PARALLEL HEARTS MATHEMATICS GAME: USING EDUCATIONAL GAMES TO

ADDRESS THE STEM FIELD GENDER GAP

By

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Abstract

Despite equal educational opportunities, a gender gap develops in the science, technology, engineering, and mathematics field amongst American adults. This is caused by various societal factors including pressure for females to pursue more "feminine" careers, biased grading systems, and a vicious cycle of mathematics teaching. Even though females score as well as males on standardized tests, during their middle school years there is a steep drop off in females interested in pursuing STEM careers. This project attempts to close this gap by creating interest in mathematics during these students' most formidable years through the use of computer games. Parallel Hearts, a 2D puzzle game designed to teach mathematics to 7th grade students, is examined and successfully tested in a classroom setting to show that female players of this age can be targeted and interest can be created in the STEM field.

Table of Contents

List of Figures:

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Chapter 1: An Introduction to *Parallel Hearts*:

During the 2012 United States State of the Union Address, President Obama emphasized the importance of increasing education in the science, technology, engineering, and mathematics fields. He proposed the creating of new teacher education programs, virtual STEM learning networks, and even a financial incentive program for students to pursue careers as teachers of STEM subjects. President Obama acknowledged the problem that American students lack in their STEM abilities. He stated that "many business leaders who want to hire in the United States but can't find workers with the right skills. Growing industries in science and technology have twice as many openings as we have workers who can do the job" (Obama). While the president's concerns about the job market are valid, there is a much deeper rooted problem with the American STEM status. According to the National Math and Science Initiative, the United States students recently finished 27th in mathematics and 17th compared with the rest of the world. Not only that but 2008 only 4% of bachelor degrees were awarded for engineering in the United States, compared to 31% in China. The fact is that the United States is drastically falling behind in STEM based education. While the problem may be multitier, one of, if not perhaps, the largest contributing factor, is the lack of women in the professional STEM field.

There exists today a significant gender gap amongst Americans in the STEM field.

Figure 1. Gender Shares of Total and STEM Jobs, 2009
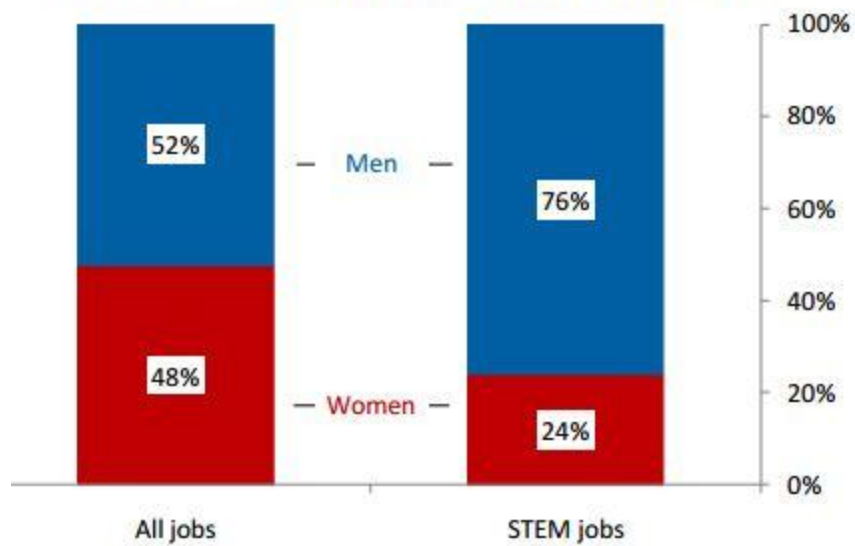
Figure 1.1 A clear gender gap in the STEM fields

According to the United States Department of Commerce (as seen in Figure 1.1) females only

represent 24% of the STEM field population while representing 48% of the rest of the work force

(Beede, et al. 3). While this is an obvious problem, the bigger issue comes from the trend that is

developing.

Table 1. Total and STEM Employment by Gender and Educational Attainment, 2000 and 2009
(thousands of workers)

	Male		Female		Percent Female	
	2000	2009	2000	2009	2000	2009
All workers	69,098	73,580	60,619	67,058	47%	48%
College-educated	18,995	22,167	16,415	21,433	46%	49%
STEM workers	5,321	5,640	1,680	1,790	24%	24%
College-educated	3,259	3,738	1,002	1,199	24%	24%

Figure 1.2 No change in the gender gap between 2000-2009

According to the same study (seen in Figure 1.2), there has been no increase in the women in the

STEM field from 2000-2009 (Beede, et al. 4). This means that whatever the problem that is

causing this gender gap to occur is not being addressed.

2

In this essay, I attempt to identify the root causes of this trend and create a potential solution. Because of the positive effects of computer games on motivation and time on task, as well as female's enjoyment of these games it is possible to create a game that motivates female players and gets them interested in pursuing STEM based fields. This is why I created *Parallel Hearts,* a 2D puzzle game that teaches students about mathematics (playable at: http://bombsheltergames.com/GameBuild/WebPlayer/WebPlayer.html).

In a 2010 study entitled "STEM Perceptions: Student & Parent Study*"* performed by Harris Interactive and sponsored by Microsoft, the true potential for games as an inspirational source. In other words, the data suggests a correlation between playing video games as a motivational factor for entering STEM based fields. According to the study, 63% of male college students attributed their interest in the STEM field to video games. Females, however, were less affected by games, with only 31% citing them as a contributing factor (13). This discrepancy may be attributed to the myth that girls do not play video games or even due to the lack of games that specifically target the female audience. This thesis argues that it is indeed possible to create a computer game that encourages girls to enter the STEM field. By targeting the demographic most likely to give up on STEM education, middle school girls, and creating a game specifically tailored to their preferences, it is possible to spark interest in the STEM field and create lasting change in their future decisions towards STEM careers.

In order to argue this point, I take the following structure: (2) A Literature Review of Women in STEM and the Effects of Games on Learning: I begin with identifying the causes the of the STEM field gender gap, arguing that it is caused by both cultural pressures as well as biased teaching methods. From there, I identify the positive effects of games on learning as well as examine some existing games that successfully teach students. (3) Designing *Parallel Hearts*

for the Middle School Demographic: I then identify how best to design games for this particular population. In this same section, I discuss how *Parallel Hearts* was designed to meet these needs. From there I go further into depth about the design of the game, including the core experiences as well as the artistic design and game mechanics. (4) Testing Among the Target Demographic and Iterative Feedback: While this game is still early in its development cycle, I discuss an early play test that was conducted with a 7th grade classroom and the findings associated with it. (5) Looking Forward: Finally, I conclude with the iterative steps I will take in order to maximize the potential of this game as well as create a more structured assessment of its educational merit.

Chapter 2: A Literature Review of Women in STEM and the Effects of Games on Learning

In order to best design games that make meaningful and lasting change towards closing the STEM field gender gap, it is essential to understand both the root causes of the gap and why creating a game is the best solution. In this section of the thesis I examine past research about women in the STEM field as well as the proven benefits and detriments of games on education and motivation. This section serves as the ground work for the design of *Parallel Hearts,* heavily influencing the design process in order to create a game that best motivates middle school girls to pursue STEM careers.

Cultural Predispositions Towards Women in STEM

Despite equal educational opportunities for both male and female American students in the K-12 system, a trend emerges between genders during the middle school years. Instead of both genders gaining interest in the same fields, gender patterns emerge. According to Sophia Castambis' study "The Path to Math: Gender and Racial-Ethnic Differences in Mathematics Participation from Middle School to High School," the effects of gender on affect and achievement in different subjects amongst eight graders: "beginning in middle school, girls show less interest in mathematics and science and have more negative attitudes toward these fields" (199). The change in interest has long-term repercussions. As fewer females become interested STEM, fewer females choose to pursue STEM related careers.

Sophia Catsambis examines these female attrition patterns in her article. After surveying 24,500 students from 1,052 schools, she determined that this gender gap is not a result of poor

achievement in females. In fact, "female students do not lag behind male students in test scores and grades and that white female students are exposed to more learning opportunities in mathematics than are male students. However, all female students tend to have less interest in mathematics and less confidence in their mathematics abilities" (199). Despite predispositions of gender, such as girls are good at reading and bad at math (and vice versa for boys), Catsambis proves that girls are equally as capable as boys in the STEM fields. According to the study, males and females scored almost identically on mathematics achievement tests (51.54 mean vs. 51.35 mean [204]). Females are even "more likely to enroll in high-ability mathematics classes than are male students, even when the educational, social back- ground, or social-psychological characteristics of students are held constant" (204). This suggests that there has to be much more to the gender gap then simply poor achievement—the commonly held belief that women choose not to study math or other STEM topics because they are bad at it is not supported by the research.

Reasons for these gender differences are multitier, stemming from differences in teaching styles, neighborhood upbringing, and societal expectations. Closing this gap will take early intervention, and middle school seems the ideal place to target this intervention. As students enter seventh grade, they are taken away from the integrated curriculum of K-6 and enter discipline specific class. Each student will typically take one hour of math class a day in addition to their other classes. That is why the game designed for this study targets middle school females. The hope being that if educators can inspire their students early on, they will be able to anticipate and resist this gap and create equal opportunities for females in STEM fields. However, in order to close this gap it is imperative to better understand these root causes.

Teacher Anxiety

Despite males and females sharing a learning space (in most settings), a gender gap in STEM fields still develops. According to Catambis, gender "differences in the domains of opportunity, achievement, and choice emerge during the middle grades" (199), but interestingly enough "gender differences in performance and course work are minimal, but strong differences exist in attitudes and perceptions of the usefulness of mathematics" (200). Poor performance in mathematics would easily attribute to a loss of interest among the female population; however, since achievement remains constant this cannot be the case. The loss of interest can be partially attributed to the culture of the primary school setting. Sian L. Beilock et al attempt to explain this phenomenon through their study of female teacher anxiety concerning mathematics. By surveying seventeen female teachers from five different public schools as well as measuring their mathematics knowledge, they found that a teacher's anxiety and mathematic proficiency can reflect in the students.   According to their article "Female teachers' math anxiety affects girls' math achievement":

> There was no relation between a teacher's math anxiety and her students' math
> achievement at the beginning of the school year. By the school year's end,
> however, the more anxious teachers were about math, the more likely girls (but
> not boys) were to endorse the commonly held stereotype that "boys are good at
> math, and girls are good at reading" and the lower these girls' math achievement.
> Indeed, by the end of the school year, girls who endorsed this stereotype had
> significantly worse math achievement than girls who did not and than boys
> overall. (1)

Since the teacher feels inadequate or anxious about math, so too will the female students. This is due to the emulative nature of young students. Beilock explains that "children are more likely to emulate the behavior and attitudes of same-gender vs. opposite-gender adults. Girls may be more likely than boys to notice their teacher's negativities and fears about math. This, in turn, may have a negative impact on girls' math achievement. (1)" Since young students look to their teachers behaviors to emulate, they are, in turn, emulate on their confidence. By extracting the learning from a teacher's anxiety and placing it into a virtual environment it is possible to eliminate this short-coming. Games can allow for the rebuilding of a student's confidence through a structured reward system and adequate motivational elements.

While it may come as a surprise that elementary school teachers have anxiety when teaching math, the evidence suggests that there is good cause for this negative affective reaction. According to Beilock, most colleges in the United States require little to no mathematics training for their elementary teaching programs. This means that teachers who may have high anxiety towards math performance can easily become elementary school teachers. This anxiety can heighten due to the performance-based nature of teaching. With all eyes on the teacher it, anxiety can reach a new high. Since over 90% of elementary school teacher are female, this anxiety can set in early, reinforcing the stereotype of women in STEM (Beilock 1). When the students finally graduate to middle school, female students face an even more obstacles.

