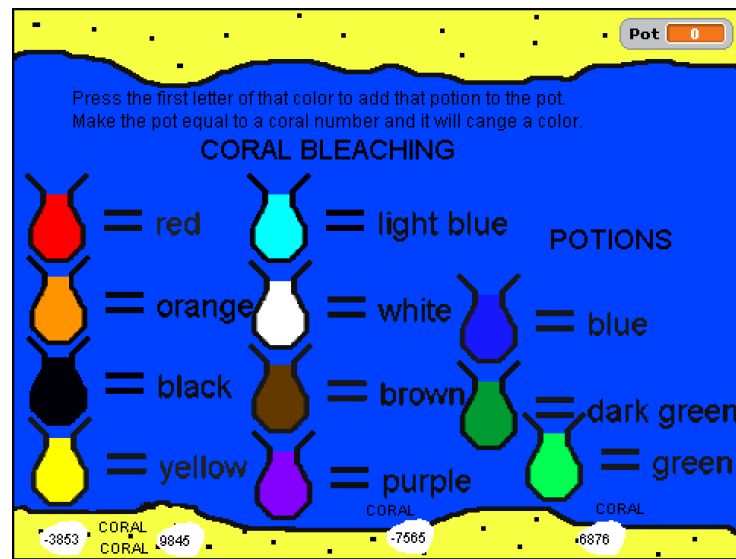


Figure 4.6 Eli’s game is about coral bleaching. A student colors each element. Corals are at the bottom; they are white in color because of a loss of pigmentation.

The discussion among the students in both groups shows that at this stage, students needed teacher mediation and support to keep focused on the task and to explore their ideas more deeply. Even though the students asked good questions of each other, a teacher was required to facilitate the discussions, particularly when students’ had difficulty explaining their ideas (as shown above in Eli’s case) or engaged in off-task discussions. The following excerpt shows how subtle prompting from the teacher could move discussions toward helping the student focus his or her ideas better:

Adria: “Well my game is about Global warming, the way that I show global warming in a fancy way so that it will be more fun for kids, because you are a knight with armor trying to go kill the dragon which is heating fire on earth to try to like make it blow up. And if you do not get there in time the earth blows up.”

Co-teacher: *“So you are using a character appealing to the kids?” ...*

Adria: *“Yeah.”*

Co-teacher: *“...but we are not learning about dragon right. We are learning about what?”*

Adria: *“Global warming.”*

Co-teacher: *“How are you teaching them?”*

Adria: *“I am teaching them because, I do not know if they already know this, but when you use electricity, it heats it. I can make the dragon something.”*

Larry: *“The dragon could be named pollution.”*

Co-teacher: *“That is a good idea.”*

Larry: *“Or pollutionator.”*

Adria: *“Yeah.”*

Larry: *“His name [the knight] should be recycler.”*

Overall, these discussions seemed helpful for the students to discuss their environmental problems and game design ideas. With teacher guidance, the students were able to evaluate each others' ideas and provide constructive feedback. Without teacher facilitation, discussions were less reliably productive.

Unstructured Collaborations

The results of this study showed that learning by game design promoted social interaction and therefore collaboration among students. During the individual game design tasks, there were a number of unplanned collaborative interactions. These

interactions were observed in video recordings where students frequently asked questions to one another and the teachers. In this section, the interaction between four students with diverse prior knowledge in computer skill and environmental awareness was analyzed. These students were Isabella, Adria, Megan, and Amber. In line with previous studies by Turner and Dipinto (1996) and Kafai (1996d), video observation of these four students showed that they interacted and collaborated with each other informally throughout the game design process. The following categories emerged based on analysis of observations and interview transcriptions: help seeking, instant peer feedback, and distributed expertise.

Help seeking: It was observed during the game design that the students requested more help than they did in their other classes. During the post-interviews, the four students observed through video recordings reported that they rarely asked for help from their peers. However, the video observations showed that they frequently asked for help from their peers when they were designing the games. As was expected, the observations showed that the students requested more help during the first design sessions, which decreased gradually up to the last design session. It was also observed that the students with more *Scratch* prior experiences also sought help, but less frequently compared to the students with less *Scratch* prior experiences.

The help that students needed was mainly about game design strategies, programming concepts and the functions of *Scratch*. For example, Amber asked Isabella how to use the *Scratch* Image editor to create her own game characters, after seeing she had her own images in her game. Some other students also asked each other how to

implement certain game features in their games. Isabella, for example, asked Megan how to add scoring to her game. Thus, it became evident that involvement in the game design increased students' willingness to communicate when it came to doing actual tasks without waiting for teacher's encouragement.

Instant peer feedback: Students were motivated and curious to look at each other's games. By looking at games, they provided informal feedback to each other. These instances of sharing helped students to stay on track with a better game design. A teacher cannot review all the students' games at once, therefore peer evaluation is crucial. Even though there was a separate session for the sole purpose of peer evaluation, these formal sessions did not appear as helpful or as detailed as informal feedback.

These unplanned evaluations took place when a student would show her game to the person next to her, saying "see what I have." It was observed that the student who watched the game gave either negative or positive feedback; what's critical, however, is that the feedback was constructive. For example, Isabella was showing Megan how she designed clouds for her game background, and the first comment that Megan made was "you should change this to white" (referring to the color of an image in her game).

It was found that the four students analyzed in depth made requests to try each other's games. After a student made some progress on the game, another student sitting next to her would typically ask to try it out. There were also cases where a student asked a peer to test her game. Adria, for example, reported that she tried her own games several times and wanted Megan to try her game too before the second graders came for testing. Amber reported how she learned by watching others' games

Amber: *“Well, after watching their games, I was looking at what they did to make stuff move like that.”* (She was pointing out how she used arrow keys as the control options for her game avatar.)

Researcher: *“I see, and then you put these on your game?”*

Amber: *“Yeah.”*

Qualitative and quantitative evidence showed that the students resolved each other’s design problems together even though they were assigned to work on design tasks individually. Since it was perceived that there was not a single expert in game design in the class, the students negotiated different aspects of game design. After Amber asked Adria for help, Adria asked her some questions to understand her game. Amber then explained the sprites and how she used them in her game. The following conversation is one example that occurred between the students during the game design.

Adria: *“Do you want the person to disappear?”*

Amber: *“Yeah.”*

Adria: *“I cannot do that but I can do, when the starfish touches one (referring to the pollution) it becomes blue”* (The original color was gray and the background of her game was blue, in other words it disappears.)

After Amber accepted that suggestion, Adria said: *“You want this one, and then,..”* (giving options and) *“You can do anything you want after you touch it.”*

It was observed in this design process that students helped each another in many ways. Adria, for example, mentioned that she received assistance from Megan about moving scripts, but she helped Amber with other tasks. It was found that the peer

knowledge sharing was mainly about game design and strategies, but not about environmental content. Adria reported that she did not trust her peers' help on her environmental topic; therefore, she requested assistance from the teacher. Yet, video observation showed that she frequently requested help from peers about game design and programming concepts. This confidence in relation to game design but not environmental content might have to do with the instant feedback that the students received when it came to game design. When a student received help from a peer, the game debugging would instantly show the accuracy of the information provided. However, this might not be the case for help related to environmental content. Overall, involvement in the game design process helped these four students to interact in order to co-construct their knowledge.

Distributed expertise: Multiple paths to learning. Different from a traditional learning environment, learning-by-game design requires students to understand that there is no mastery level of knowledge. The students could use a variety of different programming strategies to get to the same function. Even though the students saw that some students were more knowledgeable than others, they did not see them as the authority of the knowledge. For instance, the students knew that their technology teacher, the researcher, was more knowledgeable than they were. However, this did not mean that students would necessarily choose to keep to what the teacher showed them.

During one of the earlier design sessions, Amber asked the teacher for help with adding a feature for whenever her main character touched trash spots, the player got points. The teacher suggested using a long Boolean expression. However, it was found in

her final draft that she replaced this Boolean expression with a short script. The following is her response during the post interview;

Researcher: *“And there was a thing you put 'and and' thing remember you had that?” (Looking into script for the Boolean expression she had on her game.)*

Researcher: *“Did you take this out?”*

Amber: *“Well, I took this out because a friend told me that you do not have to make too long. You can just have [this] other thing.”*

Researcher: *“Who said so?”*

Amber: *“Megan.”*

Researcher: *“But, does it still do the same function?”*

Amber: *“Yeah.”*

This showed that knowledge in learning-by-design approach is not limited to a single authority, e.g., a teacher. Instead, the students can use different strategies and approaches, depending on what is identified as most viable to them.

The data showed that the role of teachers with a learning-by-design approach is not knowledge transmitter, but a co-learner and facilitator. For instance, it was observed at one of the design sessions that Isabella asked the teacher about adding a timer in her game. After he looked at the *Scratch* settings and could not figure out the solution, he asked the rest of the class if anyone could help her. Larry then showed the teacher and Isabella how to set a timer in her design. Similarly, Adria asked the teacher how to add the ability to move different directions using arrow keys. The teacher then asked Isabella to help Adria, since she had just learned that feature from the teacher. It was observed

that Isabella successfully added the moving feature to Adria's game. Learning from peers helped the students not only learn basic coding from each other but also to collaborate on the entire game design. For example, students had a chance to explore how others implemented features of *Scratch* in their designs while providing help. The students who provided help also extended their understanding through the practice of teaching to others.

Instead of teaching every step of game design, the teacher showed the students how to access necessary information. As Kafai (2006) highlighted, learning-by-game design changes the delivery of instruction. Instead of giving the same instruction to all students, instruction is based on individually-defined needs and goals. Based on the students' level of expertise, the help that they needed varied. It was observed that almost every student requested some sort of help from the teacher. What is important is that all students requested varying types of assistance based on their level of expertise and their game design.

The teacher promoted peer collaboration in the project by referring some of the students' questions to other students who already knew the answer to a specific problem. As Adria and Megan mentioned in their post-interview, the students had a perception from the traditional classroom setting that a teacher would not be happy if students talk too much in class. With game design, however, this type of unstructured collaboration among students was essential to its success.

Sharing projects

Constructionist learning environments require sharing as an external process where students share their designed artifacts with a given community. In this research, two types of sharing activity were studied: peer-testing and audience testing.

Peer testing. Three types of peer-testing occurred in this study: informal testing, online testing, and formal testing. Since unstructured (informal) peer testing was presented in the previous section, it will not be repeated here again.

Online testing was expected to be productive for the students to test each others' games out of classroom. However, a technical problem that appeared on MyLingua did not allow the students to try each other's games. The students reported during the post-interviews that they had tried to play peer's games on MyLingua in the first days of the design sessions, but their computers were freezing because of technical problems. Even though this problem was reported to the external hosting company, unfortunately it was not fixed in time.

In line with previous studies (Hmelo et al. 2003; Kolodner et al. 2000), the researcher requested that game designers test each others' games and evaluate them based on provided criteria (Appendix F). The formal testing took place two sessions prior to the second grade testing. After the students filled out evaluation reports, the teacher combined the responses for each game designer, and it was given to each student. Since Megan, Eli, and Larry were absent from that class, they did not participate in this peer testing.

Based on the students' post-interviews and class observations, most students were not happy with the points that their peers gave. As it is shown in Appendix F, on average students received some low and some high scores. Since some students received low scores from their peers, they said that this evaluation process was discouraging for them. However, the formal peer evaluations may have helped to spread strategies and ideas throughout the group. Sometimes, new features or strategies appeared in the students' design soon after the testing, which might be attributable to ideas gained from peers. For example, Tanya reported the following features that she learned from reviewing others' games:

Researcher: "After trying these games, did you learn something from them to improve your game?"

Tanya: "Well, with the letters, I learned that from Lacy's game that I want to put that in, too. Timing, I got from Isabella's game. I want to put this into my game."