As students move from elementary to middle school, the predominance of female teachers fades away. More male teachers enter the educational space, as subjects begin to be taught independently, rather than as a collective. According to Catambis, this new male presence, combined with the more competitive and unstructured nature of the middle school classroom undermines female students' self-confidence as well as their confidence in their academic

abilities (204). On top of that, female students are the victim of even more biases at the middle

school level. According to a study of 240 girls about their feelings towards math, Qing Li, in her

essay "Teachers' Beliefs and Gender Differences in Mathematics: A Review," found that "the

highest proportion of female students demonstrating positive attitudes towards mathematics was

found in all-girls' secondary schools where mathematics was taught by female teachers, while the

lowest proportion was in coeducational secondary schools where mathematics was taught by

male teachers" (67). Li continues, explaining that the causes of this gap could be based in the

biases of the male teacher. Among teachers she interviewed, Li discovered that male teachers

were hesitant to call on female students because they were afraid they would get emotionally

upset if they were unable to solve the problem correctly. Li also found that the students

themselves reported that they felt like the teachers did not believe that mathematical problem

solving was useful for them. These biases, combined with a higher expectation for mathematical

achievement among males (70), means that students are, in fact, not receiving equal education.

Female students are denied opportunities to participate, are graded less harshly, and are subject

to the preexisting stereotypes of both male and female teachers. Unfortunately, the school setting

is not the only place females are being short changed in the STEM development.

Neighborhood Effects

Even before females reach middle school, and perhaps even elementary school, they may

be encouraged to not care about the STEM fields. A study performed by Doris Entwisle et al

measured the math achievement of students who remained in the same neighborhood versus

those who moved. The study examined students less than six years eleven months in age in over

twenty schools. Furthermore, the students' parents were interviewed, checking for things like

parent achievement, observations of children's activities, children's ability to do work, family configuration, and parental expectations. The objective measure of math achievement was based on the California Achievement Test scores that were given in October and May of the same school year (825). According to the results of this study, "over their first two years of school, boys 'gains in math reasoning achievement were more sensitive to resources outside the home than were girls" (822). Specifically, male students benefited from activities outside of the classroom like neighborhood play. Doris et al found that "boys played in three times as many games at high levels of complexity as girls did, and the play activities for boys were twice as likely to be highly complex than were those of girls." These complex games help develop basic mathematics skills. Applying specific rules, negating others is similar to creating proofs in mathematics. Picking teams helps lays the ground-work for equalizing equations and keeping score can help syllogistic logic (834). Games can be highly beneficial to young learners and since Doris found that parents "purchase more toys and games encouraging math skills for their sons than for their daughters" (833), a tentative correlation can be drawn: Girls are not given access to the materials developed for math-skill building, nor are they expected to perform well in this form of abstract representation.

Hypothetically, then, if girls were able to access this kind of play, they might be able to close the STEM field gender gap. Luckily, computer games can easily allow for this type of play. Shared play and cooperative experiences are all possible through games. They do not even require multiplayer or networked play. Since games are often a spectacle, this shared play can be created with only a single game.

The Effects Computer Games on Learning

As stated above, there are numerous learning benefits associated with play. It can help reasoning skills, mathematic logic, statistical tracking, etc. but that is just traditional outdoor play. The use of interactive computer games can also boost STEM learning and interest in a variety of ways. According to Rosas et al essay "Beyond Nintendo: Design and Assessment of Educational Video Games for First and Second Grade Students," "[t]here is ample empirical evidence supporting the positive effects of computer games as instructional tools, indicating that they strengthen and support: School achievement: they favor a better performance in algebra, increase reading comprehension, spelling and decoding of grammar" (73). Rosas et al argue that computer games can also increase motivation towards learning, attention and concentration, and cognitive abilities, but these are not the only benefits. Merrilea J. Mayo describes even more positive effects of video games on learning in her two essays "Games for Science and Engineering Education," and "Video Games: A Route to Large-Scale STEM Education?" Mayo writes that not only do games increase motivation but they also increase time on task, adapt to the learner, have a massive reach, provide immediate constructive feedback, and offer complex and cooperative learning opportunities (79). While some of these benefits, such as games' far reaching nature and their ability to increase time on task, are fairly obvious and straight forward; the others are a bit more complex. In order to fully understand how best to use games, we must examine how games create each of these benefits specifically.

Adaptive to Learner

Apart from increasing motivation, games are also beneficial to STEM learning because they are able to adapt to the player/learner. Mayo explains that games argues that "complex tasks are presented first as a small core experience that is practiced multiple times before being progressively extended into a longer, more complex sequence" (79). This creates an adaptive experience as players are aided in their experience early on, then left to their own devices as they progress through the game. It is something referred to as the learning curve in video games as described in Greg More and Andrew Burrow's essay "Observing the Learning Curve of Videogames in Architectural Design" (3). Players are offered assistance early on and the game adapts according to their proficiency. Players only advance to the later stages of the game when they are skilled enough to do so. Otherwise they remain in the earlier stages until they master those essential skills. This is ideal for laying the groundwork for learning. Video games emulate Miller's pyramid of learning.
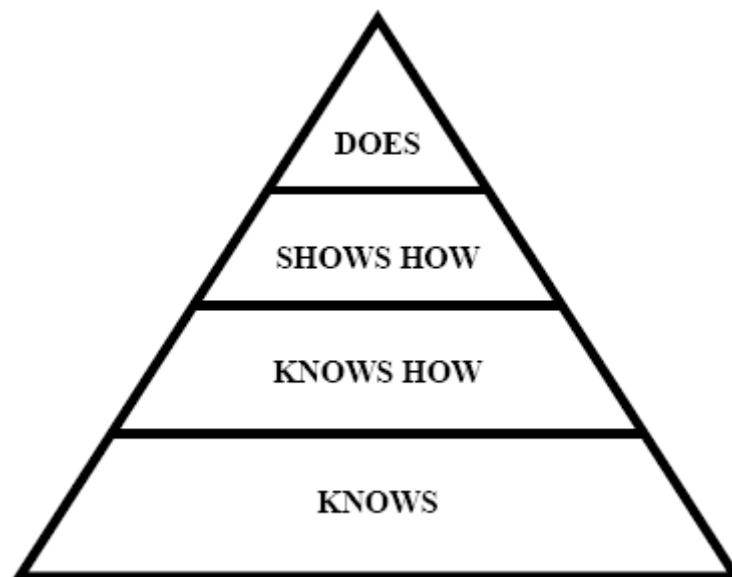
Figure 2.1: Pyramid of Learning (Lindell 3)

G. E. Miller writes, in his work "The Assessment of Clinical Skills/Competence/Performance" that the pinnacle of knowledge is one's ability to do, as seen in Figure 2.1. While Miller uses this pyramid to describe mastery of medical concepts, the same principle can be applied to any type of learning. Luckily, this is the exact shape that video game learning takes. In the tutorial phase of a computer game, the game informs the player so they know what's going on, then it instructs the player so they know how to do something, then it shows them how to do it, and then force them to actually do it. Take the opening sequence of the Super Nintendo game Mega Man X.

When the player first plays the game the opening menu appears and the player is forced to choose an option. When they do, the tiny avatar of Mega Man fires his gun, confirming the selection. This simple animation informs the player that Mega Man shoots the gun in the game. Next, in the first level, Mega Man is encounters an enemy that he cannot jump or walk through. The player is forced to experiment with the controller until they realize that one of the buttons fires the gun. Now the player knows how to shoot. At the end of the level, after Mega Man is defeated in a predetermined sequence, his friend and ally appears on screen and charges his weapon, disabling the enemy. This shows the player how to fire the charged shot. Finally, as the game progresses, the player is forced to use this charged shot ability to continue their progress.

This is only a small example from a very short part of the game, but the pattern appears over and over again throughout games. In fact, according to game theorist Jesse Schell in his book *The Art of Game Design: A Book of Lenses,* "Lectures, reading, and videos all have the weakness of being linear, and a linear medium is a very difficult way to convey a complex system of relationships. The only way to understand a complex system of relationships is to *play* with it, and to get a holistic sense of how everything is connected" (446). Play is an extremely

powerful teaching tool and computer games maximize its efficiency through their adaptation and structured guidance of the player.

Complex and Cooperative Learning

Despite their ludic nature, computer games have a lot in common with the scientific research and study. Games force players to experiment, form hypotheses, test their hypotheses, revisit said hypotheses, and then form conclusion based on the results of their experiments. According to Mayo, this is almost identical to the scientific method taught in most schools (79). Problem solving is the exact purpose of games. According to game designer Raph Koster in his book *A Theory of Fun for Game Design,* "fun from games arises out of mastery. It arises out of comprehension. It is the act of solving puzzles that makes games fun. In other words, with games, learning is the drug" (40). If learning is the drug that causes enjoyment in a game, then it seems logical that games be used for educational purposes. Games embody complex learning and if structured properly, it is possible to teach the player real world, educational concepts and outcomes, rather than simply the mechanics of the game.

Perhaps even more important than games' ability to foster complex learning is their ability to enable collaborative learning. Collaborative learning is a proven classroom concept that is often incorporated side by side with independent work in the United States public school system. It relies on a particular view towards intelligence that is arguably more comprehensive. Educational theorist Kenneth Bruffee argues in his foundational text *Collaborative Learning* that knowledge is not simply what a person knows; it is their ability obtain information from their environment (24). This means that a student who works in a large group is more intelligent, as the group allows them to form a large pool of knowledge. In traditional, commercial games, this

14

is seen frequently. Players collect their knowledge of a game and share with their friends or through the internet, the most efficient strategies. They pool their knowledge in order to maximize their performance in the game. It is possible to do the same with educational games, expanding each of the players collective knowledge.

This also plays into noted educational psychologist Lev Vygotsky's theory on the Zone of Proximal Development (ZPD). The Zone of Proximal Development is the zone in which a student can surpass their base knowledge if given structured assistance, usually in the form of scaffolding. Collaborative learning allows for students to reach the upper limits of their Zone of Proximal Development as it allows each student to benefit from the other's strengths (86). Take, for example, two students paired together for an assignment. One student is good at math but poor at English, the other vice versa. If the team is given a math problem, the team will be able to perform well. The student who is poor at math will be helped along by the one who is good at it, thereby increasing the effectiveness of the lesson. If the problem were an English oriented question the effect would be the same. One student structures the problem and helps the other to reach the upper limit of their Zone of Proximal Development. Games can help their players reach the upper edges of their ZPD. Multiplayer, collaborative, or even shared play allows for each of the players/spectators to contribute to the play experience. More experienced, or better versed players can scaffold the game, collectively pushing the learning to the edges of the ZPD. If the game's learning is centered on educational content rather than strictly game mechanics, then this learning will prove beneficial to the player. These are only some of the proven benefits of collaborative learning.

Collaborative learning also allows for the formation of learning groups. Learning groups are a strategy used within American classrooms to allow students to utilize each other's skills.

They teach cooperation, leadership, and help create a sense of belonging. In Doly Young's essay "Creating a Low-Anxiety Classroom Environment" she explains how "Krashen posits that anxiety in the language learning context is wrapped up in the phenomenon he refers to as 'club membership.' He argues that the affective filter is down when you consider yourself a member of the group" (3). The Affective Filter is a negative learner response to their environment. For example, if a student feels pressured or anxious, the Affective Filter rises and a student is less likely to retain what is being taught. It is no surprise that students are more likely to participate and learn when they are in a welcoming area and feel like they belong. Games allow for the lowering of the Affective Filter. Students can take on a new role and inhabit the role of the avatar. They also benefit from a protected reinforcement structure. Games allow for immediate, positive feedback, reassuring the player. There are also no time constraints on teacher based judgment.

Games have the ability to link multiple players at once and place them in the same learning environment, it is possible to enable collaborative learning that may otherwise not be possible. Students can learn mathematical concepts together or even be paired with experts around the globe. Collaborative and complex learning are both essential to fostering meaningful and lasting learning and through computer games, both are easily achievable.

Brain Chemistry

Recent research in a specific science suggests that games trigger blah blah in brains, providing yet more evidence in favor of the efficacy of games as teaching and learning tools. In a 1998 study by the Hammersmith Hospital of London and the Division of Neuroscience and Psychological Medicine at Imperial College School of Medicine in London, researchers studied

the effects of computer games on the release of dopamine in the brain. Using a PET scan on 8 males ages 36-46 years old playing a tank based computer game for 50 minutes, they measured dopamine levels in the ventral and dorsal striata, which are areas of the brain that are involved in goal-directed motor behavior (Koepp et al 266). The study found that dopamine levels in the test subjects were twice as high as those in the control group. In fact, dopamine levels were "similar to that observed following intravenous injection of amphetamine or methylphenidate." Methylphenidate, more commonly known as Ritalin, is a prescription drug prescribed to people with ADHD to increase focus. This similarity to a drug designed to increase attention is not surprising. Indeed, as Maya points out, the release of dopamine in the brain is a "chemical precursor to the memory storage event" (33). This strongly suggests that a computer game can help prime the brain for memory retention. This is an extremely useful tool for STEM learning, which is a complex process built on earlier lessons. In order to conduct a simple lab test in a Chemistry class, for example, students must have learned, remembered, and then applied all chemical properties associated with the experiment, the scientific method, and the laboratories processes associated with conducting an experiment.

Far Reaching and Increased Time on Task

The final benefits of computer games are perhaps the most obvious. Computer games are extremely far reaching and increase the time on task of the students playing them. According to the ESA's 2005 Survey of the video game industry, the average gamer plays about 6.8 hours a week. A separate survey, known as the National Norms Survey conducted by UCLA's Higher Education Research Institute found that college bound high school students spent five to eight hours a week on homework. This means that students are spending almost the same amount of

time playing computer games as they are doing their homework. This opens up a vast opportunity to expand the use of educational games. If a game were appealing enough to young players and enjoyable enough to match the time students spent playing their normal games, it would be possible to effectively double the amount of time a student spends learning outside the classroom. This is a real possibility considering millions of students play these video games.

According to the NSF Science and Engineering Indicators 2008, only about 450,000 students enter STEM fields annually. This is only a tiny fraction of the people that play a single video game such as *World of Warcraft*. Massive Multiplayer Online Role Playing Games (MMORPG) can bring in as many as 11 million subscribers for a single game. Their reach is unprecedented. Even serious games such as *America's Army 3* can reach as many as 10 million players at a given time. Even educational games have found huge success. *Whyville*, an educational game for K-12, currently has 5 million subscribers with 60,000 joining each month. Also, the average player spends 30+ minutes playing per login and 68% of players are girls ages 10-14. (*Whyville* 1). This is means that each of these students is gaining 30+ minutes of educational exposure every time they login. The population that properly designed educational games could reach is immense, and if these games focus on teaching STEM skills it is possible to make significant progress in ending the gender gap, especially if 68% of these players are female.

Positive and Negative Results of Existing Educational Games

After identifying the potential benefits of video games to learning, I now turn to actual video games to judge their effectiveness. In a 2003 study of 96 eighth grade students playing a physics game designed to teach electromagnetism, researchers Kurt Squire et al found significant

learning gains as described in their essay, "Electromagnetism Supercharged! Learning Physics with Digital Simulation Games." Over the period of an entire lesson block, the experimental group was left to use the educational game *Electromagnetism Supercharged!* while the control group received traditional classroom instruction via their normal teacher. By the end of the study, the researchers had found that students partaking in the computer game had increased their understanding of the content by 28% as compared to the control group, which improved by 15% (517). This learning was measured via a pretest, posttest comparison. Furthermore, female understanding increased by 23% compared to the control group's 5%. While this difference may support using games to teach females, it also shows the disservice that is being done to the female students. If males are learning three times more than females than these games must be ineffectively targeting the female demographic. It is the goal of the later discussed game to address this issue.

Kurt Squire et al are not alone in their discovery that games can be beneficial to the learning process. Other findings in Phillip McClean et al's essay "Virtual Worlds in Large Enrollment Science Classes Significantly Improve Authentic Learning" and R. Rosas et al study of educational Nintendo Game Boy use in elementary school classrooms in their essay "Beyond Nintendo: Design and Assessment of Educational Video Games for First and Second Grade Students" support the claim that games can be used to improve student learning.   Both studies showed considerable learning gains for those partaking in the experimental group. McClean et al showed that the use of active engagement is the key to achieving meaningful learning amongst middle school students. They compared two educational games with a control group, who partook in regular classroom lecture, and a group that saw a web based presentation (3). Using the traditional classroom learning as a baseline, they found that the passive, web based

presentation increased learning from 0-30% compared to the games which increased learning by 15-63% (5). The results imply that it is not simply the act of learning on a computer that makes computer games so beneficial; it is their interactive nature, as described in the previous section of this paper.

Rosas et al also found that games can increase learning compared to traditional teaching methods, but only in certain areas. According to their study, they found significant increases in learning in subjects such as spelling and mathematics but found no difference between experimental and control groups when it came to reading comprehension. This could be attributed to the rule based nature of games being similar to the structure of both mathematics and spelling, but it does show that games are not ideal teaching tools for all such areas. In fact, despite the success of these select games, there are also cases where games like these can struggle. By identifying games' weaknesses, it is possible to improve upon them, creating more holistic and useful educational games.

Room for Improvement

Even though many of these studies have shown that games do, in fact, increase learning amongst students, there have been some studies that indicate otherwise. Take, for example, Jason Eliot et al's study of the effects of a 3D graphical math game on student's learning. In a study of two high school math classes, over eight days, Eliot et al used a 3D math game called *AquaMOOSE* to teach the mathematical principal of polar coordinate space (4). Using a pre and posttest, they found no statistically significant evidence that their virtual environment did anything to increase student learning (5). Upon surveying the students, potential causes for the failure became apparent. One student described the experience as follows: "I mean, I really

didn't understand it overall. It was ok. But like just to do, I wouldn't do it. Not to just have fun. I didn't think it was fun. If anything, it confused me even more." A second student stated that "after the test I will forget, because it's not interesting to me" (6). These students touch on a very important point. Educational games, like *AquaMOOSE* often place too high of an emphasis on the learning goals and not enough emphasis of the enjoyment/fun factor of the games. When a designer ignores the gamic elements their software, they lose the benefits that are associated with games.

It is an unfortunate truth that when it comes to educational games, education is often put before the game. If a teacher is under a time crunch or other pressure and must choose between the game or the educational content, it is often the game mechanics that get cut. When the game mechanics go, so too do the pre-described benefits of said games. *AquaMOOSE* exemplifies this. Other problems stem from the budget and quality behind these games. According to a student surveyed by Henry Jenkins in his article "Game Theory*,"* "the biggest qualm with educational software is the quality. Most look like infomercials, showing low quality, poor editing, and low production costs." Jenkins goes on to write: "frankly, most existing edutainment products combine the entertainment value of a bad lecture with the educational value of a bad game. Most rely on drill and memorization and have graphics and gameplay that fall well below industry standards. But what if we could turn that around?" Jenkins poses a fair question. What if it were possible to turn educational games around? What if it were possible to have $500 million educational games? Would they be the ultimate teaching tool, able to teach any subject, better than any traditional method? While it is true that high production value may eliminate the poor graphics and low budget feel of some games, I would argue that it will not serve as a cure-all. Simply put: Games are not always the best tools for teaching.

Transference and the Appropriate Use of Educational Games

While I have argued extensively for the use of games in education throughout this thesis, it must be said that games, and more specifically, certain game mechanics, are not ideal for the learning environment. Some gameplay mechanics have been known to hinder a students' ability to learn from games or apply their learning to the outside world. This application of gained knowledge is referred to as transference in the educational community. Kortling et al and the Netherlands Organization for Scientific Research define transference (or transfer) in their article "Transfer of Gaming: Transfer of training in serious games" as one's "ability to flexibly apply (parts of) what has been learned to new tasks and/or situations, i.e. real world tasks as well as in terms of preparation for future learning" (19). They further define transfer in gaming specifically as "the degree to which knowledge, skills and attitudes are acquired by playing a game can be used effectively in real (operational, professional) situations" (20). This concept of transfer is the corner stone for all educational games. It is the goal for which all serious games strive and without it, are effectively useless. If students play a game and cannot apply what they learned within the game to the outside world, then the game is ineffective to that defined goal or objective. It would be equivalent to learning addition in the classroom and then being unable to apply that math to giving change at the store or calculating distances. And this is in fact where it sometimes gets stranger with games: the teacher thinks that she is teaching math but the students learn how to hold a pen. Games always teach—they just don't always teach what we think that they are teaching.

Transfer of education goals and objectives is essential to the learning process. That is why designers of these games must be incredibly careful with their design choices, as some game mechanics hinder transfer. One example of game mechanics negatively affecting transfer comes

from a study by Van Eck and Dempsey on the effects of competition within games on transfer. In their essay entitled "The Effect of Competition and Contextualized Advisement on the Transfer of Mathematics Skills in a Computer-Based Instructional Simulation Game," Eck and Dempsy examined 128 students in grades seven and eight using a 3D mathematical game based on the National Council of Teachers of Mathematics (NCTM) 2000 mathematics curriculum standards. Within the 3D game system, the experimental group was told that they would be competing against a computer character. They got to choose their ability, ethnicity, and gender. While playing the game, the avatar of their competitor was present on screen at all times. The control group had no such competition but members were informed to work quickly and efficiently.

Using a pretest and posttest, Eck and Dempsy measured a negative correlation between the competition and the amount of transfer. This meant that the students who were competing against their computer avatar did worse than the control group. This went against Eck and Dempsy's initial hypothesis. They believed that extrinsically motivated students would be "motivated by social standing and recognition, competition against other individuals may serve to increase their efforts and perseverance in the instructional game in order to gain standing among their peers." Intrinsically motivated students, however, would be "motivated may likewise compete against their own score to see how much better they can do" (25). Though this was disproven by their own research, they did offer some insight as to why they thought competition was bad for transfer. They surmise,

> It may be that the presence of competition creates an affective environment in
> which contextualized advisement cannot be fully attended to or processed because
> learners are concerned about the time they have taken (which is displayed on

screen) and with beating the competitor. In other words, competition may inhibit

metacognitive skills, attention, and elaboration. (37).

Eck and Dempsy argue that competition can increase the emotional pressure on a student,

effectively creating a hostile learning environment. This added pressure decreases how much the

student learns because they spend too much time worrying about this added pressure that they do

not focus on their work. This is the Affective Filter in action. It is worth noting that while games

can be used to eliminate the Affective Filter (as mentioned in the section "Complex and

Cooperative Learning" of this thesis), they can also increase it. It is a matter of using game

design principles properly. One has to understand the context of the game and identify which

characteristics of games are beneficial to learners and which are detrimental. Since competition

is an element in almost all games, it is a not a simple task.

While Eck and Dempsy may blame the Affective Filter for the negative impact of

competition on transfer, it is not the only cause. Another potential cause for their results is the

effect of gaming culture on the students. Games, by their definition, are meant to be played, and

as such, are meant to be won. David Parlett, a noted game historian, defines a game as:

A twofold structure based on ends and means:

Ends. It is a contest to achieve an objective (The Greek for game is agon, meaning

contest). Only one of the contenders, be the individuals or teams, can achieve it, since

achieving it ends the game. To achieve that object is to win. Hence a formal game, by

definition, has a winner; and winning is the "end" of the game in both senses of the word,

as termination and as object.

Means. It has an agreed set of equipment and of procedural "rules" by which the

equipment is manipulated to produce a winning situation.

(David Parlett 1)

Parlett emphasizes the importance of the competition within games. Someone has to win, which means that someone has to lose. Conflict and competition are part of all games and, Parlett is not the only one to think so. Clack C. Abt, author of *Serious Games* also writes that "a game is a context with rules among adversaries trying to win objectives" (6). Games are goal based and require a winner. Players want to win. It is the motivating factor for most gamers and is ideally the goal of all participants.