As the analysis showed, peer-testing could be effective for some students to learn new strategies from each other and implement them in their games. However, teachers may want to be cautious about using formal evaluation in the same way, as it appeared to cause discouragement for some students.

Second Grade Testing. Consistent with prior studies of game design (Harel & Papert, 1991), 2nd graders from the same school tested the fifth graders' games twice. For both testing sessions, the same process was used. Each fifth grader was assigned to have at least three second graders to test the game. After the testing process, the second

graders were told to fill out an evaluation form that was introduced by their classroom teachers (see Appendix E). After the testing process, which took approximately 30 minutes, the students gathered in the middle of the class to give general feedback about the games.

The video observations, interviews with fifth graders and reflection notes from second and fifth graders show the emergence of three main patterns:

- (1) There were some positive and negative implications of having second graders as game testers;
- (2) Interactions during the game testing engaged students in learning;
- (3) Evaluation of the games helped the students to revise their games and therefore learn new concepts about environmental content and programming.

It was observed that designing games for second graders had both positive and negative implications for the process of learning by design. It was found helpful and beneficial to establish a target audience for the games. This certain target audience guided the fifth graders to design their games based on the criteria of second graders as game players. For example, Adria discussed with her classmates that she wanted to make her game more fun since second graders would want more fun games for their learning. After this discussion in one of the formal discussion session with peers, she decided to name the dragon *pollutionnator* (the enemy heating the earth in her game). She, however, did not use this name after the first second grade testing. Even though this study expected that the students would improve their learning while they were teaching others, it was found that most students tried to keep their game content simple.

The goal of the testing process was twofold: different community members to share artifacts, and target audience group to evaluate the artifacts. The testing process primarily served as a means for the game designers to share their games to construct their knowledge. As a secondary goal, the testing process served as an evaluation of the students' products. Similar to the peer testing process, 2nd grade testing also was designed so the game designer would interact with the game player and improve the game players' learning. Since the goal of sharing with others is more than testing, the process is more than formative or summative evaluation. The following section describes the testing sessions and the benefit of these sessions for both second graders and fifth graders.

The goal of sharing is not merely displaying an end product, but it is showing others for interaction, collaboration, and learning from each other. The video observations showed that the fifth graders engaged in and enjoyed the process of showing their games to others. During this engagement, the students explained their games by means of the content that they were trying to represent. Even though the sharing process in constructionism predicts that students learn from one another and revise their design based on other artifacts, the testing process with second graders was not as effective as expected. Since the second graders did not design games to share, the interaction was limited to the comments and evaluation scores for the games.

Even though the evaluation process by the second graders was not a two-way collaboration, it may have been useful to improve the learning of the designers. The data show that after two testing sessions by the second graders, the fifth graders revised content representations, improved their learning in content and programming, followed the principles of interaction design, and learned how their games were perceived. Game

analyses showed that Lacy, for instance, had water pollution as the main environmental issue in her game before the testing session. But after the testing session, her topic changed to recycling. In other words, she extended her representation and added bins to recycle the trash from the water. Change was also found in Adria's games. Before the first testing session, her game player could win the game only when they touched the dragon. But after the testing, she changed the way that the players had to solve other environmental problems (by touching necessary icons) such as air pollution, overuse of energy, littering, and oil spills in order to win the game.

Even though the students were expected to improve their learning about the domain after the testing session, this was observed only with few students. Kyle, for example, reported in his reflection to the first testing session that *"I think I should make them learn more about bacteria, and I should also have better d[i]rections."* After the first testing session, he also added information for each game character, such as *"I am bacteria 2 I am really dangerous try to avoid me"* and *"Hello! The fisher cleaned me without water"* for the fish that spreads bacteria, and *"Hello! I am medicine if you get on me I will heal you"* when the player clicked on medicine. Kyle reported in his reflection after the second testing session that *"they (the second graders) learned a lot more than last time"*. He searched on the internet and asked the teacher to decide what type of bacteria is dangerous and what type of medicine could help to heal a patient in real life. Some students also reported that the second graders already knew the environmental content and therefore they decided to focus more on the game design.

The game analysis showed that the testing sessions had more effect on students' programming concepts. As it was explained before (corresponded to Research Questions

1), most of the students, especially the girls, increased the number the programming concepts in their games after the first testing session. Based on the game evaluation results from the second graders (Appendix E), some fifth graders tried to add new levels into their games that required learning new programming concepts, such as *broadcasting*.

It was found that summative evaluation in learning-by-game design still serves as formative evaluation because (1) the students may keep redesigning their games based on comments or (2) take these design ideas and keep constructing their knowledge. Even though most of the fifth graders reported before the second testing session that their games were done, they reported in their reflection notes and post-interviews that they wanted to improve their games based on the second graders feedback (Appendix E) during the second testing sessions.

Indeed, the testing sessions encouraged the students to rethink how they implemented some principles of interaction design in their game designs. The analysis of the games showed that students made some changes in their games after the testing session. Eli, for example, added labels to the coral shapes to provide clearer navigation. In order to increase the readability of the text, Lacy revised the text of her game instruction. It was also found that most students extended the time on their timers based on the second graders' comments. Adria and Eli also used background sound to make their games more appealing.

A Single Case

This section provides a rich description of a single case study of one student. Adria was selected as a representative case, since she started the game design project with little prior experience in gaming and computing and average prior knowledge in environmental content. According to environmental knowledge pre-test result, she scored 71 out of 100. Her score for the environmental awareness survey was 93 out of 100. As it was supported with the interview transcripts, Adria had less gaming and computing interest prior the game design project. Her pre-survey scores were for GDI 16 (out of 32), for CI 18 (out of 24), and for CE 19 (out of 20).

Adria had comparatively less experience with game playing (compared to the class game play average). As Table 4.1 shows, she rarely played computer games. According to Table 4.2, she had explored *Scratch*, but reported she was never able to design something that functioned properly. She mentioned during her pre interview that she expected to have difficulty with the game design project because of her low confidence and experience with designing with *Scratch*.

During the first few design sessions where the students were mainly conceptualizing their ideas and planning for the designs, Adria started designing games and switching to a new game after each day. On the first day of the design session, she noted on her online planning posting that “I’m doing rainforest destruction. My idea for the game is to have them walking around the forest putting tree trunks on the stump.”

However, it was observed during the design sessions that Adria did not start designing her game. When the researcher asked her about this, she mentioned that she

had a plan to design a game about rainforest destruction but was not sure what to do. She exhaustedly mentioned that she did not have enough *Scratch* skill to make a game about rainforest destruction, even though she was able to use the image editor of Scratch to add or edit game sprites, which was the first step prior to programming the game. After researcher encouragement and mediation, she agreed to draw some main sprites of the game she was planning to design.

It was found in her daily planning that she posted online on the second day of the design that “I changed my mind now, you have to walk around a beach picking up stuff, and you have to put it in a recycling bin or a trash can.” After analyzing her game about rainforest destruction, she already drew some main sprites in a short time but changed to a new game. When she was asked why she switched to a new game, she mentioned that making a game about rainforest destruction would be too hard to design and therefore she decided to make a different one. She spent one design session to draw sprites for her new game.

The observations and game analysis show that Adria started a totally new game idea again during the third design session. In her game, she decided to make a maze game (see Figure 4.1) where a knight tries to stop a dragon from heating the earth. During a conversation with the teachers, she mentioned that the dragon represents global warming which increases the Earth’s temperature, and the knight represent human beings trying to stop global warming. After the peer interaction and teacher mediations, Adria also added new environmental concepts and issues to her game. She, for example, added a car in the maze that the knight should touch (to solve air pollution problems that result from car exhaust) in order to win the game.

After Adria settled upon this game idea that she learned from her classmate, every design session became more productive for her. She started asking the teacher and peers for more help adding new features instead of frequently expressing her weakness in the game design. It was found that she asked her classmates if the second graders would know certain concepts that she was planning to add to her game. While she was designing her game day by day, she was also learning new *Scratch* features by asking if there were certain commands that would enable her to add certain functions to her game.

It was also interesting that the game design process by its nature promoted peer interaction and collaboration. Adria, for example, had a chance to show some *Scratch* features that she learned from her other classmates during the project. It was observed that she frequently asked Megan and Isabella who were sitting next to her to try her game. After each try, her classmates provided constructive feedback for her to improve the game.

Another interaction occurred during the testing session with the second graders. It was found during a discussion prior to the 2nd grade testing session that Adria was trying to make a game that 2nd grade would learn from and enjoy. After the testing session, she mentioned that the 2nd graders liked to have more 'fun' and therefore she made some changes in her game such as adding background sound and new actions to make the game more 'fun'. Because of these new changes, there were significant changes observed in the number and type of programming concepts she used in her game.

Overall, it was found that conceptualizing the idea and integrating this idea into a computer game was the main obstacle for Adria during the project. Changing her game idea was not only about the artifact but also the concepts and content. It was found in her

first two game design attempts that Adria tried to implement her environmental concept into the games, but with her lack of experience in design and *Scratch*, she decided to choose a game first and then add some environmental content to this game. It is possible that Adria was not aware of a game design idea and therefore she had several false starts, since she was one of the students with the least game play experience. It was also interesting that Adria kept increasing her skill in the design and programming after she decided a game topic. She also negotiated with her classmates and teachers about the environmental content of her game as well.

Adria's test and survey after the study varied. According to the results she increased her score for environmental knowledge test from 71% to 79%, but her score for environmental awareness survey was decreased from 93% to 87%. Even though there was a decrease in her score for computer enjoyment survey, she did increase her score for game design interest (GDI) survey. Her scores for computer importance (CI) survey remained the same. In addition, she made the following comment during the post-interview which summarizes how she felt more comfortable about game design and how she saw game design as an effective means for her learning:

Researcher: *"Would you like to do [a game design project] again next year for other classes?"*

Adria: *"Probably, because it is much more fun instead of sitting around and copying things into a notebook or doing regular research, making a game is much more fun because you yourself get to actually enjoy [it], ... Some people do not really ... enjoy ... doing research and like when you finish your game you can play it. But when you finish your report, all you can do is read it over and over,*

but when you make a game you can improve because you can download it and do it on your own computer. ... you make a new game because like the knowledge you do in our report you know things and you can answer questions, but with the knowledge you get from making a game you can make more games and do stuff and have fun.”

CHAPTER 5

GENERAL DISCUSSIONS AND IMPLICATIONS

Summary and Discussion for Research Question 1

RQ1: *What game design characteristics and programming concepts do students use as they work with Scratch to program their games?*

This question aimed to explore elementary school students' design and programming experiences while they designed educational games. The findings show that both girls and boys used similar game characteristics and programming concepts in their games. In general, the learning by game design activity uncovered students' potential in computing. By end of the study, students were able to represent their design thinking in the games with unique game characteristics by using different *Scratch* programming concepts as well as their own graphic designs. The game design process empowered and challenged students to make their own decisions (Nesset & Large, 2004) in a learning-by-design context.

Game Characteristics

The students' game worlds showed that the students were able to structure their thinking in an organized way. From the size ratio of the characters to color matching of each sprite, the students organized their design thinking in their games successfully. In addition, the students aligned the contexts for their game worlds with their design characteristics. For instance, Nick created a world that matched his game topic, with fish

moving around in the sea, and a ship oil spill as the cause of the problem to be solved in the game.

In addition, most of the students were able to consider accessibility of their games. Besides providing detailed instructions at the beginning of the game, the students also decided to use commonly used arrow keys for the control options. Students also used variety of feedback types to reinforce their game players. Students used different scoring and timers to show competency in their games and used text, graphic, or sound feedback about players' success and failure in the game. Students' artistic skills were also demonstrated in the project. Students drew their own graphics for their game world, and some students were able to add sound to their games. Moreover, one student, Eli coded his own original background music in *Scratch*. Overall, students showed evidence of organization and creativity throughout the game design process.