This can cause serious problems for educational games. Since games are meant to be won, players often do whatever it takes to win the games. Mackenzie Wark puts it perfectly in his book *Gamer Theory:* "Uncritical gamers do not win what they desire; they desire what they win. The score is the thing, the rest is agony" (20). Unfortunately for educational games, "the rest" is the content that teaches the student. If a player's only goal is to win a game, he will maximize their efficiency even if it means ignoring all of the content put forth by the educator. Players will manipulate, exploit, or even cheat at the game in order to receive the honor of "winner." This is why competition is detrimental to these types of games. It reinforces this aspect of gaming culture. In order for a game to be truly beneficial, it must acknowledge and embrace gaming culture. It must be designed so that it forces players who are only interested in winning to apply the learning goals of the game. The dominant strategy must be the use of skills that the game is teaching. Otherwise, through no fault of his own, the player will ignore the parts of the game that are not associated with winning.

Maximizing Transfer

It is clear that gaming culture can interfere with achieving real educational transfer, but there are many things that can help maximize it. Kortling et al write in their study of transfer and serious games that in simulations, it is generally thought that the "similarity between a synthetic world (simulation) and the real world results in transfer; that is: higher degrees of similarity lead to higher transfer" (20). This makes sense in many contexts. It has to do with *Fidelity* – the extent to which a simulation looks like the real thing, and Validity – a simulation is valid if it fulfills its intended use when placed in its intended training program (21). If a simulation looks and feels like the real thing, it is no surprise that knowledge carries over. Think of a flight simulator. If a simulation uses a joystick to fly, has a genuine looking cockpit with all of the instruments, and realistic sound effects, the participant is more likely to carry over what they learned than if they use a keyboard and mouse in a cartoonish cockpit. Since, according to Kortling et al, "[t]ransfer is determined by the similarity between game and operation task with regard to the required human information processing involved" (26), it makes sense that a more realistic simulation leads to more transfer. This, however, is only true for perceptual motor tasks.

Since transfer is broken up into two different types—vertical transfer and horizontal transfer—not all simulations and games have to be precisely accurate in their depictions of their intended learning goals. Vertical transfer, according to Eck, "happens when learning contributes directly to the acquisition of a superordinate skill or bit of knowledge." This is the type of transfer associated with flight simulators. The participant has a specific skill that they want to grasp. It is highly specialized and often context specific. The other, more commonly used type of transfer is horizontal transfer, which Eck defines as the "sort of transfer that occurs when a child recognizes that the fractions he is learning about in school are relevant to the problem of

deciding how to divide up a prized, but jointly owned, marble collection" (26). This is the type of transfer that educators are looking for. It is just like in a math class. The teacher may ask the students to figure out the time of collision between two trains traveling towards each other at different speeds, but that is the intended learning goal. They are not trying to train future train conductors; they are trying to teach the principles of velocity, acceleration, division, etc. This means that educational games do not require this specific, context oriented style of design. The creators f these games are free to take new and creative approaches to game design. They are, however, still bound be the restrictive, rule based structure of games.

Since games are computer programs, they must operate on a set of specific rules. They become rigid structures that are often unable to adapt to learners and their play styles. They offer little room for teaching more abstract skills like courage general factual knowledge. They lack human judgment and emotion. What they are best at is teaching structured, rule based operations. Kortling et al compiled a list of the skills best suited for enhancement and transfer via computer games:

Attitudes	
Motivation	++
Initiative	+++
Integrity	+
Honesty	+
Courage etc…	-
Knowledge	
Task-specific facts	++
General facts	+/-
Rules and Procedures	+++
Mental models, schemata	++
Social Skills	
Communication	+++

Cooperation, collaboration	+++
Leadership	++
Emotional Skills	
Nonverbal communication	+/-
Self efficacy	++
Empathy	++
Stress tolerance, hardiness	+++
Cognitive skills	
Interprestation	++
Calculation, problem solving, decision making	+++
Planning	+++
Self-reflection	++
Perceptual-Motor Skills	
Searching	-
Detection	-
Perception	+/-
Operation	+/-
Motor Performance	--
Physical Fitness	++

+++,++,+,-,--,--- meaning excellent, good, reasonable, little, very little, no transfer

Figure 2.2: Positive effects of games on transference

As you can see in Figure 2.1, games excel in cognitive skills as well as knowledge and social skills but like in teaching perceptual motor skills and attitudes. That is why, I argue, computer games are ideal for teaching mathematics in both the gameplay and the content. Computers are essentially mathematical machines. They function via mathematics and, as seen above, are great at teaching rules and procedures, calculation, and planning, all of which are essential understanding the field. This is why this project focuses on teaching mathematics. By acknowledging the strengths of educational games and designing specifically to appeal to those strengths, it is possible to avoid the pitfalls that many games fall victim to.

Chapter 3: Designing *Parallel Hearts* for the Middle School Demographic

As with altering one's design to maximize learning gains, so too must a designer tailor their design to certain demographics. Different cultures, age groups, and genders all have differing preferences when it comes to video games. In order to best design games for these demographics it is imperative to understand these preferences and cater to them. While the differences between a 15-year-old's and a 17-year-old's taste in games may be very slight, the differences between a boys and a girls' can be quite large. Since this study targets middle school females, I will now explore elements of games that have been observed as appealing more to females. As I move through this discussion, I am aware that there is a danger in slipping into essentialist discourse—"girls like this; boys like that." I begin this section with a strong statement that there is wide variation in games and gamers. The purpose of this section, however, is to synthesize the literature concerning girls as gamers, focusing on defining a general thread of likes and dislikes that will guide the game design and execution of *Parallel Hearts*.

Female Player Preferences

In a 2000 article by Cecilia M. Gorriz and Claudia Medina entitled "Engaging Girls through computer Software," Gorriz and Medina write about how the video game industry is strictly geared towards the male audience. They write that "games have addressed only male interests and play patterns" and that ", most computer games on the market—which, again, target boys and young men—are highly competitive and have rigid rules" (44-45). They continue, arguing that females do not respond well to rigid structures and respond better to more free-form types of play. While this male obsession with the game industry may have been true in 2000,

today, we are seeing a much different trend in games. According to the Electronic Software Association, women now represent 47% of the game playing population (ESA). And this makes sense with an expansive view of computer games that accounts for Facebook games, games on mobile devices, and solitaire on the computer. Game developers have responded to these demographic numbers and have started designing games more geared towards female audiences with games like the *Sims*, *Roller Coaster Tycoon*, *Farmville*, and the like. But what makes these games appeal to women? Luckily, much research has been done to better understand the play habits of females and what precisely appeals most to them in the video game world.

In a focus group put on by University of Maryland Baltimore County, 30 female students, in grades 6-12, from both public and private school, were studied as they played various video games selected by the researchers. After playing the games, the students discussed openly with the group what they liked and did not like about each of the games/software and what they would like to see in games. Through this discussion group, the researchers uncovered many female design preferences. First, the researchers noted that the players preferred the games free-flowing movement and did not place emphasis on completion or winning (Miller, 31). They noted that the female players enjoyed the *Myst* environment because there were no guided paths to follow, no points, and no time limit. This is especially intriguing, as most traditional console video games are very strict, level based games. They incorporate a point system and have a distinct goal. This suggests that in order to appeal an expanding female audience, designers might break away from traditional design paradigms and explore a more open form of play.

Another particularly interesting finding from this study was that girls placed a high emphasis on graphic quality and sound design. According to the study's article, "Girls' Preferences in Software Design: Insights from a Focus Group," voice quality, music, and

atmosphere were all things that the players described as "highly important" (32). This is particularly interesting, as many game designers will argue that graphics and audio are merely polish for a game, and that a true game is all about the core mechanic. This focus group revealed otherwise.

Like sound, narrative plays an important role in games that women profess liking. In a study put conducted by Purple Moon, a former Palo Alto-based game design company, 2,000 preteen (10 to 12) and teen (13-17) girls were interviewed about their video game preferences. The study revealed a number of valuable female gamer preferences: "girls often identify with characters in video games and mimic the main character. They like to act out other lives but prefer to do so in familiar surroundings with characters that behave like people they know" (Gorriz and Medina, 47). This suggests that strong, relatable characters provide females someone to empathize with and should play a greater role in game design. Similarly, I would argue that this observation should affect the design of educational games. If female players like to relate to the character within the game, then it is possible to create behavior in the character that you want players to reenact in real life. For example, if a game is trying to encourage females to learn science and pursue degrees in the STEM field, then a real life, relatable character like Madame Curie would be a logical choice for a heroine. This way, females can see her passion and success and emulate it through their play. In contrast, a character that resembles the demographic so that players can empathize with them would also be effective.

A second meaningful finding of this study has to do with the types of games females enjoy. According to the researchers at Purple Moon, "girls prefer to use puzzle-solving skills rather than their eye-hand reflexes." They also found that "girls like complex social interaction. They are fascinated by relationships between characters and other game players" (47). These are

crucial bits of knowledge for designing the types of games for women players. If game designers, whether they are designing for educational or commercial purposes, can incorporate these elements, it may be possible to create games that better target the female demographic.. In terms of education, this is exciting news, as female players disproportionately report that they enjoy puzzles. This can be useful in teaching logic problems and mathematical concepts.

This study also supports the findings of the University of Maryland study in that it found that "girls prefer collaboration to competition. Girls prefer working together to accomplish a task than trying to outdo someone else to the findings" (47). This is similar to Miller's findings in that girls are not interested in winning as they are in exploring the game. Purple Moon also found that "Girls enjoy nonclosure and exploration. Girls don't put a large emphasis on whether they've completed a stage before moving on as today's computer games typically do," (47) again, reinforcing the findings of Miller. By incorporating these player preferences into the design of educational games, it is possible to maximize the engagement of the player and create a game that female player will continue to play and enjoy.

Using the play preferences described above, I set out to create a game best suited to spark interest in the STEM field. Since games have been identified as a contributing factor as to why people enter the STEM field, creating a game that specifically targets the female demographic may help address the STEM field gender gap. A game that motivates middle school girls to pursue math or simply a game that shows that math can be exciting or appropriate for girls could have a lasting impact. For these reasons I created, *Parallel Hearts,* a game that specifically targets the female demographic in order to increase their interest in STEM.

Parallel Hearts is a 2D side scrolling puzzle platformer that is designed to teach middle school females about angles. The game was built exclusively in the Unity game engine using C# and javascript as well as a Unity visual scripting plug-in called PlayMaker, by Hutong Games. All programming was done by Owen Leach, art assets were drawn by contracted artists Bennett Tyler and Beth Hankel.
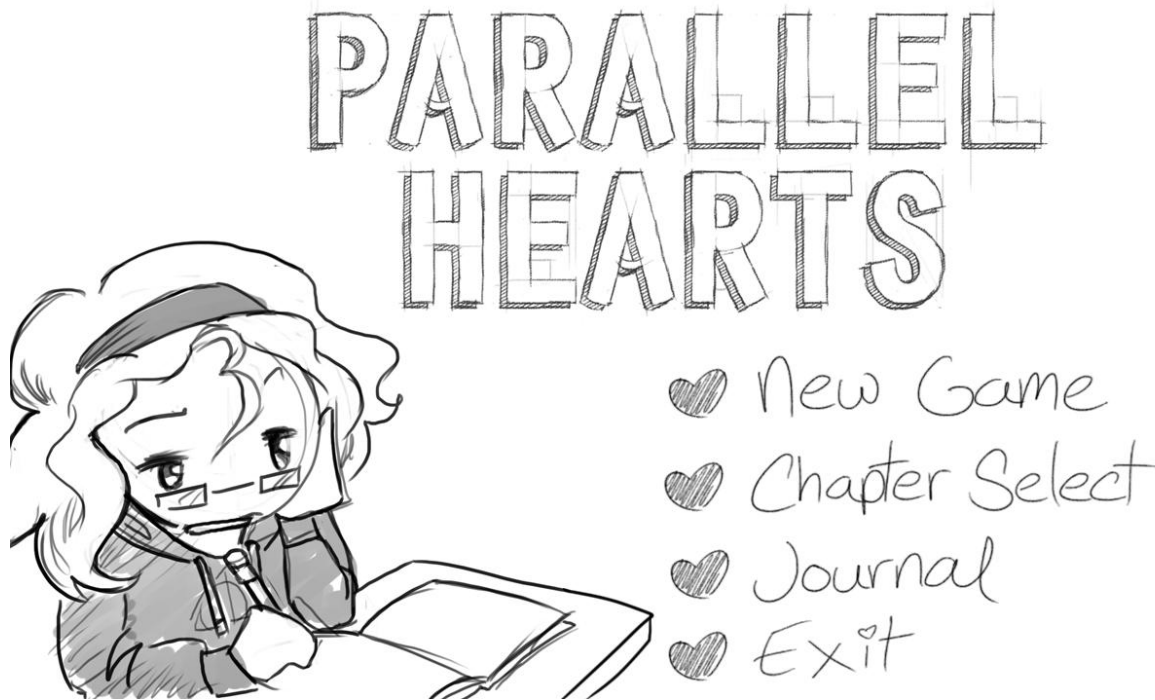