Consistent with prior research (Kafai, 1996a; Pinkard, 2007), this research used the lens of gender differences to analyze game characteristics. Unlike prior studies (Kafai, 1996a), this study did not uncover clearly distinguishable gender differences in game characteristics. Differences seemed due to the different purposes and game worlds developed by the designers. Unlike prior studies, there was no clear generalization about the students' games as representing boys' games or girl's games. In fact, one girl added a fighting conversation and action into her game, which prior research has shown to be typically characteristic of boys' games. This difference from prior studies warrants future investigation.

Programming Concepts

Like previous studies (Maloney, et al. 2008), the students of this study were also unable to define the term *programming*. During the pre-interview, most of the students explained the term as setting up a computer or installing software on computers. Nevertheless, students' programming concepts progressed while using *Scratch*. The findings confirmed prior work (Robertson & Howells, 2008) that visual programming toolkits such as *Scratch* can help novice programmers easily combine commands. With these combinations, the students made scripts that ran actions as part of their games. Similar to Maloney et al., the students of this project were successfully able to decide their own programming in their scripts with little mentor assistance. Despite students' minimal prior experience with *Scratch* and almost no design experience, most of the students were able to have a functional game after the 10th design session, and after the 6th session for the experienced students.

The success of these young students lends support to the conclusion that elementary students can access complex programming concepts and create computer games if the software they are using and visual interface is developed for their level of experience (Lin et al, 2005). The results clearly show that all participants of this study, without exception, finished a game that was meaningful to them and the community around them. These results may also have implications to influence the cycle of elective technology education courses and computer clubs that attract and sustain students who are already strongly interested in computer science (Repenning & Iannidou, 2008).

Indeed, prior research has shown that students who took object-oriented programming courses using visual interfaces like *Scratch* performed better at C++ and Java programming courses (Cooper, Dann, & Pausch, 2000). Technology education

teachers may also consider integrating a learning-by-game-design approach into their curriculum to improve programming. This can be helpful especially for students who have technophobia. However, this does not mean that the goal should be making all students technophiles, being strong fans in computerization and new technologies. Instead, the goal is to reduce students' technophobia in programming which typically starts at an early middle-school level. In this study, for example, a few girls already had a fear of programming, but that was overcome after they finished their games successfully.

This study showed that students were able to use different advanced level programming concepts at elementary grade level. None of the students had any difficulty with adding *statements* to their programming scripts. With the simplified *Scratch* command block, the students did not have difficulty with collisions, but they could not set other Boolean expressions without the teacher's help. The students' use of *conditions* and *loops* were limited to 'forever' or 'if' command blocks. Students rarely used 'if else' or other complex command blocks in their games. An extended similar study may find the causes of students' choices of different commands.

Similar to Pinkard's (2007) findings, this study showed that most of the girls started the game design project with less prior experience compared to that of the boys. However, the number and type of the programming concepts used in the girls' games showed that they were able to conceptualize these concepts and build their scripts as well as the boys. Indeed, the results of this study also show that some of the girls used advanced programming concepts of *Scratch* such as *broadcasting* that the boys rarely used.

Previous studies have suggested that involving students in programming at an early age could help develop computing and programming interests (Kelleher & Pausch 2006; Moskal, et al. 2004; Repenning & Iannidou, 2008). The results showed that the students' reported interest toward game design, computer enjoyment, and computer importance varied. However, consistent with a previous study (Rankin, Gooch, & Gooch, 2007), it was also found that game design can have both a positive and negative impact on students' attitudes about computing. Overall, on a 100 scale, boys' average scores for the both pre- and post-surveys were above 80% and girls scores were above 65%. The survey analysis showed that boys started with 88% game design interest, and their interest decreased by 5%, whereas the girls started with 65% game design interest which increased by 4%. For the computer importance survey, boys increased their scores from 81% to 89% , while girls kept the same scores at 77%. The scores for the computer enjoyment survey showed that boys had 85% in pre-survey and 83% for post-survey, where girls had 84% for pre-survey and 80% for post-survey.

Nevertheless, most of the students expressed that they liked the game design project, despite the fact that they were challenged by the programming. Consistent with previous studies (Malan & Leitner, 2007), even students with low prior game design or programming experiences reported a high interest in doing a similar game design project in the future.

Summary and Discussion for Research Question 2

RQ2: *How did students represent and revise environmental science concepts throughout the design process?*

The results showed that there was little to no difference between students' pre-test and post-test scores on environmental knowledge after the game design project. These findings can be explained by the following: (1) the sample size was too small to detect such knowledge gains; (2) since the topic itself was broad (i.e., students chose which environmental topic to pursue), these general assessments did not measure students' individual progress in their specific area; and (3) the post test was taken on the last day of school, which could have affected student attention to the test. Because there was no control group, the researcher was not able to compare the results with other groups having different instruction. Moreover, detecting pre-post differences on multiple-choice tests in constructionist environments can be difficult to achieve. Indeed, other researchers studying similar environments acknowledge this assessment challenge (Ioannidou et al., 2003; Tanghanakanond et al. 2006).

Based on these data, it is possible to conclude that factual or declarative knowledge could be learned more efficiently and effectively with other learning approaches. As others have indicated (Fortugno & Zimmerman, 2005), games might be more effective for showing and embodying processes but less effective for delivering facts. The findings from this study support the notion that what is learned in a constructionist environment is difficult to measure using pre-post assessments of knowledge gains. However, the results show promise for the use of game design as a way

to help students better connect “knowing” with “acting” (Barraza & Walford, 2002; Tuohino, 2003). With the learning-by-game-design, the students showed evidence of thinking about causes and effects of environmental problems and integrating them with responsible actions that needed to be taken by the game players.

Since the students’ learning trajectory differed based on their game design, it was not possible to anticipate the same outcomes from all students. Even if all students decided to make a game based on one single topic, students would still likely end up creating different games. It was observed in the study that each student, even if collaborating with others, designed a game that represented individual ideas. Because of that, individual students needed and sought different information for their designs. Thus, each student’s learning was different, and a test with limited questions might not be adequate for assessing what was learned from all students. Therefore, learning-by-game-design may be more effective for individualized learning.

This study used a constructionist learning framework to support students’ extension of understanding by designing external artifacts. By designing a game, students were able to successfully transform their thinking into an external and physical representation. During this process, the students were able to monitor their learning by designing a game and critically examining what they needed to know to further improve their designs (Chapman, 2009). This study provides some insights into the conditions under which the students’ “need to know” emerged naturally as a result of engaging in the game design process.

Even though most of the students were able to represent their ideas successfully at the end of the study, the process of creating the games was often characterized by starts

and stops. It was challenging for students, particularly those without experience in game design, to develop a coherent game idea that was tightly integrated with a content domain that was concurrently developing. This points to a knowledge paradox with constructionist learning environments in general and game design in particular: Learning-by-design is assumed to promote meaningful understanding of a topic domain as students create personally-constructed artifacts (Papert, 1980). Yet, the cognitive demands of developing an artifact when both programming knowledge and domain knowledge are low, may be difficult for students to overcome without adequate time and support. In this study, students who had some background knowledge of the programming software seemed to progress more rapidly and cohesively than students who were new to the software. The results showed that the students with low prior experiences made wholesale changes to their games over time, since they did not have adequate technical skills in *Scratch*. Similar to findings of Rankin, Gooch, and Gooch (2007), the students with the low *Scratch* experience worried about the design process and changed to another game that they thought would be less technically difficult. In contrast, the students with high *Scratch* experience focused on one game and implemented their environmental ideas into the games. Thus, technical knowledge in a learning-by-design environment might be important for helping students compensate for the high level of metacognitive and cognitive task demands. Future research could investigate this issue further along with the question of whether the same pattern emerged with students having high and low domain knowledge.

Summary and Discussion for Research Question 3

RQ3: *How do students share knowledge, strategies, and projects for game design?*

Social interaction and collaboration is highlighted in most of the learning-by-design research (Harel & Papert, 1991; Kafai, 1996a; Kolodner et al 2000). During the study, there were unplanned interactions and unstructured collaborations as well as planned interactions, including group discussion, peer testing sessions and second grade testing sessions. The unplanned interactions documented on video recordings showed that the game design process, by its nature, promoted interaction and therefore collaboration between and among the students. Consistent with previous studies, the students did not compete with each other; instead, they helped each other to improve their games (Bruckman, 1998; Kafai 1996b; Han & Bhattacharya, 2001; Robertson & Howells, 2008). Students requested help from each other and the teacher on demand, not at scheduled time frames. Instead of giving the same instruction to everyone, instruction was specific to students' learning needs.

The students requested more help from each other in the integrated technology-science classes than they did in other classes, as they reported in their interviews. With the game design process, the students did not appear to see anyone as the only expert. They negotiated with each other while they were receiving or giving help. It was also found that the students were curious to look at each other's games frequently. By looking at games, they provided informal feedback to each other.

Based on previous studies (Harel & Papert 1991; Kafai, 1996b; Kolodner et al. 2000; Hmelo et al 2003; Reppenning & Iannidou, 2008), this study also implemented

discussion sessions for the students to discuss their environmental topics, design ideas, and provide solutions for emerging issues. Similar to Daiute's (1992) findings, this interaction brought diverse expertise to bear. With the facilitation of teachers, students learned from each other about their topics and games, and gave new ideas to improve their games. However, it was also found that the teacher's guidance and monitoring was important to keep the discussions productive.

Another set of interactions among the fifth graders was established during a peer testing session where students tested other classmates' games and provided feedback. As Morney-Hernandez and Resnick (2008) stated, testing peers' games can lead to the emergence of trends. In other words, each student had a unique design idea and content representation. Through game testing, some of the students in this study implemented ideas and representations of others into their games. Tanya, for instance, reported that she used letters in a rebuilt version of her game after she saw letters used in a classmate's game. Students who played Nick's game also reported that they should not spill oil in water. Zhang, Scardamalia, Lamon, Messina, and Reeve (2007) note that the spread of ideas across a community is characteristic of a productive knowledge-building community. However, it appeared that the peer rating part of the testing session was less useful, as the peers were tough critics of each other, which was sometimes discouraging for the students.

As Kafai (1996b) highlighted, creating artifacts that represent understanding by its nature promotes dialogue and negotiation with others. Having a target audience group affected the game design process in distinctive ways. The result showed that the fifth graders felt responsible to teach second graders about environmental issues. It was

observed that the students set teaching goals from beginning of the study and were asking each other how to make the game more interesting and fun so that the second graders would enjoy playing them. The students' reflections after the first testing sessions also showed that the students noticed gaps in their games and wanted to make their games ready for the next testing session.

In accordance with Papert (1991), the results of this study showed that the sharing process prompted the students to revise their games. Some students, such as Lacy and Adria, decided to change the representations of the environmental issue in their games. Another student, Kyle, realized that the second graders should learn more about bacteria, and he added more information about bacteria after researching and asking the teachers. The changes that the rest of the students made were mainly about programming concepts and game interface.

As Delanoy (1997) stated, the teachers' role in the learning-by-design-approach should establish constructive relationships, rather than supplanting students' creation and design. The results of this study showed that the teachers were co-learners and facilitators. Instead of teaching every step of the game design, the teacher showed the students how to access necessary information. Indeed, the teacher promoted peer collaboration in the project by referring students with their questions to other students who already knew solutions for those specific problems.

Implications of Instructional Design

Based on the results of the study, there are several conclusions that can be offered as suggestions for improving the instructional design of learning-by-game design.

Game Design

The current study suggests that the type of games students played may have had an effect on the game characteristics they used (primarily platform). It may be helpful in the planning phase to present some games with a variety of game characteristics. Another way to improve students' use of various game characteristics is peer testing, where students learn how to implement new game characteristics from each other. Thus, researchers may structure game testing sessions in a way that students can interact with those students who have different game ideas.

In this study, use of graphics and advanced game characteristics were beyond the scope of the study. However, future studies with students advanced in gaming may use different game design software for better graphics. RPG makers or pro Gamemaker type of software might be adequate to design 3D games in future studies.

Programming

The success of these young students lends support to the conclusion that elementary students can access complex programming concepts and create computer games if software and visual interface is developed for their level of experience. These results may also have implications for the redesign of technology education curriculums that can attract all students, since current technology education models are limited in K-12 environments (Repenning and Iannidou, 2008). Indeed, integrating game design in

courses may influence the cycle of elective technology education courses and computer clubs that attract and retain students who are already strongly interested in computer science (Repenning & Iannidou, 2008).

The present study showed that students at young age achieved beyond the expectations of current technology education courses offered in elementary and high schools (Lin, et. al. 2005). The participants of this study were able to use different programming concepts to design a functional game. The game analysis showed that students with little prior experience with programming were able to design a game in ten design sessions (each session was 45 minutes). Meanwhile, it took only six design sessions for students with more prior experience to design a functional game. Thus, studies or design sessions should be arranged not shorter than that length in order to provide adequate time for students to be able to make a functional game.

It was evident in the students' games that regardless of gender or prior experience with programming most students were able to use different programming concepts in their designs. However, it was found that students used only the concepts that they were shown or that were tried by teachers or classmates. It could be more productive during the game design sessions to present different programming concepts with some examples. Students can use these concepts based on their design ideas. Using different programming concepts may improve students' algorithmic thinking as well.

Prior studies (Malan & Leitner, 2007; Maloney et al. 2008) have suggested that programming with Scratch could help the participants of this study to more easily understand other complex programming languages. This claim warrants further

investigation. Computer science courses from elementary to college level may use Scratch as a primary step into advanced programming languages.

Learning and Representations about Environment

Observations and game analyses showed that the more students conceptualized their understanding prior to the design, the better they represented their ideas in the games. Thus, it is important that the students have enough time for information gathering and preparation. This preparation is not limited to the domain subject; the students should have some knowledge of the design tool before starting the design phase. As the results showed, students who had a high level of *Scratch* experience represented their ideas more easily and successfully without as much trial and error. As Kafai et al. (1998) emphasized, the focus has to be on how the students represent what they know, rather than how to design it. Otherwise, design tools, which Papert (1991) proposed as tools-to-think with, could turn into tools-to-think about. Thus, the selection of the tool for the design is a crucial part of a learning-by-design study.

The current study showed that the participants at the age of 10, supporting the claim by Palmer and Suggate (2004), were able to explain the complexity of some relationships among the environmental issues and portray accurate explanations of the causal relationships of the environmental issues. As Duan and Fortner (2005 p. 30) suggested “educators should choose effective sources and formats to make more complicated environmental issues tangible and understandable”. Thus, game design could be a strategy to help students at a young age conceptualize these complicated issues.

Students’ perception of games affected the games that they designed and therefore their representations of environmental content. Since it was the first time most of the

participants designed educational games, they frequently insisted on creating games containing less environmental content. Adria, for example, told the teacher that the second graders would like to play fun games, not educational games. This perception that educational games cannot be fun might come from students' lack of experience with educational games. Thus, researchers and/or teachers may explain in advance how to embed both fun and educational content into the games in a balanced way.

Sharing Artifacts

Requiring students to design educational games for another audience or other students affected their designs and representations in several ways in this study. First of all, asking the students to design a game for a target audience prompted them to organize their ideas for a specific objective. Second, it served to add content to the games in a way that someone else could learn it. Without a goal, the games could turn into entertainment games with no obvious purpose. Third, the students had a chance to see how successfully they represented their ideas in the games and how that was perceived by the 2nd graders.

Nevertheless, selecting a target audience inherently limits the designers' representations and, therefore, their learning. It was found in the present study that choosing second graders had both positive and negative implications. Because of their grade levels, some second graders had a hard time understanding the content and the direction for the game. Some fifth graders tried to keep the environmental content in the games simple for the second graders. As a result, the process of creating a game did not challenge them enough to research for more information. It was also observed after the sharing process that some students took out some of the content from their games instead of adding new content. Therefore, one possible implication might be to make the target

audience closer to the age range of the student designers. It would be interesting to investigate whether having older students as the audience would affect that process. After asking some students how they would change their games if they had to design games for 6th graders instead of 2nd graders, all the students mentioned that they would make harder games for 6th graders. It is possible that as a result, students could be engaged in the content more thoroughly to make more sophisticated knowledge representations.

As Papert (1991) emphasized, constructionist learning environments promote a wide spectrum of learning in different areas. The results of this study showed that the game design process required students' social/collaboration skills, learning skills, and mathematic skills. It was observed that the students appeared highly motivated to complete the game design. This study was conducted in a regular classroom setting, and the students were not trained to act differently. However, similar to other studies (Resnick 1997; Spitulnik, Zembal-Saul, & Krajcik, 1998; Robertson & Nicholson, 2007; Robertson, Howells, 2008), students showed evidence of sustained attention, engagement in their own learning, listening skills, help seeking, organization skills, and responsibility. Similar to Resnick and Ocho's (1991) findings with a LEGO/Logo design project, the students in this study showed they could apply some mathematical concepts while designing their games. All students, for instance, applied integer numbers and coordinates by adding moving scripts to their game characters. This points to additional potential benefits of learning by game design that could be explored in future research.

Online interaction

It was observed that the lack of experience with online collaboration did not allow the students to interact or collaborate online for their designs. Most of the students were

able to post their responses online for the daily prompts, but the students did not interact or collaborate online for the project (in part due to technical issues with the course management site). In future efforts, teachers might also assign students to collaborate online outside of class, which might lead to more testing and sharing of ideas.

Implications for Classrooms

Learning-by-game design provided an individualized learning environment (Yelland, 1997). Teacher facilitation and monitoring is crucial during the design process. Domain subject teachers, the science teachers in this study, have to evaluate students' representations of scientific concepts in the games frequently in order to prevent the project from turning into a free game play activity. As previous studies suggested (Harel & Papert 1991; Ioannidou et al. 2003), the teachers should keep the balance with daily evaluation and prompts to keep attention on the domain subject. It is also important for teachers to be comfortable with the design tools, to respond to students' design questions, and to facilitate interactions properly.

It was shown that students were able to finish their game designs within the designated time frame. It is important in schooling that a unit is covered within a certain time period. Thus, this study combined a technology education course and a science class in such a way that students used class time for both courses to design games. Within the given time frame, the participants of this study achieved class objectives for both a programming unit in the technology education class and an environmental education unit in science class. Based on this study, it is recommended for classroom teachers to

designate at least twelve class periods to expect a functional game from the students that represents some understanding of the content. As the results of this study show, students' prior knowledge in the content area and prior experience in the design tools should be considered for when planning the length of time required for an adequate implementation.

Game Design: A Dynamic Learning Process

The present study provided some insights into the process by which students dynamically develop artifacts in a learning-by-game design project. This section presents a conceptual framework that illustrates this process, based on previous frameworks (Lier, 2004; Kolodner et al, 2000; Renick, 2007). The framework is rooted in the notion that learners develop understanding by designing and sharing artifacts (Papert, 1983), and they progressively expand their learning through interactions with tools and community members. As Figure 5.1 shows, during the design and sharing process, the designer has four main interactions: design tool, teachers, peers, and game testers. As the arrows portray, the more interaction the students have, the more design experience and representations that potentially develop.

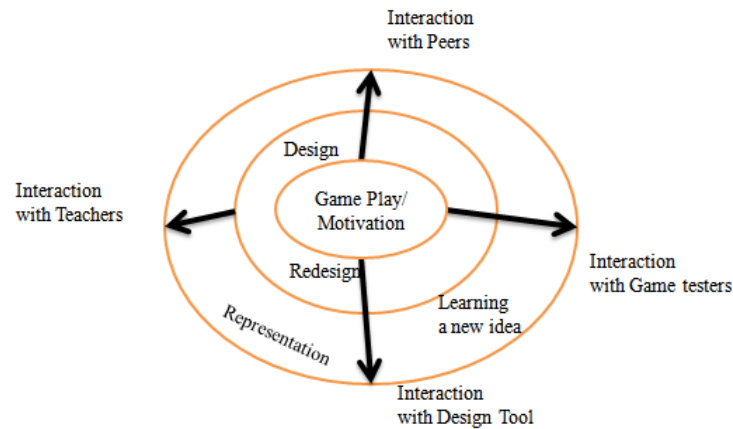


Figure 5.1 A dynamic learning process with game design in the classroom

As shown in the framework, game design becomes a dynamic learning process where students' self-motivations about game play prompts interactions, and these interactions prompt additional information seeking and new interactions. Students typically enter the learning environment motivated by game play which becomes a starting point for learning. During the design process the students interact with the design tool and externalize initial representations about their games and content knowledge. Interacting with the design tool as an “object to think with” (Papert, 1983) is central to the dynamic learning process. While designing, learners conceptualize their ideas, reformulate these ideas, and implement them into the design.

The process of designing and testing leads to continual redesign. Peer interaction plays a role in the redesign process, as they not only share games, but share ideas, concepts, and strategies (Gargarian, 1996). This sharing expands students' ideas, which are acted upon through the design tools. Interactions with game testers also lead to redesign. After the designer develops a prototype, the game is shared with the target

audience from whom designers receive feedback. Based on this feedback, the designers start another redesign process. The design process is perhaps most affected by interactions with teachers, who not only facilitate the designers' learning but also help them to expand their ideas for further designs. During this interaction, teachers may provide necessary information or ideas to scaffold the students' design, or refer the students to a source, design tool or peer.

Conclusion

The current study investigated how children designed computer games as artifacts that reflected their understanding of environmental knowledge. The study showed that the students were able to successfully express their personal thoughts and intentions by designing and developing computer games in an accessible programming environment. Corroborating the findings of previous studies, this study showed that students become active participants and problem solvers by designing their own games. The students were able to conceptualize their knowledge of environment using computer gaming as a resource. Findings showed that students' representations of environment changed from 'knowing' to 'acting' with the game design.

The students also engaged in social interaction by discussing their ideas, helping each other, and sharing their designs. In addition, the interaction between fifth graders and second graders also added value to our study. As it was mentioned above, the fifth graders decided to make changes to their games after the second graders played their games. This indicates that second graders also helped the fifth graders to redesign their

games by giving feedback about their games. It was found that there were some sharp changes in programming concepts in some students' games. By designing games for a target audience, students considered the principles of interaction design for the second graders. Overall, our research points to game design as a promising learning strategy that was highly engaging for students and promoted collaboration on individual designs (Robertson & Howells, 2008).

Overall, this study showed that game design in a classroom setting was constructive for most participants to

- conceptualize their knowledge of environment and programming
- reformulate their understanding
- engage in their learning
- represent their understanding of environment
- be able to express their ideas
- take ownership of their own learning (Cheng, 1998)
- help each other on the design and programming
- spend extended time to work on the game design
- engage in community

Future Studies

Rooted in constructionism, this study on learning-by-game design holds promise for informing future research. Since there are always new developments in game design technologies, future studies could focus on taking advantage of new technological features and platforms to improve the quality of the games, the collaboration among the students, and the learning of target subjects. For instance, Microsoft plans to release *Kodu*, a simple game development environment for use on the *Xbox* platform (<http://research.microsoft.com/en-us/projects/kodu/>). *Kodu* was designed as a visual programming language specifically targeted towards children. Further research with these technologies could also look at how students act while they design games. Applications like these may also open up new venues for research on game design in more informal contexts, like homes or after school clubs.