Figure 3.0.1: The title screen of *Parallel Hearts*

In *Parallel Hearts,* the player takes on the role of Mae, a high school girl who doesn't quite fit in. The game takes place mostly in her dreams, where she attempts to use math to try and solve her emotional problems. The player must traverse a 2D landscape, traveling left to right, to reach an end goal, overcoming certain obstacles as she goes. The learning is centralized in the gameplay but is reinforced via the reward system as well as the narrative. In order to reach

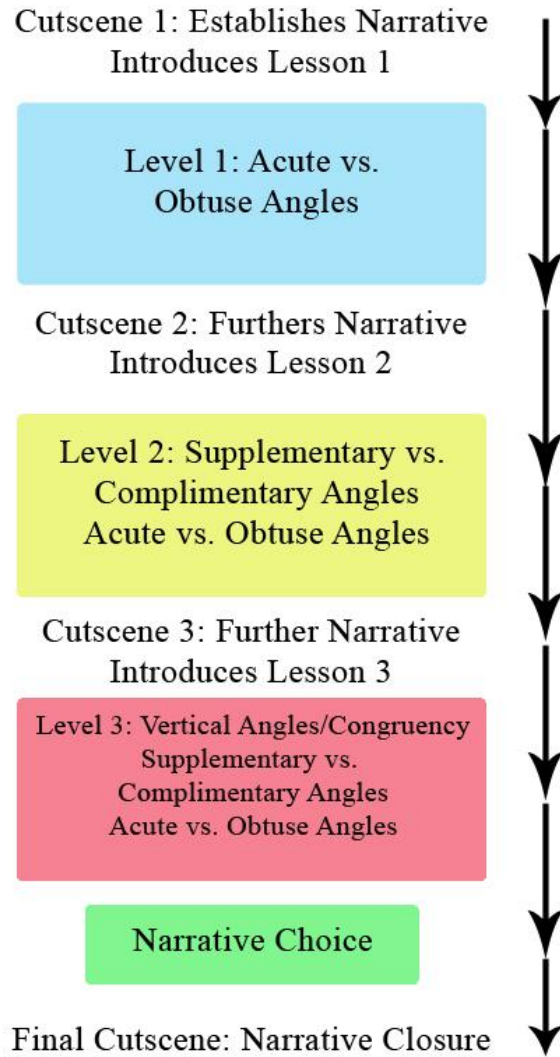the end, the player must be able to master the specific mathematical concepts presented in each level.

Cutscene 1: Establishes Narrative
Introduces Lesson 1

Level 1: Acute vs.
Obtuse Angles

Cutscene 2: Furthers Narrative
Introduces Lesson 2

Level 2: Supplementary vs.
Complimentary Angles
Acute vs. Obtuse Angles

Cutscene 3: Further Narrative
Introduces Lesson 3

Level 3: Vertical Angles/Congruency
Supplementary vs.
Complimentary Angles
Acute vs. Obtuse Angles

Narrative Choice

Final Cutscene: Narrative Closure

Figure 3.0.2: Each level builds upon the lessons presented in previous levels

Figure 3.2 demonstrates how each level focuses on teaching a different principle about angles, such as acute vs. obtuse angles and supplementary vs. complementary angles. Each level builds off of the previous level, reinforcing what the player has learned throughout the game.

Implementing Female Player Preferences

Since the goal of this project is to spur interest in mathematics amongst girls in the middle school grades, each aspect of the game was designed to appeal specifically to their tastes. Using the preferences described in the above, I crafted a game that appeals to each preference with the hopes of attracting the female players to the game, increasing their interest in STEM. To reiterate, these preferences included:

- A less competitive game

- Free-flowing movement without focus on achievement or winning

- High graphic quality

- Puzzle solving over hand-eye coordination

- A relatable protagonist

- Non-closure and exploration

- Complex social interaction

- Cooperation over competition.

In order to accommodate each of these tastes, many traditional gaming conventions had to be broken. The first preference of a less competitive game meant that *Parallel Hearts* would feature no competition at all. The game is entirely single player. There are no competitive elements, no leader boards, no timer, and no scoring system. The game is designed that no one can brag over their fellow classmate as to how well they did in the game. This ties into the second preference, free-flowing movement without focus on achievement or winning.

While *Parallel Hearts* does encourage the player to finish the storyline, it does not reward the player for doing so efficiently or effectively. There are no consequences for dying

(besides re-spawning at the previous checkpoint), and the reward structure is based solely on exploration. Collecting the numerous pickups does not help in the completion of the levels, it only allows for further understanding of the narrative. This appeals to the preference of free-flowed movement without emphasis on completion or winning.

Female preferences are further catered to via the use of a relatable protagonist as well as a visually appealing art style. The protagonist of the story is Mae, a high school girl who does not fit in. She is extremely shy and does not have too many friends. She finds solace by recording her feelings in her diary. One day, a new boy enters her class and she immediately has feelings for him. Initially, she is too scared to talk to him but she decides to treat her emotional situation like a math problem and solve it via mathematics leading to the gameplay. Eventually, she asks the boy out, going to the movies only to realize that he is not interested in her. Heartbroken, she once again must overcome her feelings of rejection. She decides to attend prom, despite not having a date. While there, the boy sees the Mae and is in awe of her beauty. He asks her to dance and it is up to the player to decide whether or not to accept his offer. By basing the narrative on common tropes of tween fiction, it is possible to create a character that females of this age group can relate to. If the players relate to the character, they are more likely to identify with her plight increasing interest in the game and perhaps mimicking her behavior, in this case, her use of mathematics in everyday life.

In terms of graphical quality, the game is entirely 2D and drawn in the Chibi anime art style. It is identified by its over the top cuteness and short characters. The word Chibi is slang in Japanese for a short person. Cute graphics are often used in games designed for younger female players and *Parallel Hearts* echoes this trope. According to Wenhui Cheng, in his essay "Research on Artistic Charm of the Young Girl Images in Japanese Anime" two types of female

representation exist in anime: the Sexy Type, and the Pure Type. The Sexy Type of representation is characterized by body proportions including "plump breasts, high buttocks and slender waist." The characters "attract[s] the public's attention by [their] plump sexy appearance" (936). The Pure Type of female character portrayal is quite the opposite. Pure Types are characterized by their naïveté and cuteness. Their body proportions are also skewed but in different fashions. Their characteristics include "large eyes, charming small mouth, tiny nose, white skin and shiny glossy hair" (935). These characteristics convey a different image, using different tactics to draw the attention of the viewer. Pure Type characters gain attention because they are typically "kind, brave, helpful and selfless spirit" making "the roles exude women brilliance" (936). Since female players benefit from a character they can emulate and relate to, this Pure Style was deemed a much better option.

Figure 3.0.3: Mae, the protagonist, drawn in the Chibi style

Figure 3.3 demonstrates how Mae resembles the Pure Style. She has a large head to body ratio, large eyes, small mouth, and white skin. The Pure Style is also, according to Chenge, associated with Kindness, bravery, and female brilliance. Each of these characteristics would benefit the players and would help them overcome societal pressures that stress abandoning the STEM

fields. The Chibi art style of *Parallel Hearts* provides these positive characteristics for the player to emulate and were among the most cited features that the players enjoyed during the play test.

Apart from the graphics, *Parallel Hearts* also targets female players through its mechanics. In general, female players have been shown to enjoy puzzle-solving games over games based on hand-eye coordination. This is why all of the gameplay mechanics are puzzle based. While players do have to navigate the game world via some coordination (using arrow keys and spacebar to move) there is little coordination required. Jumps are easily made and the paths are straight-forward. The puzzles come into play via identifying and unlocking the path ahead. Players must identify which angles to step on (acute angles "erase" the player, sending back to the last checkpoint) and must alter certain angles to open up new paths. It is a game of identifying the optimal solution to the problem presented to the player. Navigating through the game world is the puzzle itself. This emphasis on puzzle completion makes the game more accessible to players who are not adept at hand-eye coordination. This is not to say that females are worse at hand eye-coordination, only that by making the game easier for players who lack certain dexterity, it possible to open up the game to a wider audience. Female players have, however, been identified as enjoying puzzle games more than hand-eye coordination games as discussed earlier in this chapter.

Finally, while the game does cater to cooperation and slight social interaction, it does not lend itself particularly well to the level of social interaction that many female players prefer. *Parallel Hearts* is played in a group, classroom setting with open communication. Players are allowed to share and collaborate their experience. This is beneficial to the players as there are numerous benefits of collaborative learning but it lacks in that it takes this learning outside of the game space. There are no game mechanics that encourage cooperation or interaction. It relies

solely on the individual. This is, in part, due to a lack of dedicated resources. Networked play is a much larger task that would take much more time to implement. That is why, if this game were to be developed further, it would incorporate much more cooperation and social interaction through the use of multiplayer, shared gameplay. The game would also incorporate an open communication system to allow for discourse amongst the players. Discourse allows the learners to contextualize what they are learning.

Collaborative discourse and argumentation are essential to the learning process. Jonathan Osborne describes their importance in his article "Arguing to Learn in Science: The Role of Collaborative Critical Discourse," observing that collaboration and argumentation "offer a means of enhancing student conceptual understanding and students' skills and capabilities with scientific reasoning" (463). This is only possible, however, if students are "provided structured opportunities to engage in deliberative exploration of ideas, evidence, and argument" (466). This is why *Parallel Hearts* needs to incorporate more collaborative gameplay elements. An open channel of communication, via voice chat or text based chat, amongst players would allow players to open up channels of discourse, deepening their learning. Players who do not understand the content or are drawing the improper conclusions about the lessons will gain clarity and understanding. By playing games collaboratively, it is possible to experience a far more productive and persuasive serious/educational game.

The Core Experience

Parallel Hearts' core experience was designed to emulate the feeling of being out of place in a high school environment. This was chosen because it is a common trope among tween

fiction. Harry Potter and Twilight both have a main character who has trouble fitting in and for good reason. A character who struggles in everyday life is easily relatable and provides catharsis when they escape this outsider life, finally becoming accepted. In the Twilight series, the main character, Bella Swan, is an outsider because she is a new student at a school. In Harry Potter, the title character is an outside because of his non-magical upbringing. Each of these characters go on to overcome their differences, eventually finding a place in their society, providing a solid framework for the standard, coming of age story. *Parallel Hearts* is no different.

In *Parallel Hearts* the main character was designed to be a shy outcast. She doesn't have any friends and only finds solace by writing in her journal. By creating a character that struggles in everyday life, a more compelling narrative is established. Now, the character has a challenge to overcome and must do so or risk the loss of something, in this case, the potential romance with a new boy in class. Every aspect of the game was designed around emulating the feeling of being an outsider in high school, and around two core experiences, self-doubt and loneliness.

In order to create the core experiences of loneliness and self-doubt, both the narrative and the gameplay were designed around them. The environment of each level took inspiration from *Limbo*, a game that encapsulates the feeling of loneliness quite well. In *Parallel Hearts* each level takes place in Mae's dreams where she is alone in a dark forest. The entire game is done in black and white with the dark tones in the background to show the contrast of the lonely black forest and the pure innocent Mae. Level One also includes eyeballs that follow Mae around, watching her wherever she goes.