Another area of future research around children's game design centers on the collaborative design and development process. Although students might develop their games individually, our project demonstrated the importance of informal sharing of strategies, tips, and testing with others. Although some online sites or virtual worlds are available for children to engage in social interaction with privacy and security (i.e. Whyville, Teen Second Life, Active World), few sites exist for children to share games they have designed online. Further engineering research may focus on platforms where children can build artifacts together virtually.

Based on some evidence presented in this study, future research may pay attention to the fact that there were more sharp changes in the number of programming concepts

that the girls used in their games over time compared with the boys. Because of a small sample size and limited number of game design sessions, this study was not able to sufficiently make a claim for a clear difference between girls' and boys' use of programming concepts over time. The researcher suspects that the girls' low prior experiences with game play and game design may have influenced the changes over time. It is possible that the low prior experiences pushed the girls to a trial and error approach to learn the programming, and that caused the change in the number of the programming concepts. Similar to Lin et al. (2005), it was observed in this study that the students used trial and error techniques until they got their game scripts working; hence, they used a large number of programming concepts in their games during this exploration phase.

The sharing process was observed as another influence on the girls' use of different programming concepts over time. For instance, the numbers of programming concepts dropped significantly in the girls' games after 2nd graders tested their games. Yet, the numbers of programming concepts in the boys' games were not affected significantly. Indeed, further studies may examine the effect of different sharing processes and interventions on the presentational trajectories of new programming concepts used across genders.

Accordingly, future studies may investigate ways to implement some positive findings of learning-by-game design approach in a K-8 classroom setting. The primary study may examine if there is any difference in the long-term academic achievement between students who design games and those who learn with traditional instruction. Another classroom-based study may conduct studies to provide effective tactics to reduce request for support from teachers which could be applied to informal settings as well.

Limitations

The current study has certain limitations that need to be taken into account. The results of this study showed that teachers must first be exposed to gaming (Tiong &Yong, 2008) and game design tools since students in this study appeared to frequently need teacher support. It was observed that the absence of a researcher for even a short time caused problems for students in finding help with their questions, since other teachers were not knowledgeable enough to help the students with their design-related questions.

Although it is highly suggested that students should be free to have collaborative talks, this may sometimes cause noise, and some students may take advantage of that. One student, for example, reported that she did not frequently address her classmates with questions because she thought the teacher would be angry with her if she talked with others. Students should know that the game design process is still part of the regular class time. Thus, at the beginning of the study, classroom teachers would have to explain how the class procedures would take place during game design, discussion, and testing sessions, each of which would require different class procedures.

This study aimed to provide an online system where students can test each others' games online and leave feedback for each classmate. However, a technical problem with the hosting company that stores MyLingua course management system in their server did not allow the students to play games online. It was possible to upload games on the system, yet the web browsers would freeze when opening a game on MyLingua. Even

though the school contacted the hosting company, the problem was not solved in adequate time.

Another technical limitation was observed with Scratch software. Students had difficulty creating new game levels. Larry, for example, reported that he had to redo all the programming after he decided to add another level. Since the Scratch programming consists of command blocks, a few of the students sometimes had a hard time setting scripts in the narrow *Script Panel*. The students reported that the timer command block, which was widely used by the students, was not working as properly as other variables. The students also reported that they could not set the timer for a certain time, and therefore their games were not functioning as they had wanted.

In addition to these limitations, there were other factors that might affect the results of the current study; (1) the study was at the end of the year when students were mentally ready for vacation. (2) unexpected technical problems, and (3) lack of teacher support. Last, the class size (and hence research sample) was small. This made it more difficult to confidently present patterns that differentiated students on some factor, such as gender.

REFERENCES

- Almedia, L. (2008). *The phonemonological exploration of user-design in gifted rural high school when designing their own games*. Unpublished doctoral dissertation, The Pennsylvania State University.
- Barraza, L. & Walford, R. A. (2002). Environmental Education: A comparison between English and Mexican school children. *Environmental Education Research*, 8, 171–186.
- Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., Bransford, J. D., & The Cognition and Technology Group at Vanderbilt (1998). Doing with understanding: Lessons from research on problem- and project-based learning. *The Journal of the Learning Sciences*, 7, 271-311.
- Baytak, A., Land. S. M., & Smith, B. (2008). An exploratory study of kids as educational computer game designers. In M. Simonson (Ed.), *the Association for Educational Communications and Technology. Thirty-First Annual Proceedings, 2008* (39-47). Orlando: AECT.
- Bishop, T (2005, July 19). Gates laments decreasing interest in computer science. *Seattle Post*, Retrieved April 10, 2009, from http://www.seattlepi.com/business/233128_gates19.html
- Blankinship, E. J (2005). *Who's got game (Theory)?*. Unpublished doctoral dissertation, MIT.
- Bonanno, P. & Kommers, P.A.M. (2008). Exploring the influence of gender and gaming competence on attitudes towards using instructional games. *British Journal of Educational Technology*, 39, 97–109.
- Brandes, A.A. (1996). Elementary school children's images of science. In Y.B. Kafai, M. Resnick (Eds.) *Constructionism in practice: Designing thinking, and learning in a digital world* (pp.37-69). Mahwah, NJ: Lawrence Erlbaum.
- Bruckman, A. & Resnick M. (1995). The MediaMOO Project: Constructionism and professional community. *Convergence*, 1(1), 94-109.

- Bruckman, A. (1998). Community support for constructionist learning. *Computer Supported Cooperative Work*, 7(1), 47-86.
- Callan, J.M. (1994). Attitudes towards computers: The gender gap revisited. The Information Industry in Transition, *22nd Annual Conference of the Canadian Association for Information Science*, Montreal, Canada. (pp. 46-54) retrieved March 17, 2009 from http://www.cais-acsi.ca/proceedings/1994/Callan_1994.pdf
- Carlson, P. (1993). Environmental investigations. *The Science Teacher*, 60(2), 34-39.
- Chapman, R. (2009). Encouraging peer sharing: learning reflections in a community of designers. In Y.B. Kafai, K.A. Peppler, & RN. Chapman (Eds.), *the computer clubhouse: Constructionism and creativity in youth communities* (pp. 81-90). New York: Teachers College Press.
- Cheng, A. C. (1998). *A graphical programming interface for a children's constructionist learning environment*. Unpublished master thesis. MIT.
- Cobern, W. W., Gibson, A., & Underwood, S. A. (1995). Everyday thoughts about nature: An interpretive study of 16 ninth graders' conceptualizations of nature. *Paper presented at the annual meeting of the National Association for Research in Science Teaching*, San Francisco, CA.
- Coffin R.J. & MacIntyre P.D. (1999). Motivational influences on computer-related affective states. *Computers in Human Behavior*, 15, 549-569.
- Cooper, S., Dann, W., & Pausch, R. (2000). Alice: A 3-D tool for introductory programming concepts, in *proceedings of 5th annual CCSC Northeastern Conference* (pp.28-29). Ramapo, NJ.
- Day, J. (2004). *Connections: Combining environmental education and artwork in the primary grades for sustainability*. Unpublished master thesis, University of Phoenix
- Dickey, M. (2005). Engaging by design: How engagement strategies in popular computers and video games can inform instructional design. *Educational Technology Research and Design*, 53(2), 67-83.

- Dresner, M. & Gill, M. (1994). Environmental education at summer nature camp. *Journal of Environmental Education*, 25(3), 35-41.
- Duan, H. & Fortner, R., W. (2005). Chinese college students' perceptions about global versus local environmental issues. *The Journal of Environmental Education*, 36(4), 23-32.
- EarthWatch (2009). Retrieved April 15, 2009 from EarthWatch website:
www.earthwatch.org
- Emmerson, F. (2004). Exploring the video game as a learning tool. *ERCIM News*, 57, 30.
- Erickson, F. (2006). Definition and analysis of data from videotape: Some research procedures and their rationales. In J.L, Green, G. Camili, & P.B. Elmore (Eds.), *Handbook of complementary methods in education research* (pp 177-192). New Jersey: Lawrence.
- Evans, S.M. & Gill, M.E. (1996). School children as educators: The indirect influence of environmental education in schools on parents' attitudes towards the environment. *Journal of Biological Education*, 30(4), 243-248.
- Evard, M. (1996). Children's interests in news: On-line opportunities. *IBM Systems Journal*, 35(3), 417-430.
- Filho, W. L., Murphy, Z., & O'Loan, K. (1996). *A sourcebook for environmental education: A practical review based on the Belgrade Charter*. Bradford/Carnforth, UK: ERTCEE/Parthenon Press.
- Fisman, L. (2005). The Effects of local learning on environmental awareness in children: An empirical investigation. *The Journal of Environmental Education*. 36(3), 39-50.
- Forrest, K., Schnabel, D., & Williams, M. (2006). Earth day. *Teaching Children Mathematics*, 12(8), 408-409.

- Fortugno, N., & Zimmerman, E. (2005). Learning to play to learn – lessons in educational game design. *Gamasutra*. April 5, Retrieved June 1, 2009 from http://www.gamasutra.com/features/20050405/zimmerman_01.shtml
- Foster, A. A. (2005). Student interest in computer science plummets technology companies struggle to fill vacant positions. *The Chronicle*, 51(38), A31.
- Gargarian, G. (1996). The art of design. In Y.B. Kafai, M. Resnick (Eds.) *Constructionism in practice: Designing thinking, and learning in a digital world* (pp.125-160), Mahwah, NJ: Lawrence Erlbaum.
- Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-Learning*, 2(1), 1-16.
- Gnadinger, C. M. (2001). *Peer scaffolding during joint productive activity in multi-age settings*. Unpublished Thesis. University of Louisville.
- GRACE (2009). Retrieved April 10, 2009 from global resource action center for the environment website: <http://www.gracelinks.org/>
- Grant, M. M. (2002). Getting a grip on project-based learning: theory, cases, and recommendations. *Meridian: A Middle School Computer Technologies Journal a service of NC State University, Raleigh, NC*, 5 (1). Retrieved May 1, 2007 from <http://www.ncsu.edu/meridian/win2002/514>
- Habgood, M. P., Ainsworth S.E., & Benford, S. (2005). Intrinsic fantasy: Motivation and affect in educational games made by children. *Proceedings of the AIED 2005* Retrieved April 2, 2009 from <http://www.informatics.sussex.ac.uk/users/gr20/aied05/finalVersion/JHabgood.pdf>
- Haigh, M. J. (2006). Promoting environmental education for sustainable development: The Value of links between higher education and non-governmental organizations (NGOs). *Journal of Geography in Higher Education*, 30(2), 327–349.
- Han, S. & Bhattacharya, K. (2001). *Constructionism, learning by design, and project-based learning*. In M. Orey (Ed.), *Emerging perspectives on learning, teaching,*

and technology. Retrieved April 29, 2007, from <http://www.coe.uga.edu/epltt/LearningbyDesign.htm>

- Harel, I. & Papert, S. (1991). Software design as learning environment. In I. Harel S. Papert. (Eds.). *Children designers: Interdisciplinary constructions for learning and knowing mathematics in a computer-rich school* (pp.41-85). Noorwood, NJ: Ablex.
- Hay, K. E. & Barab, S. A. (2001). Constructivism in practice: A comparison and contrast between apprenticeship and constructionist learning environments. *The Journal of the Learning Sciences*, 10(3), 281-322.
- Heo, H. (2004). Inquiry on storytelling for the web-based environmental learning environment. *Association for Educational Communications and Technology*. 19-23
- Hmelo, C.E., Holton, D.L., & Kolodner, J.L. (2000). Designing to learn about complex systems. *The Journal of the Learning Sciences*, 9(3), 247-298.
- Holts, Rnehart, & Winston, (2005). *Environmental science*. (Teacher's Edition). Austin. TX: Holt Science and Technology.
- Hooper, K. P. (1998). They have their own thoughts: Children's learning of computational ideas from a cultural constructionist perspective. *Unpublished doctoral dissertation*. MIT.
- Huang, S. & Hsu, W. (2005). Factors that influence students' learning attitudes toward computer courses --An Empirical Study for Technology and Vocational Institute Students in Taiwan, Conference , Retrieved April 2, 2009, from <http://web.idv.nkmu.edu.tw/~khsu/main/paper/conference/2005%20Hawai%20Conference.pdf>
- Ioannidou, A., Rader, C., Repenning, A., Lewis, C., & Cherry, G. (2003). Making constructionism work in the classroom. *International Journal of Computers for Mathematical Learning*, 8(1), 63-108.
- ISTE (1998). Technology education standards for students. National education technology standards for students 1998. Retrieved April 11, 2009, from

http://www.iste.org/Content/NavigationMenu/NETS/ForStudents/1998Standards/NETS_for_Students_1998_Standards.pdf

ISTE (2008). National educational technology standards (NETS) and performance indicators for students. *National education technology standards for students 2008*. Retrieved April 11, 2009, from http://www.iste.org/Content/NavigationMenu/NETS/ForStudents/2007Standards/NETS_for_Students_2007_Standards.pdf

Kafai, Y. B. (1996a). Gender differences in children's constructions of video games. In P.M. Greenfield & R. R. Cocking (Eds.). *Interacting with video* (pp. 39–66). Norwood, NJ: Ablex.

Kafai, Y. B. (1996b). Learning through artifacts: Communities of practice in classrooms. *Artificial Intelligence Society 10(1)*, 89-100.

Kafai, Y. B. (1996c). Software by kids for kids. *Cummmunication of the ACM, 39(4)*, 38-39.

Kafai, Y. B. (1996d). Learning design by making games: Children's development of design strategies in the creation of a complex computational artifacts. In Y.B. Kafai & M. Resnick (Eds.). *Constructionism in practice: Designing thinking, and learning in a digital world*. (pp.71-96). Mahwah, NJ: Lawrence Erlbaum.

Kafai, Y. B. (1998). Video game designs by girls and boys: variability and consistency of gender differences. In J. Cassell & H. Jenkins (Eds.), *From Barbie to Mortal Kombat: Gender and Computer Games* (pp. 90–114). Cambridge, MA: MIT Press.

Kafai, Y. B. (2005). The classroom as living laboratory: design-based research for understanding, comparing, and evaluating learning science through design. *Educational Technology, 45(1)*, 28-34.

Kafai, Y. B. (2006). Playing and making games for learning: Instructionist and constructionist perspectives for game studies. *Games and Culture, 1(1)*, 36-40.

- Kafai, Y.B, Franke, M.L, Ching, C.C, Shih, J.C, (1998). Game design as an interactive learning environment for fostering students' and teachers mathematical inquiry. *International Journal of Computers for Mathematical Learning*, 3, 149–184.
- Kafai, Y.B. & Harel, I. (1991). Learning through design and teaching: Exploring social and collaborative aspects of constructionism. In I. Harel & S. Papert (Eds.), *Children designers: Interdisciplinary constructions for learning and knowing mathematics in a computer-rich school* (pp.111-141). Noorwood, NJ: Ablex.
- Kahn, K (1999). A computer game to teach programming. *The Proceedings of the National Educational Computing Conference*. Atlantic City, NJ
- Ke, F. (2008). A case study of computer gaming for math: Engaged learning from gameplay? *Computers & Education*, 51, 1609–1620.
- Kelleher, C. & Pausch, R. (2006). Lessons learned from designing a programming system to support middle school girls creating animated stories. *IEEE Symposium on Visual Languages and Human-Centric Computing*. (pp.165-172).
- Kindborg, M. & Sökjer, P. (2007). How preschool children used a behaviour-based programming Tool. *Proceedings from Interaction Design and Children (IDC 07)*. Aalborg, Denmark.
- Knezek, G., Christensen, R., & Miyashita, K. (1998). Instruments for assessing attitudes toward information technology. Denton, TX: Texas Center for Educational Technology. http://www.tcet.unt.edu/START/assess/as_att.htm
- Kolodner, J.L., Camp, P.L., Crismond, D., Fasse, B., Gray, J., Holbrook, J., Puntambekar, S., & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design into practice. *The Journal of the Learning Sciences*, 12(4), 495-547.
- Korhonen, K., & Lappalainen, A. (2004). Examining the environmental awareness of children and adolescents in the Ranomafana region, Madagascar. *Environmental Education Research*, 10(2), 195-216.

- Koutz, K. & Kofoed, U. (2004). Studying computer science in a multidisciplinary degree programme: freshman students' orientation, knowledge, and background. *Journal of Information Technology Education*, 3, 227-244.
- Jianguo, M. (2004). Teaching environmental awareness in mathematics. *Chinese Education and Society*, 37(4), 53-56.
- Jinliang, W., Yunyan H., Ya, L., Xiang, H., Xiafei, W., & Yaunmei W. (2004). An analysis of environmental awareness and environmental education for primary school and high school students in Kunming. *Chinese Education and Society*, 37(4), 24-31.
- Land, S.M. & Hannafin, M.J. (1997). Patterns of understanding with open-ended learning environments: A qualitative study. *Educational Technology Research & Development*, 45(2), 47-73.
- Land, S.M. & Greene, B.A. (2000). Project-based learning with the World Wide Web: A qualitative study of resource Integration. *Educational Technology: Research and Development*, 48(1), 45-66.
- Lier, L.V. (2004). *The ecology and semiotics of language learning: A sociocultural perspective*. New York: Kluwer academic publishing,
- Liveearth, (2009). One world. One climate. Be the change. Last accessed on April 16, 2009 liveearth.org
- Lin, J., Yen, L., Yang, M., & Chen., L. (2005). Teaching computer programming in elementary schools: A pilot Study. Presented at NECC, Taiwan, Retrieved March 25, 2009, from http://www.stagecast.com/pdf/research/Lin_NECC2005_Paper_RP.pdf
- Malan D. J. & Leitner, H. H. (2007) *Scratch* for budding computer scientists, *SIGCSE*, 2007, Covington, Kentucky.
- Maloney, J., Peppler, K., Kafai, Y., Resnick, M., & Rusk, N. (2008). Programming by choice: Urban youth learning programming with Scratch. *SIGCSE 2008* Portland, Oregon, USA Retrieved March 20, 2009 from <http://info.scratch.mit.edu/Research>

McDougal Littell (1993). *Ecology*. Evanston, IL: McDougal Littell.

McCrea, E. J. (2006). The roots of environmental education: How the past supports the future. *Environmental Education and Training Partnership (EETAP)*. Retrieved April 16, 2009 from http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/1b/c6/41.pdf

Merriam, S. B. (1988). *Case study research in education: A qualitative approach*. California: Jossey-Bass Publishers.

Millner, D. A. (2005). *Hook-ups: How youth learn through creating physical computer interfaces*. Unpublished master thesis. MIT.

Monroy-Hernández, A. & Resnick, M. (2008). Empowering kids to create and share programmable media. *Interactions*, 15(2), 50-53.

Moodle (2009). Moodle community. Retrieved April 30, 2009 from <http://moodle.org/>.

Moore, D. (2008, April 11). National Science Foundation offers \$2.7 million to foster kids' interest in computer science. *News Center (Dallas, TX)*. Retrieved April 10, 2009 from <http://www.utdallas.edu/news/2008/04/11-001.php>

Morgil, I., Arda, S., Secken, N., Yavuz, S., & Oskay, O. O. (2004). The influence of computer assisted instruction on environmental knowledge and environmental awareness. *Chemistry Education: Research and Practice*, 5(2), 99-110.

Moskal, B., Lurie, D., & Cooper, S. (2004). Evaluating the effectiveness of a new instructional approach. *Proceedings of the 35th SIGCSE technical symposium on Computer science education*. (pp. 75-79), Norfolk, Virginia,

Musser, L. M. & Malkus, A. J. (1994). The children's attitudes toward the environment scale. *Journal of Environmental Education*, 25(3), 22-26.

Negev, M., Sagy, G., Garb., Salzberg, A., & Tal. A. (2008). Evaluating the environmental literacy of Israeli elementary and high school students. *The Journal of Environmental Education*, 39(2), 3-20.

- Nesset, V. & Large, A. (2004). Children in the information technology design process: a review of theories and their applications. *Library and Information Science Research*, 26(2), 140-61.
- Nicaise, M. & Crane, M. (1999). Knowledge constructing through hypermedia authoring. *Educational Technology Research and Development*, 47(1), 29-50.
- Nicolaou, C., Korfiatis, K., Evagorou, M., & Constantinou, C. (2009). The development of decision-making skills and environmental concerns through computer-based, scaffolded learning activities. *Environmental Education Research*, 15(1), 39-54.
- NPD.com (2008). Press release. Retrieved April 11, 2009 from http://www.npd.com/press/releases/press_080811.html
- NPD.com (2009). Press release. Retrieved April 11, 2009 from http://www.npd.com/press/releases/press_090202.html
- Overmars, M. H. (2004). Learning object-oriented design by creating games. *IEEE Potentials*, 23(5), 11-13.
- Pacheco, P., Motloch, J., & Vann, J. (2006). Second chance game: local (university-community) partnerships for global awareness and responsibility. *Journal of Cleaner Production*, 14, 848-854.
- Palmer, J. A. & Suggate, J. (2004). The development of children's understanding of distant places and environmental issues: report of a UK longitudinal study of the development of ideas between the ages of 4 and 10 years. *Research Papers in Education*, 19(2), 205-237.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books.
- Papert S. (1991). Situating constructionism. In I. Harel & S. Papert. (Eds.), *Children designers: Interdisciplinary constructions for learning and knowing mathematics in a computer-rich school* (pp. 1-13). Noorwood, NJ: Ablex.