Figure 3. 0.4: A glaring eye, embodying Mae's Anxiety

The eyeballs, as seen in Figure 3.4, represent the anxiety of being in high school and the pressure of always being viewed and judged. They follow the character's movement with unblinking devotion. However, they do not interact with the game. In this way, I tended to ensure that they were a projection of Mae's self-perception.

These feelings come through in later levels as well. As Mae gets rejected by her potential boyfriend, dark versions of herself appear, embodying her self-image.

Figure 3.0.5: The dark version of Mae represents self-doubt

The dark images of Mae represent all of the bad that she sees within herself. They also add a new gameplay element. Players must avoid these dark Mae's or risk being erased, spawning at the closest checkpoint. These feelings are furthered by journal pages that the player can unlock, giving the player a deeper look into what Mae is thinking as well as incorporating more mathematics learning.

In the final level, I needed to show that Mae started to view herself rather than imaging external representations of herself. In this process, Mae overcomes these self-doubts, the imagery changes.
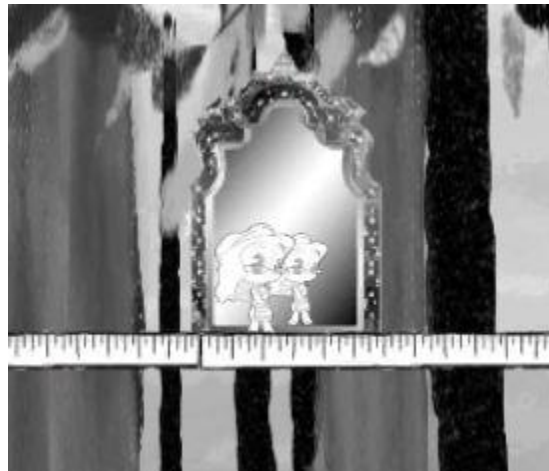
Figure 3. 0.6: Mae's self-confidence restored, she is now able to look at herself in the mirror

Instead of dark figures and eyeballs, mirrors (seen above in Figure 3.6) now appear in each of the levels. When Mae walks past one, she no longer sees her dark self; she sees her own reflection, representing part of her catharsis. She has overcome her self-doubt and is now able to look herself in a mirror. The final catharsis comes as a choice for the player. After Mae is rejected by the boy is interested in, she decides to attend the prom anyway. While at the prom, the boy sees

how beautiful she looks and asks her to dance. The player then decides whether the two of them

should be like parallel lines, never intersecting (not to dance with him), or to be like intersecting

lines (to dance with him).
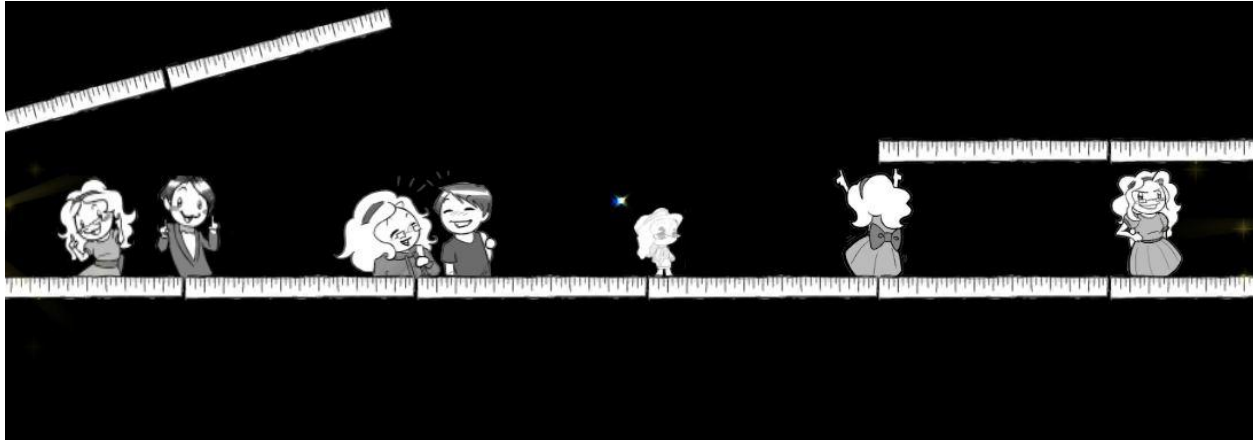
Figure 3.0.7: The final choice of *Parallel Hearts*, to dance with the boy or dance alone

Figure 3.7 demonstrates this choice. If the player chooses not to dance, Mae proudly dances

alone on the dance floor, not caring what anyone else thinks. In the final journal entry, Mae

decides that she is going to stop caring about others' opinions and focus on being herself. If the

player chooses to dance with the boy, they dance happily together and in the final journal entry,

Mae concludes that it is important to find someone that loves her for her and not who she

pretends to be. She vows to never pretend to be anyone but herself and if he doesn't like it, too

bad. These final choices embody the transformation of Mae from the lonely, self-doubting

introvert to someone who accepts who she is and is proud to be it.

Learning goals

While *Parallel Hearts* is designed to appeal to female players it is more importantly designed to teach the players about mathematics, specifically angles. Angles were chosen because of the ease in which they can be turned into a game and because of their inclusion in the Massachusetts Comprehensive Assessment System (MCAS) at the 4th, 8th, and 10th grade level. The MCAS is a test that students of Massachusetts schools must pass in order to graduate secondary school (Mass DOE).

Parallel Hearts is designed to be only part of a complete lesson. It is intended to be used immediately after initial instruction and introduction into the angle unit. The goal of the game is to get players excited about the subject matter and more comfortable with it. It should reinforce the lesson already taught by the teacher. After the game is completed, more instruction, as well as formal assessment is still required. These responsibilities fall on the instructor using the game. It is not a standalone game, merely a piece of a larger whole.

Level	Lesson	Emotional Experience
Level 1	Acute vs. Obtuse Angles (Grade 4)	Judgment/Anxiety
Level 2	Supplementary vs. Complementary Angles (Grade 4)	Self-doubt
Level 3	Vertical Angles/Congruency (Grade 8)	Confidence (initially depression)
Level 4	Parallel Lines Cut by a Transversal Line (Grade 10)	Confidence (if not cut)

Figure 3.0.8: Lesson plan and emotional experience for each

Figure 3.8 shows that the game itself was initially broken up into four different levels, each teaching a different subject about angles, all of which represent different grade level

subjects. The first level focuses on a 4th grade topic, the difference between acute, obtuse, and

reflex angles. Through the gameplay, the player must avoid stepping on acute angles.
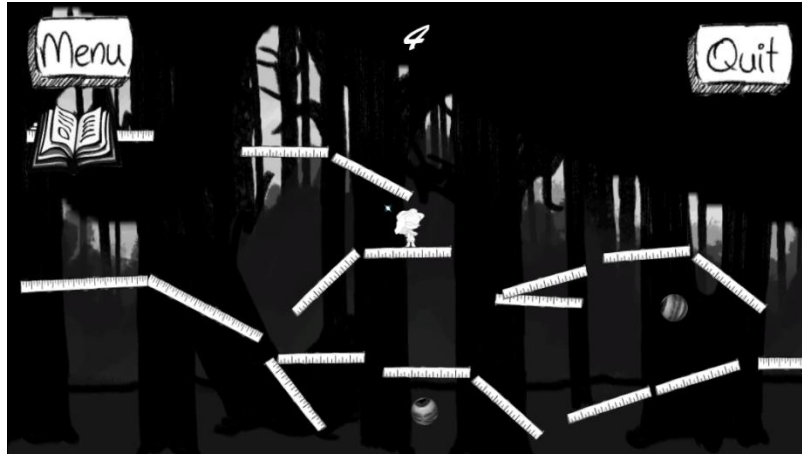

Figure 3.0.9: Level 1: The player can only jump on obtuse angles

Figure 3.9 shows the types of choices the player must make. There is only one optimal path

through to the end of the level. The must identify the correct angle types on the fly or risk being

erased and starting from the previous checkpoint. This forces the player to quickly learn the

characteristics of each of the angles and identify which ones are safe to jump on. The player must

also use switches to alter existing angles to open up new paths, being sure to make them obtuse

or reflex angles, or risk being erased.

Upon completing the first level, the player experiences some cut scenes that further the

narrative, then is placed into the second level. The second level focuses on teaching the

difference between supplementary and complementary angles, while still incorporating the rules

of acute and obtuse angles, reinforcing the previous lesson. By incorporating the previous

lessons, the game creates scaffolding for the more advanced topics, allowing for an increased

ZPD. In level two, the player must identify which angle pair is which, each having its own unique properties.
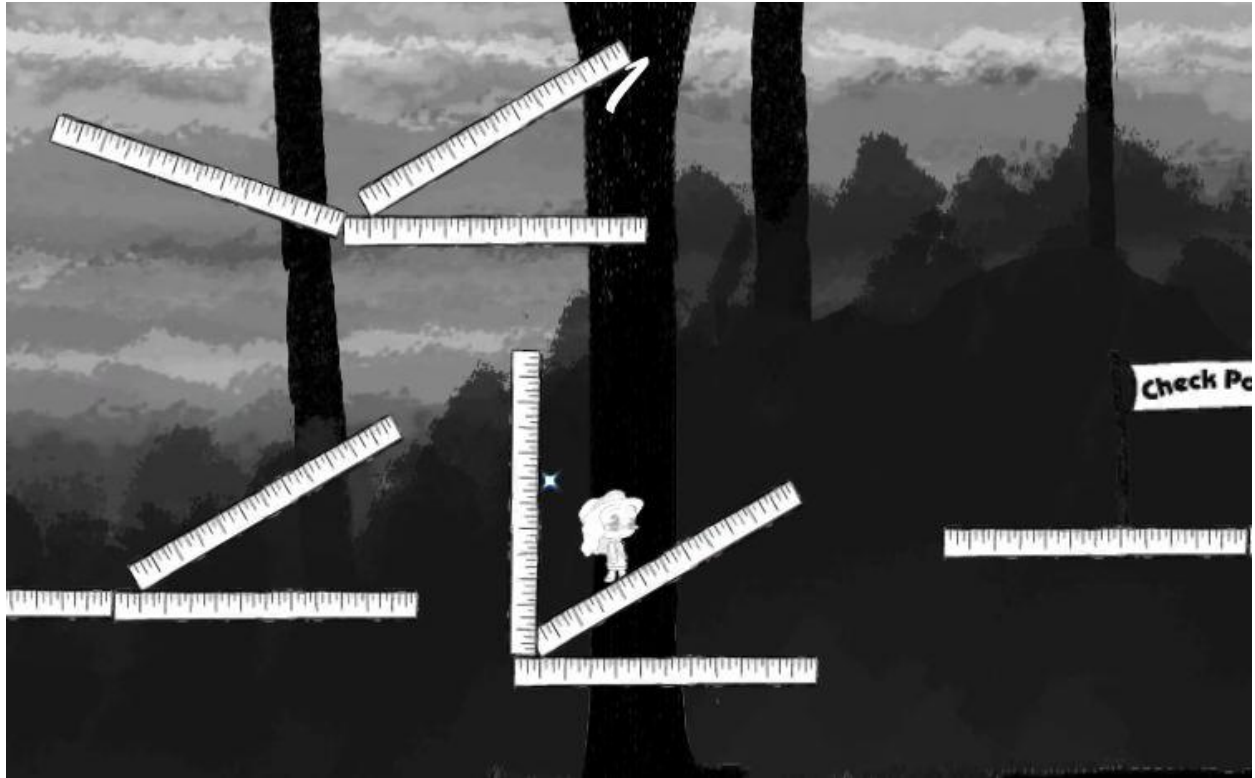
Figure 3.0.10: Level 2: The player must identify supplementary and complementary angles

Supplementary angles, as seen above in Figure 3.10 launch the player into the air while complementary angles act as solid ground. Any other angle pair causes the player to fall through. The player must use these characteristics to navigate their way through the game world.