- Papert, S. (1993). *The children's machine: Rethinking schools in the age of the computer*. New York: Basic Books.
- Patton, M. Q. (2002). *Qualitative research and evaluation methods*. Thousand Oaks, CA: Sage Publications.
- Peck, K. (2005). A conversation with Kyle Peck on the future of education (technology). *The NETC Circuit*. Retrieved April 11, 2009 from <http://www.netc.org/circuit/>
- Pennsylvania Department of Education. (2002). Pennsylvania Academic Standards for Environment and Ecology Retrieved March 15, 2009 from <http://www.pde.state.pa.us/k12/lib/k12/envec.pdf>
- Peppler, K. A. & Kafai, Y. B. (2005). Creative coding: The role of art and programming in the K-12 educational context. Retrieved March 15, 2009 from <http://scratch.mit.edu/files/CreativeCoding.pdf>
- Peppler K. A. & Kafai, Y. B. (2007). What video game making can teach us about learning and literacy: Alternative pathways into participatory cultures. *The Digital International Game Research Association meeting*, Tokyo, Japan.
- Perciles, K. (2007). Game2Learn. Retrieved April 4, 2009 from <http://game2learn.wikispaces.com/Student+games>
- Pinkard, N. (2007). Girl power, encouraging sixth grade girls to give video games a try. Retrieved April 2, 2009 from http://spotlight.macfound.org/main/entry/pinkard_girl_power_encouraging_girls_games/
- Pinkett, R. D. (2000). Bridging the digital divide: sociocultural constructionism and an asset-based approach to community technology and community building. *The 81st Annual Meeting of the American Educational Research Association (AERA)*. (pp. 24-28), New Orleans, LA
- Plass, J. L., Goldman R., Flanagan, M., Diamond, P., Dong, C., Looui, S., Rosalia, C., Song, H., & Perlin, K. (2007). RAPUNSEL: How a computer game design based on educational theory can improve girls' self-efficacy and self-esteem *The 87th Annual Meeting of the American Educational Research Association*, Retrieved

March 10, 2009 from

http://create.alt.ed.nyu.edu/courses/2176/reading/AERA_07_Rapunsel_Plass_et al.pdf

- Prensky, M. (2008). Students as designers and creators of educational computer games: Who else? *British Journal of Educational Technology*, 39(6), 1004-1019.
- Rankin, Y., Gooch, A., & Gooch, B. (2007). The impact of game design on students' attitudes about CS. In *Conference Proceedings of Microsoft Academic Game Days SIGCSE Conference*.
- Reiber, L. P., Luke, N., & Smith, J. (1998). Project KID designer: Constructivism at work through play. *Meridian: A Middle School Computer Technologies Journal*, 1(1), Retrieved February 10, 2009 from http://www.ncsu.edu/meridian/jan98/feat_1/kiddesigner.html
- Repenning, A., & Ioannidou, A. (2005). Game design for education. Tutorial conducted at the 4th *International Conference for Interaction Design and Children*, Boulder, Colorado. Retrieved May 15, 2009 from <http://www.cs.colorado.edu/conferences/idc2005/tutorials/Repenning-tutorial.pdf>
- Repenning, A., & Ioannidou, A. (2008). Broadening participation through scalable game design. *SIGCSE Bulletin*, (40)1, 305-309.
- Resnick, M. (1993). Behavior construction kits. *Communications of the ACM*, 36(7), 64-71.
- Resnick, M. (2007). Showing the seeds for more creative society. *Learning and Leading with Technology*. (Dec-Jan 07/08) Retrieved from <http://web.media.mit.edu/~mres/papers/Learning-Leading-final.pdf>
- Resnick, M. & Ocko, S. (1991). LEGO/Logo: Learning through and about design. In *Constructionism*, I. Harel & S. Papert. (Eds) Norwood, NJ: Ablex Publishing. Retrieved from <http://llk.media.mit.edu/papers/ll.html>
- Resnick, M. & Rusk, N. (1996). The computer clubhouse: Preparing for life in a digital world. *IBM Systems Journal*, 35(3), 431-440.

- Rist, R. C. (1982). On the application of ethnographic inquiry to education: Procedures and possibilities. *Journal of Research in Science Teaching*, 19, 439-450.
- Robertson, J. & Howells, C. (2008). Computer game design: Opportunities for successful learning. *Computers & Education*, 50, 559-578.
- Said, A., M., Yahaya, N., & Ahmadun, F. (2007). Environmental comprehension and participation of Malaysian secondary school students. *Environmental Education Research*, 13(1), 17-31.
- Sands, M., Moukhine, N., & Blank, G. (2008). Widening the pipeline of k-12 students with Flash, *Consortium for Computer Science Education*, April, Wagner College, New York Retrieved, April 2, 2009 from <http://www.lehigh.edu/launchit/papers/CCSCNE08-Flash.pdf>
- Savage, T., Sánchez, I., A., O'Donnell, F., & Tangney, B. (2003). Using robotic technology as a constructionist mindtool in knowledge construction. *Proceedings of the The 3rd IEEE International Conference on Advanced Learning Technologies* (pp. 324-325). Greece.
- Schanck, R. & Cleave, J. (1995). Natural learning, natural teaching: Changing human memory. In H. Morowitz & J. Singer (Eds.), *The mind, the brain, and complex, adaptive systems* (pp. 175-202). Reading, MA: Addison-Wesley.
- Seif El-Nasr, M. & Smith, B. K. (2006). Learning through game modding. *ACM Computers in Entertainment*, 4(1), 1-20.
- Shaw, A. (1996). Social constructionism and the inner city: Designing environments for social development and urban renewal. In Y.B. Kafai, & M. Resnick (Eds.), *Constructionism in practice: Designing thinking, and learning in a digital world* (pp. 175-207). Mahwah, NJ: Lawrence Erlbaum.
- Sherburn, M. & Devlin, A. S. (2004). Academic major, environmental concern and arboretum use. *The Journal of Environmental Education*, 35(2), 23-48.
- Shobeiri, S. M., Omidvar, B., & Prahallada, N. N. (2007). A comparative study of environmental awareness among secondary school students in Iran and India. *International Journal of Environmental Reervation*, 1(1), 28-34.

- Spitunilk, M. W., Zembal-Saul, C., & Krajcik, J.S., (1998). Using hypermedia to represent emerging students understanding: Science learners and preserves teachers. In J. J. Mintzes, J. H. Wandersee, J. D. Novak. (Eds.), *Teaching Science for Understanding* (pp. 229-259). San Diego: Academic Press.
- Squire, K., Giovanetto, L., Devane, B., Durga, S. (2005). From users to designers: Building a self-organizing game-based learning environment. *TechTrends*, 49(5), 34-74.
- Stage, F.K. & Manning, K. (2003). *Research in the college context*. New York: Brunner-Routledge.
- Stern, T. I. (2007). NetSctarch: A networked programming environment for children. Unpublished master thesis. MIT.
- Sylvan, E. (2005). Integrating aesthetic, engineering, and scientific understanding in a hands-on design activity. *Interaction Design for Children Conference*, Boulder, Colorado Retrieved from http://llk.media.mit.edu/papers/sylvan_IDC2005.pdf
- Tangdhanakanond, K., Pitiyanuwat, S., & Archwamety, T. (2006). A development of portfolio for learning assessment of students taught by full-scale constructionism approach at Darunsikkhalai School. *Education*, 13(2), 24-36.
- TEMA (2009). Türkiye Erozyonla Mücadele Ağaçlandırma ve Doğal Varlıkları Koruma Vakfı. Retrieved April 10, 2009, from <http://tema.org.tr/>
- Tholander, J., Kahn, K., & Jansson, C. G. (2002). Real programming of an adventure game by an 8 year old. *ICLS*. Lawrence Erlbaum Associates, Retrieved April 2, 2009 from <http://dsv.su.se/research/kids/pdf/RealProgInICLSTemplate.pdf>
- Tiong, K., & Yong, S. (2008). Learning through computer game design: Possible success (or failure) factors. *The 16th International Conference on Computers in Education*, pg. 947-951. Retrieved from <http://www.apsce.net/ICCE2008/papers/ICCE2008-paper293.pdf>
- Tuohino, A. (2003). Environmental awareness and environmentally friendly behaviour—case Sulkava Rowing Event. *Environment Papers Series*, 6(2), 1-11.

- Turkle, S. (1984). *The second self: Computers and the human spirit*. New York: Simon and Schuster.
- Turkle, S. & Papert, S. (1991). Epistemological pluralism and the revaluation of the concrete. In I. Harel & S. Papert (Eds.), *Constructionism* (pp.161-193). New Jersey: Ablex.
- Turner S. V. & Dipinto V. M. (1996) Peer collaboration in a hypermedia learning environment. *Journal of Research on technology in education*, 29(4), 392-402.
- UNESCO (1976). *The Belgrade Charter*. New York: United Nations.
- UNEP (2009). World Environment Day 2009. United Nations Environment Program. <http://www.unep.org/wed/2009/english/>
- Uzunboylu, H., Cavus N., & Ercag E. (2009). Using mobile learning to increase environmental awareness. *Computers & Education*, 52, 381–389.
- Verenikina, I. (1998). Understanding scaffolding and the ZPD in educational research. Retrieved March 9, 2009 from <http://www.aare.edu.au/03pap/ver03682.pdf>
- Witherspoon, T. L., Reynolds, K. V., Alagic, A. & Copas, G. M. (2004). A model for an online, global, constructionist learning environment: Robotics around the world. *Proceedings of SITE 2004 15th International Conference of the Society for Information Technology & Teacher Education. Association for Advancement of Computers in Education*. Atlanta, GA. March 1-6. 3083-3088. Retrieved from <http://edtech4teachers.com/portfolio/artifacts/GLSITE2004.pdf>
- Wollman-Bonilla, J.E. & Werchadlo, B. (1999). Teacher and peer roles in scaffolding first graders' responses to literature. *The Reading Teacher*, 52, 598-607.
- Wood, R., Griffiths, M.D, Chappell, D., Davies, M. (2004). The structural characteristics of video games: A psycho-structural analysis. *CyberPsychology & Behavior*, 4(1), 1-10.
- WorldWatch Institute (2009). Accessed <http://www.worldwatch.org>

- Wu, L. (2001). *Integrated learning of mathematics, science and technology concepts through Lego/Logo projects*. Unpublished doctoral dissertation. Michigan State University.
- Yakeley, M. (2000). *Digitally mediated design: Using computer programming to develop a personal design process*. Unpublished doctoral dissertation. MIT.
- Yelland N. J. (1997). Encouraging young children's thinking skills with Logo. *Childhood Education, 71*(3), 152-155.
- Yin, R. K. (2003). *Case study research, design and methods* (3rd ed). Newbury Park: Sage Publications.
- Zimmer, M. R., Stanfford, J. F., & Stanfford, R., M. (1994) Green issues: Dimensions of environmental concern. *Journal of Business Research, 30*, 63-74.

APPENDIXES

APPENDIX A

Interview Protocol

Interview Protocol

Students were interviewed before and after the game design project. Even though there were some initial questions, the interview was open-ended students responses to prompt new questions especially during post-interview. Each student was interviewed individually in order to not be influenced by the peers. Interviews were recorded with two digital recorders as a pre-caution. And recordings were saved on computer disks.

Pre and Post-Interview Initial questions

1. Do you play computer or video games? and how often
2. What type of game do you play? Why
3. What comes to your mind when I ask you about game design?
4. What comes to your mind when I talk about computer programming?
5. Have you designed any game? What software did you used?
6. What is difference between an animation and a game?

(The rest of the questions were asked only at the post-interview)

7. Did you enjoy the game design project?
8. What most did you like about making games?
9. Do you think it was hard to design, what was the hardest part of the game design?
10. Would like to do again next year for other classes? (if yes, for all classes or just one and why)

Questions about Environment

1. Why do you think environment is important?
2. Are you aware of any environmental problem locally or globally?

(The rest of the questions were asked only at the post-interview)

3. What environmental problems you selected and why

4. What solution did you come up with?
5. Do you think 2nd graders learn about that problem and solution?

Questions about Collaboration

(The rest of the questions were asked only at the post-interview)

1. In other classes, how often do you ask your teacher when you need help?
2. In other classes, how often do you ask your friends when you need help?
3. Did you get help from any of your classmates? (if yes)
 - a. What kind of help? About game design?
 - b. About Scratch?
 - c. About environmental content?
4. Who did you ask for help
5. Why (was he/she more knowledgeable?)
6. Did you ask help online?
7. Did the help you received solve your problem?
8. Was this game your idea? Or did you influenced by other games?

Questions on Scratch

1. Show me which tool you use to edit sprites
2. Which command do you use to make a sprite move
3. Which function would you use to make some actions repeat forever under some circumstances
4. Which command would you use to add a scoring panel on a *Scratch* design

APPENDIX B

Students' Attitudes toward Game Design and Computing

Part-1: Computer Attitude Questionnaire (CAQ)

Administration Procedures for CAQ: Students will take this questionnaire before and after game design. The questionnaire will take approximately 10-20 minutes. The students will take this questionnaire on MyLingua which is password protected.

Part-1: Computer Attitude Questionnaire (CAQ)	SD	D	A	SA
1. I enjoy doing things on a computer.	1	2	3	4
2. I am tired of using a computer.	4	3	2	1
3. I will be able to get a good job if I learn how to use a computer.	1	2	3	4
4. I concentrate on a computer when I use one.	1	2	3	4
5. I enjoy computer games very much.	1	2	3	4
6. I would work harder if I could use computers more often.	1	2	3	4
7. I know that computers give me opportunities to learn many new things.	1	2	3	4
8. I can learn many things when I use a computer.	1	2	3	4
9. I enjoy lessons on the computer.	1	2	3	4
10. I believe that the more often teachers use computers, the more I will enjoy school.	1	2	3	4
11. I believe that it is very important for me to learn how to use a computer.	1	2	3	4

Scoring for CAQ: In this part of the survey, 1 item had negative wording; Item 2. Thus, for the calculation scoring of part 1, the score of this item was reversed. Students' total score for this part was calculated as follows;

$$CAQ = (\text{var1} + \text{var2} + \text{var3} + \text{var4} + \text{var5} + \text{var7} + \text{var6} + \text{var8} + \text{var9} + \text{var10} + \text{var11}) / 11$$

**Part 2:
Game Design Attitude Questionnaire (GDAQ)**

Administration Procedures for GDAQ: Students took this questionnaire before and after game design. The questionnaire took approximately 10-20 minutes.

Part -2: Game Design Attitude Questionnaire (GDAQ)	SD	D	A	SA
1. I avoid playing games.	4	3	2	1
2. I would avoid learning a topic if it involves designing on computers.	4	3	2	1
3. I could probably teach myself most of the things I need to know about designing games with Scratch.	1	2	3	4
4. I need an experienced person nearby when I'm designing games on computers.	4	3	2	1
5. I can make the computer do what I want it to do while designing games.	1	2	3	4
6. Designing games does not scare me at all.	1	2	3	4
7. If I have problems using Scratch to design game, I can usually solve then one way or the other.	1	2	3	4
8. I will design games regularly throughout school.	1	2	3	4

The questions were modified from Bonanno and Kommers, (2008)

Scoring for GDAQ: In this part of the survey, 3 items have negative wording; Item 1,2, and 4. Thus, for the calculation scoring of part 2, these items were reversed. Students' total score for this part was calculated a follows;

$$\text{GDAQ} = (\text{var1} + \text{var2} + \text{var3} + \text{var4} + \text{var5} + \text{var6} + \text{var7} + \text{var8})$$

APPENDIX C

Environmental Knowledge Test

Environmental Knowledge Test (EK)

The environmental knowledge questions were designed to measure students learning after game design intervention. These questions were generated from the class science textbooks (McDougal Littell Science and Holt, Rinehart, and Winston). In addition, the science teacher evaluated appropriateness of the questions for 5th grade level.

Administration Procedures for EK: Students took this questionnaire before and after game design. The questionnaire took approximately 10-20 minutes. The same questions were used in the post-test. (Answers are in bold)

Scoring for EK: The students' score for multiple-choice questions were calculated as follows;

$$EK = [(total\ number\ of\ correct\ responses) \times 100] / 14$$

1-which of the following can be cause pollution?

- A-noise
- B-garbage
- C-chemicals
- D-all of the above**

2-Pollution

- A-does not affect humans
- B-can make humans sick**
- C-makes humans sick only after many years
- D-none of the above

3-which of the following is NOT the strategy to protect the environment?

- A-preserving entire habitats
- B-using pesticides that target all insects**
- C-reducing deforestation

D-increasing the use of solar power

4-Conservation

A-has little effect on the environment

B-is the use of more natural resources

C-involves using more fossils fuels

D-can prevent pollution

5. Ozone forms a protective layer in the earth's upper atmosphere. What does ozone protect us from?

A-acid rain

B-global warming

C-sudden changes in temperature

D-harmful, cancer-causing sunlight

6- Complete the following sentence by the correct term.

A(n)... is a resource that is replaced at a much slower rate than it is used.

A- nonrenewable resources

B-renewable resources

C-energy

D-food

7- Complete the following sentence by choosing the correct term.

The presence of too many individuals in a population for available resources is called ...

A-reuse

B-pollution

C-overpopulation

D-overuse

8- Complete the following sentence by choosing the correct term.

...is an unwanted change in the environment caused by wastes

A-recycle

B-pollution

C-conservation

D-reuse

9- Complete the following sentence by choosing the correct term.

The preservation and wise use of natural resources is called...

A-conservation

B-pollution

C-cleaning

D-global change

10- Complete the following sentence by choosing the correct term.

...is the number and variety of organisms in an area

- A-recycle
- B-pollution
- C- biodiversity**
- D- overpopulation

11-which of the following about hazardous waste is false?

- A-can catch fire
- B-can explode
- C-can make people sick
- D-can clean water**

12. Which of the following household wastes is considered hazardous waste?

- A-plastic packaging
- B-glass
- C-batteries**
- D-spoiled food

13. Which of the following is a renewable resource?

- A-oil
- B-iron
- C-trees**
- D-coal

14-Which of the following is NOT part of three Rs

- A-reduce
- B-read**
- C-reuse
- D-recycle

APPENDIX D

Environmental Awareness Questionnaire

Environmental Awareness Questionnaire

The environmental awareness survey is based on the survey questions for 4-8 grade level (Musser & Malkus, 1994). In addition, the science teacher and research team evaluated appropriateness of the survey questions for our participants.

Administration Procedures for EAQ: Students took this questionnaire before and after game design. The questionnaire took approximately 10-20 minutes.

Question #	Option A	Somewhat Option A	Somewhat Option D	Option D
1	Some kids like to leave water running when they brush their teeth.			Other kids always turn the water off while brushing their teeth.
	A	B	C	D
2	Some kids use both sides of the paper when they draw or write.			Other kids use only one side of the paper when they draw or write.
	A	B	C	D
3	Some kids think we should throw away things when we're done with them.			Other kids think we should recycle things.
	A	B	C	D
4	Some kids don't like to make bird feeders or bird houses.			Other kids like to make bird feeders or bird houses.
	A	B	C	D
5	Some kids are concerned about the rain forest.			Other kids aren't concerned about the rain forest.
	A	B	C	D
6	Some kids think we should build more landfills to hold our garbage.			Other kids think we should find other ways to deal with our garbage.
	A	B	C	D
7	Some kids like visiting national parks.			Other kids don't like to go to national parks.
	A	B	C	D
8	Some kids don't worry about animals			Other kids worry about animals




	becoming extinct.				becoming extinct.
		A	B	C	D
9	Some kids throw things away when they are done with them.				Other kids reuse things or give them to other people to use.
		A	B	C	D
10	Some kids think we should use chemicals and fertilizers in our gardens.				Other kids think we shouldn't use chemicals and fertilizers in
		A	B	C	D
11	Some kids pick up trash and throw it in garbage.				Other kids don't like to pick up smelly trash.
		A	B	C	D
12	Some kids don't sort trash.				Other kids sort their trash and recycle it.
		A	B	C	D
13	Some kids are excited about solar energy.				Other kids don't care about solar energy.
		A	B	C	D
14	Some kids believe people should be able to live wherever they want.				Other kids believe that people should be careful not to destroy animals' homes.
		A	B	C	D
15	Some kids worry about air pollution.				Other kids don't worry about air pollution.
		A	B	C	D
16	Some kids turn off the lights when they leave.				Other kids leave the lights on.
		A	B	C	D
17	Some kids get their parents to drive them places they want to go.				Other kids ride their bikes or walk when they can.
		A	B	C	D




APPENDIX E

Questionnaire for the 2nd Grade Testing

Questionnaire for the 2nd Grade Testings

Administration Procedures for Game Play Questionnaire: The second graders took this survey after playing each students game. This survey was done twice; on May 27th and on June 2nd.

2 nd Grader's Name:			
1-Did the game look nice?			
2-Was the game easy to use?			
3-Were the directions clear for you to play the game by yourself?			
4-Were you confused about what to do in the game?			
5-Did the game do a good job of teaching you about the environment?			
6-What would make the game better? (comments)			

Scoring  : 3  : 2  : 1

The second Graders Responses for fifth Graders Games

	Scores from the first testing session					Scores from the second testing session				
	Q1A	Q2A	Q3A	Q4A	Q5A	Q1A	Q2A	Q3A	Q4A	Q5A
Kyle	3	2.75	3	3	2.5	3	3	3	3	2.75
Larry	2	3	3	2	2.5	3	3	3	2.33	3
Amber	2.25	3	3	2.5	2.75	2.75	2.25	2.75	2.5	2.5
Isabella	3	3	3	3	2.75	3	3	3	2.33	3
Lacy	3	3	3	3	3	3	3	3	3	3
Nick	3	1	2	3	3	3	2.5	3	2.5	3
Tanya	3	2.5	2.5	2.75	3	3	3	3	2	2.75
Adria	2.5	3	3	1.5	2.5	2.5	3	3	2.25	1.5
Megan	3	2.5	2	3	2	3	3	3	2.5	3
Eli	3	2.75	2	3	2.75	2.25	3	2.5	3	1.5

APPENDIX F

Peer Evaluation Questions and Responses

Peer Evaluation

Administration of the Peer Evaluation: This evaluation process was done after four design sessions. The students were asked to respond the questions after playing each game. This testing process took 30 minutes. The responses were shared with the game designers individually.

		Kyle*	Larry	Amber	Isabella	Lacy	Nick	Tanya	Adria	Megan	Eli
1-Does the game show the cause of the environmental problem?	Yes	1		0	3	1	2	2	1		
	Somewhat Yes	2		1	0	0	2	1	3		
	No	0		1	3	2	2	1	0		
2-Does the game show the effect of the environmental problem?	Yes	0	Did not participate this testing session	0	3	1	2	3	1		
	Somewhat Yes	1		0	1	1	2	1	1		
	No	2		2	2	1	1	0	2		
3-Is the environmental problem solution in the game scientific?	Yes	2	Did not participate this testing session	1	2	0	1	2	1		
	Somewhat Yes	0		0	2	0	4	0	0		
	No	1		1	2	3	1	1	3		
4-Does the game have clear directions?	Yes	0	Did not participate this testing session	0	6	0	3	2	2		
	Somewhat Yes	1		0	0	0	1	2	1		
	No	2		2	0	3	1	0	1		
5-Did you enjoy playing this game?	Yes	1	Did not participate his testing session	1	4	0	1	2	2		
	Somewhat Yes	0		1	2	1	3	2	2		
	No	2		0	0	2	2	0	0		

*The numbers in the columns show the total number of the game tester who chose that option for the game designer.

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Curriculum Vita

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Education

2006-(intended to graduate in December 2009): Penn State University, PA

- PhD, Instructional Systems,

2004-2006: Penn State University, PA

- M.Ed, Instructional Systems,

2003-2004: New York University, NY

- Intensive English Program, American Language Institution,

1997-2002: Ege University, Izmir, Turkey

- B.S. Mathematics,
- Minor, Computer Science

Awards Received

2003-2009: Full Scholarship

Ministry of Education of Turkey to pursue my graduate study in USA

1997-2002: Full Scholarship

Turk Egitim Vakfi (Turkish Education Foundation)

Presentations

Baytak, A. (2009). Web 2.0: Open opportunities for Turkish Universities, Academic Informatics Conference, Sanliurfa, Turkey

Baytak, A. Land, S.M.Smith, B. Park, S. (2008), Children as Educational Computer Game Designers: An Exploratory Study, American Educational Technology Conference, Florida, USA

Baytak, (2006), Barriers into technology integration, Pennsylvania Education Technology Expo and Conference, Hershey, PA, USA

Baytak, (2006), Media Selection and Design, Pennsylvania Education Technology Expo and Conference, Hershey, PA USA

Other Professional Works

- Reviewer for AECT International Division
- Reviewer for AECT Management Division
- Advisory for student show case at PETE&C Learn Science with Game Design 2009
- Advisory for student show case at PETE&C Learn languages with PPT, 2008