The third and final level focuses on vertical angles and congruency. This is a more advanced topic than the previous, appearing closer to the 7th and 8th grade years. Gameplay wise, congruent angles cause the player to teleport.
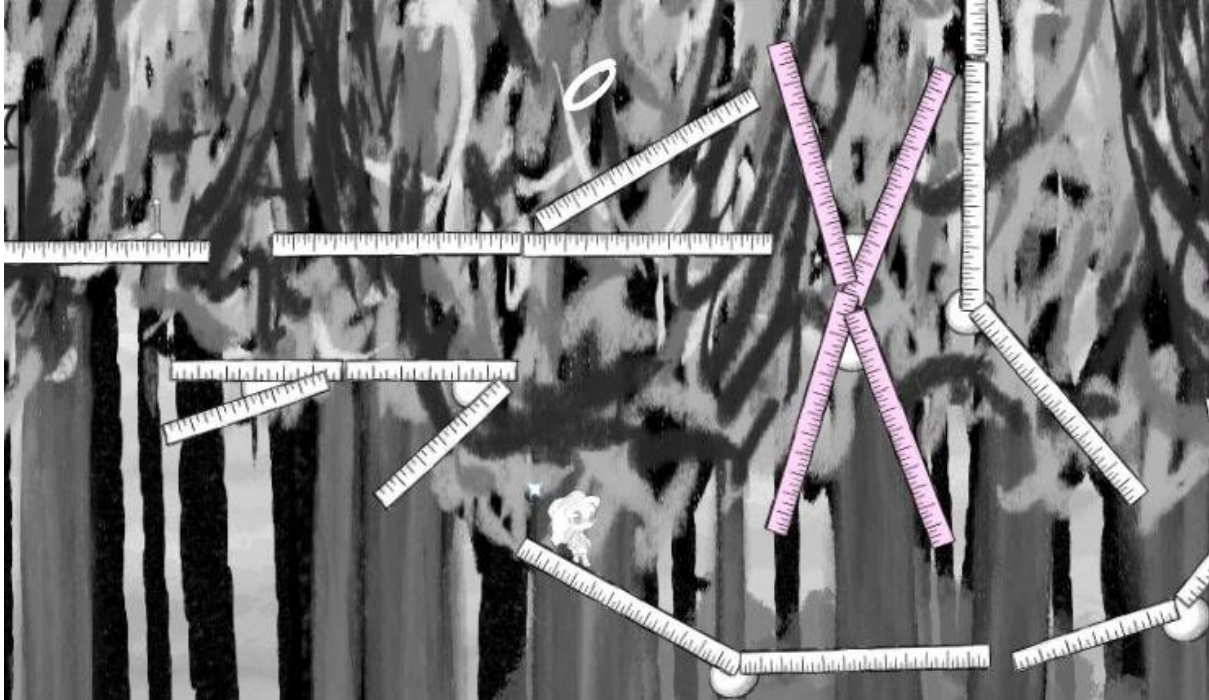
Figure 3.0.11: Level 3: Vertical angles/congruent angles cause the player to teleport

In Figure 3.11, the pink angles represent congruent angles. If stepped on, the character teleports from one place to another. It is up to the player to master this technique, altering angles to open new paths to reach the end of the game. This level, like the previous, incorporated all aspects of the previous levels.

Initially, a fourth level was created that was designed to teach the 10th grade topic of parallel lines cut by a transversal line. These have numerous mathematical properties, each of which would have been explored via a culminating level that incorporates all the principles into one. This level was cut due time constraints and the advice of the teacher hosting the play test. Her fear was that the content was too advanced for a 7th grade class and that there would not be enough time for the players to reach all of the levels, an opinion that proved true during the play test.

Each element of the design was tailored specifically to the middle school girl audience. *Parallel Hearts* targets this population specifically in order to spark interest in STEM. If the target demographic plays these games, relates to Mae, and sees that math can be fun and interesting it may motivate them to consider math as a legitimate career path. The story, reward structure, and gameplay all reinforce these concepts. In order to test the effectiveness of these strategies, a structured play test was required.

Chapter 4: Testing Among the Target Demographic and Iterative Feedback

In order to understand the effectiveness of *Parallel Hearts* and whether or not it was targeting the female population specifically, a well-structured play testing session with the target demographic was required. Unfortunately, play testing *Parallel Hearts* presented some interesting challenges. First and foremost, it was a game, and needed to adhere to traditional playtesting concerns. According to former Ubisoft Designer Pascal Luban, "Playtests force game development to center around the players instead of the hopes of the development team" (1). In other words, a playtest forces the designers to think about how their game is actually being played and not how they designed it to be played. It forces designers outside of the theoretical and into the practical. It is a process that occurs early on in the development cycle and is used to iterate on the design as the game progresses.

In addition to being a game, this was a teaching program. Thus, when I looked to testing learning software, I found that studies focus particularly on the learning goals of the game and whether or not they are achieved in the target demographic. These play tests, or user studies, usually involve a control population and a pre and posttest. They are data driven and look for learning trends amongst player. Their goal is to identify if learning is taking place, where it is taking place, what skills are being developed, and if those skills can be extracted from the learning software. Since *Parallel Hearts* straddles both sides of this, the play testing had to be a hybrid of both types of testing. That is why the initial, formalized, play test had elements of both play tests but, ultimately, focused more on the game development side, rather than the learning software side. The main reasons for this were that educational software often neglects the game play elements in favor of educational content, as seen in the previous example of *AquaMOOSE* found in the section "Room for Improvement" of Chapter 2. Also, the goal of this early iteration

of the game is not necessarily to educate but rather to advocate. *Parallel Hearts* focuses specifically on getting female players interested in mathematics rather than advancing their knowledge of mathematics.

In order to test the game elements and fun factor, the initial test focused heavily on player interviews as well as a formalized survey that identified how much the players enjoyed the game and how likely they were to play it again. Questions were asked during the play test that focused on whether students enjoyed the game, which parts they found most enjoyable, where students thought they were having trouble, what changes they would make, and other subjective questions. The goal of these questions was to evaluate the design of the game and provide guidance for the future iterations of the game. These questions, coupled with active observation of the each player's play through allowed a refined design the next time around. Take for example one active observation, that each player had trouble in the beginning of the game identifying the difference between acute and reflex angles. Stepping on the wrong angle meant certain death despite the two looking almost identical.

Figure 4.0.1: A reflex and acute angle

As seen in Figure 4.1, there is almost no discernible difference between the two angles except for the small circle that represents the angle measurement. This is an important lesson for students because angles are always about perspective. Every angle, without the inner circle to represent the angle measurement, can be seen in two ways: the interior and exterior angle. This part of Level 1 forces the player to identify which angle is which. Unfortunately, most students ran through this part, dying immediately, respawning at the checkpoint immediately preceding it and then trying the other angle. When asked why they chose the reflex angle to jump on, ten students replied, in one form or another, that they only jumped on it because the other angle killed them. This observation shows multiple problems with the design of the game.

By actively ignoring the lesson of the game a simply pursuing the winning strategy, this particular example shows that players are gaming the system. As mentioned in Chapter 2, Mackenzie Wark warns that players will often find the optimal strategy for winning a game. In

terms of *Parallel Hearts,* this means that if the player can, they will ignore the lesson in order to beat the level more efficiently. This active observation allows for a new iteration of the concept in later versions of the game. Since players are forced to understand the concept of reflex angles to advance past this part, the game can be redesigned to better emphasize it earlier. More instruction can be added, a stronger puzzle that makes the player stop and think about the properties of angles would be more efficient. Once this feature is implemented into a new version of the game, it can be retested and checked to see if it now performs more optimally. This is the core of the play testing experience: identifying pitfalls and positive aspects of the game, iterating on them, and retesting.

The lesser focus of this play test was to evaluate the learning software side of the game. In order to achieve this, both a pre and posttest were created (Appendix A and B). The pretest is designed to measure the base knowledge of each individual student. The posttest is designed to measure their ending knowledge. The two tests are based on questions with identical problem solving strategies and test the exact same skill sets. The goal of the two tests is to identify the difference in achievement between the two. Theoretically, if learning takes place, the students score on the posttest increases. A result where the pretest and posttest score were identical would indicate that no learning took place. A result where the pretest score was higher than the posttest score would mean that the testing process was flawed as students do not typically lose knowledge during a 25 minute game. A breakdown of pretest and posttest as well as the qualitative survey can be found in the forthcoming "Results" section.

Parallel Hearts was play tested on Thursday, March 28th at Fuller Middle School in Framingham Massachusetts. The play testers consisted of 22 students in a 7th grade advanced mathematics class, 11 female, 11 male. The whole session took 45 minutes, 25 minutes devoted

to actually playing the game. the rest was used for the pre and posttest (Appendix A and B). A qualitative survey was also given out at the end of the play session (Appendix C) in an attempt to identify how much players enjoyed the game and how likely they were to play it again. The students returned the surveys the following day.

The pre and posttest consisted of 7 questions that appeared on previous MCAS mathematics tests (Appendix A and B). The questions were taken from the 4th, 8th, and 10th grade MCAS tests from 2009-2011 and were specifically about angles and the topics included in the game. These topics included identifying the difference between acute and obtuse angles, understanding the properties of complementary and supplementary angles, and finally the properties of vertical angles and the meaning of congruency.
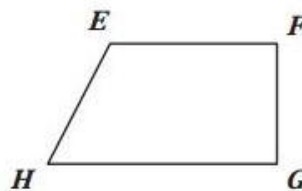
3.

Which of the following shapes has **only** acute angles?

A.

B.

C.

D.

4.
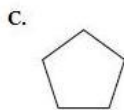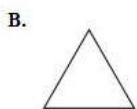
Elsa drew the quadrilateral shown below.

Which angle appears to be acute?

A. angle E
B. angle F
C. angle G
D. angle H

Figure 4.0.2: Left: Question from the pretest. Right: Question from the posttest. Both questions test the learning goal of level 1: properties of acute and obtuse angles

Above, Figure 4.2 shows two questions that test the same mathematical principle. The question on the left is from the pretest, the one on the right is from the posttest. Although the questions are different, they test the exact same mathematical principle, the ability to identify the characteristics of an acute angle based on its visual appearance. Without identical questions, such as these, the pre and posttest process would be invalid. Testing students on different knowledge at the beginning and end of a game would prove nothing.

The tests also included advanced topics such as parallel lines intersected by a transversal line to identify how advanced the class actually was. The class had had no previous instruction in transversal lines but all other topics were covered recently by their teacher. All test questions were either multiple choice or short answer, as is the form of the MCAS. The posttest included three separate questions that were based on the game. These questions asked about the characteristics of the in-game angles and were used to compare whether students could or could not transfer their game knowledge to mathematics.

The Population Already Knew Material

The scores of the pretest revealed numerous problems with the play testing population. First of all, the entire class scored perfectly on almost all lessons the game was designed to teach. Of the 22 students, each student scored perfectly on the three questions about acute vs. obtuse angles (a 4th grade level topic). The same can be said concerning the questions about supplementary and complementary angles. The only topic where the students struggled were on the questions that pertained to topics they had not covered previously in class and were above

their grade, specifically, the questions concerning transversal lines cutting parallel lines. Both genders had nearly identical performances and the posttest yielded similar results.

In the posttest, once again, the only questions that more than 5% of the class got wrong were those concerning parallel lines. However, the posttest also included questions about the content of the game. These questions were designed to test if the game concepts transferred into real world mathematics knowledge. Interestingly, student did poorly on two out of three of these questions, despite scoring perfectly on the sections that pertained to the content.

2.
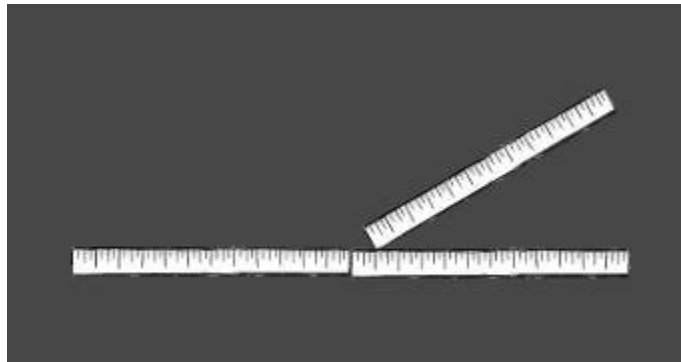
Stepping on this angle pair will cause Mae to:

    A. Be erased
    B. Bounce
    C. Fall Through
    D. Teleport

Figure 4.0.3: A sample posttest question about the game's content

Specifically, 41% of students answered the question in Figure 4.3 incorrectly. This question is designed to test if the player can identify the characteristics of in-game supplementary angles. Despite the classes' trouble answering this question, only 5% could not identify the properties of supplementary angles in a math problem. This suggests that the players are not relying on their

in-game learning. Instead, they are relying on their previous domain knowledge to solve the math problems. The content is not transferring outside of the game as well as hoped.

Insufficient Time to Test Whole Game

The second game related question the players struggle with was one that could only be answered if the players reached the final level. During the posttest numerous students raised their hand informing the moderator that they had not reached that far into the game. This shows that the students were not given ample enough time to fully explore their game, denying them 1/3 of the mathematical content. Ideally, the class would given much more time to complete the game as 25 minutes is not ample time to fully develop a relatable character, tell a compelling narrative, and to reinforce three full math lessons. The more the game is rushed and the less time the players have to complete it, the less time the student has to openly explore the content of the game reducing the positive benefits of games on learning. In future studies, I would advocate for closer to 45 minutes for the completion of the game. This would provide ample time for the completion of the lesson and would allow those students who have finished to replay the game, getting all of the hidden objects and being exposed to all of the educational content.

Female Bias Toward Game Suggests Some Success with Target Population

Apart from the pre and posttest, the students also filled out a survey about their opinions of the game (Appendix C). The survey consisted of 5 questions concerning how often the students played games, how fun they thought the game was compared to class and compared to

other games, how much they thought they learned from the game, and how likely they were to play the game outside of class. The responses were based on a five-point Likert Scale. The results of this survey revealed both positive and negative responses to the game.
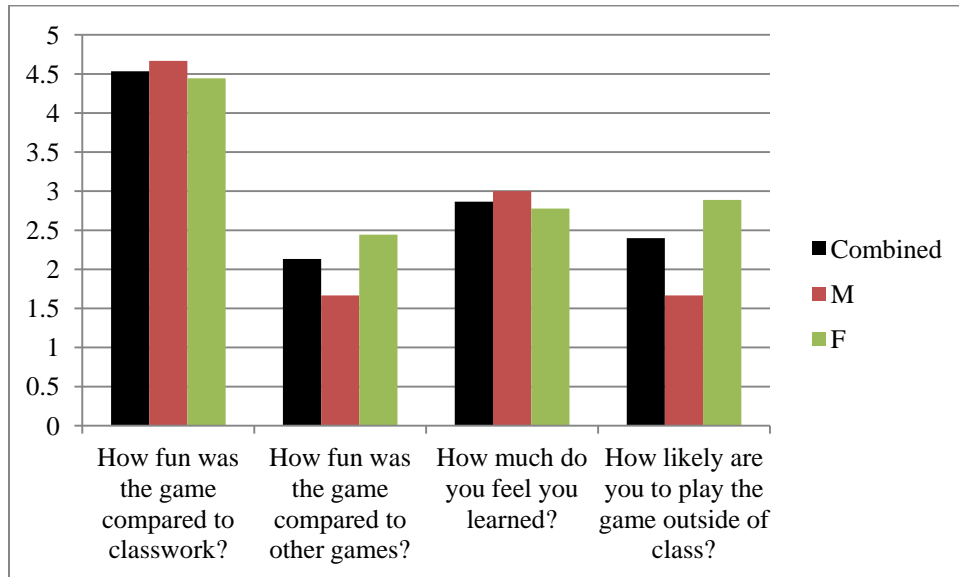
Figure 4.0.4: Averaged responses to survey questions

Figure 4.4 demonstrates the average Likert Scale responses from the play test group broken up by gender. While some of the findings of this survey came as a surprise, others were somewhat expected. Predictably, both male and female students rated the game as having a high degree of fun in comparison to their regular school work. This comes as no surprise as most students enjoy a break from their regular school work and welcome a guest that promises them the opportunity to play games. While this is expected it is still a positive result. According educational psychologist Brandi Gribble Mathers, in her essay "Students' Perceptions of 'Fun' Suggest Possibilities for Literacy Learning," "literacy activities perceived by students as fun may actually increase their motivation for reading and writing" (83). An increase in motivation is the exact

result *Parallel Hearts* is striving to achieve. An increased motivation towards mathematics during the formative middle school years may lead to students carrying that motivation with them throughout the rest of their academic careers.

An even more significant result is how the players rated their perceived fun compared to other games they play. While the class average was a 2.1333 (slightly less fun than their normal games) the female average for the class was much higher. The females of the class rated their fun compared to other games at a 2.444, only slightly less fun than their regular games. This is a positive implication. If female players consider the game almost as fun as their regular games than it is in fact possible to incorporate educational content into a game and still have it be enjoyable for the player. Even though *Parallel Hearts* was made by a team of only three people and was a very small project, it still rated almost as fun as normal games. This implies that games with a much larger budget and development cycle could find financial success in this area. With higher quality, more polished game, the players may be more likely to enjoy it, raising their fun rating even higher. If educational games could reach an equal level of fun as to standard commercial games, this would truly be a great finding. The myth that educational games are not fun would finally be dispelled. It is, however, important to note the *Parallel Hearts* did focus significantly on the fun factor of the game and less on the educational content.

The third survey question asked how much the students felt they learned in comparison to a regular class. The class answered at a 2.87, just short of a regular class' content. Though the pre and posttest proved that no learning actually took place, the students perceived that they were learning. This implies that the players felt they were learning and still enjoyed the game. These findings further the notion that educational games can still be fun. They also show that despite already mastering the content presented in the game, they still feel like the game is close to as

productive as their normal class. The helps create a sense of progress in the students and is promising in that it is not viewed as a waste of time by the students. This data could help persuade finicky teachers who doubt the merits of games in education and are hesitant to include them in their classes.

The final survey question shows the effectiveness of the game at targeting the female player. When asked how likely players were to play the game outside of class the two genders experienced their widest split, second only to how fun they perceived the game compared to other games. Female players were nearly 1.75 times more likely to play the game outside of class than male players were. Unfortunately, their inclination towards playing it outside of class was still 2.89, slightly less than neutral. This is, perhaps, the most positive finding of the study. It shows that the game is effectively targeting the female audience. It reinforces the design decisions made for the game and is encouraging for later iterations of the game. This coupled with the findings that females thought *Parallel Hearts* was almost as fun as other commercial games they have played shows that *Parallel Hearts* has a large potential. The game is enjoyed by the target demographic, so much so that they may even take it home and play. This would increase the time on task of the classroom content matter, helping maintain memory of the material between lessons and further the students' exposure to a positive example of a female in the STEM field.

Although the pre-posttest and survey yielded numerous findings, there is more to be said about the qualitative findings that occurred during the study itself. As with any experiment there are always unexpected findings that popup when least expected. This play test was no exception. During the play test itself there were three findings that were strikingly unexpected. These

included an increased emphasis on competition, a lack of interest in the narrative, and discomfort concerning the gender of the protagonist and the subject of the narrative.

Emergence of Competition

While playing the game, the class was encouraged to talk amongst themselves, sharing in their experience. While discussing the game, an air of competition started to fill the classroom. About five of the male students began to compete in order to figure out who could finish the game the fastest. This came as a surprise, as the game was designed specifically to be less competitive and more cooperative. It was meant to be an independent experience that people could share and play concurrently. Instead, the game turned into a highly competitive race. While this isn't immediately discouraging for *Parallel Hearts* because it was only males who got caught up in the competition, it is still noteworthy. What could be male competition in the first play test could easily turn to female competition during the next play test. The fact remains that the potential for competition remains despite the initial design.

The immediate obvious cause of the user created competition is the linear nature of *Parallel Hearts*. The game consists of three clearly defined levels. It has an obvious beginning, middle, and end, which is due to a combination of storytelling mechanisms as well as game mechanics. The story is a linear story that relies on players experiencing cut scenes and journal entries in a specific order. It is derived from traditional literature and follows the coming of age troupe. Unfortunately, this reliance on traditional storytelling forces a linear experience. Most books have to be read in a particular order and *Parallel Hearts* mimics those books methods. This, coupled with the linear based gameplay mechanics (each level has a specific beginning and

end), means that users can race through the game in an attempt to complete it the fastest. In order to counteract this, both the gameplay mechanics and narrative would have to be drastically altered.

A completely noncompetitive game would have to be nonlinear and entirely open and therefore no longer a game. The game would act more as a virtual environment where players are allowed to explore and partake in various educational activities, none of which lead to any sort of completion. It would be a virtual playground that players spend time in, trying out various games and lessons. It would be restricted in that the game could never be completed and no achievements or reward structures could be implemented. Rewards or any sense of completion would once again lend itself to competition.

The narrative of this new game would also have to be nonlinear. It would be an abstract type of storytelling that could not have a definitive end as an end would give something to compete for. These restrictions pose far too large of a problem to actually benefit learning. By tailoring a game to be exclusively noncompetitive in every aspect, much is lost as to what is possible in a game and the game itself loses its meaning. Games require goals and with goals come people who want to achieve those goals faster than others. *Parallel Hearts* will not be altered to adjust for the emergence of competition but it will followed closely. If the problem persists the game may benefit from being extracted from the classroom environment and become a standalone product played at home. With no peers watching, players may be less likely to rush through the content in an attempt to beat their peers.

The sense of competition that arises during *Parallel Hearts* reaffirms current theory about competition in schools. According to Peter Smith in his book *The Nature of School Bullying: A*

Cross-National Perspective, "[students] quickly learn that school performance determines to a large extent their social status, they are rewarded for their achievements and punished for their failures" (214). This means that students can view any situation as an opportunity to maintain or improve their social status through competition. And while this study is linked to bullying, it does help to make sense of larger cultural practices in the classroom—cultural practices that affect the ways in which people interact with games. Thus, I can tentatively conclude that since the competitive nature of school is hard-coded into the students, it is not surprising that students strive to compete in any way they can.

Ignoring the Narrative

The second surprise came when numerous students were unable to identify the plot of the game. The narrative cut scenes explain how the story of the game relates to the mathematical concepts. Despite the players self reporting that they enjoyed the game, they spent little time experiencing the narrative. *Parallel Hearts* includes the option to skip cut scenes, journal readings (which include narrative as well as educational content), and the tutorial text. The skip feature was put in for players who were playing multiple times and did not want to view the narrative multiple times. Its inclusion proved detrimental to the narrative experience as numerous students elected to use it, neglecting all of the benefits of a central narrative. The players no longer relate to the female character, there is no longer a drive to complete the game to experience the entire story, and the context of the art is ultimately lost. While eliminating the skip button may stop players from clicking through the game it is not the ideal solution.

The disregard of narrative in games is a well-established concept. According to Craig A. Lindley, in his article "The Gameplay Gestalt, Narrative, and Interactive Storytelling," "the higher levels of narrative form [can] often be completely eliminated with very little impact upon the core gameplay experience" (206). This is no surprise as the narrative is often added as a secondary experience for only particular players to enjoy. The gameplay is what primarily drives players to games and it is gameplay that keeps them.

Unfortunately, with the loss of the narrative comes the loss of connection with the avatar. If there is no context to who the character is or what they are going through then it become more difficult to relate to the character. This is detrimental to the learning process because avatars allow students to remain entirely anonymous. Anonymity itself eliminates all social pressure, risk of bullying, worries of fitting in, or concerns of being viewed as unintelligent because there is zero accountability for one's actions. Without all of these concerns, anxiety will be eliminated and students will be much more likely to participate in cooperative play and not have their learning blocked by their anxiety. The avatar has also been known to increase self-confidence, one of Stephen Krashen's factors which determine the Affective Filter.

According to the study "Second Language Use, Socialization, and Learning in Internet Interest Communities and Online Gaming" by Steven Thorne, Rebecca Black, and Julie Sykes, "one's avatar constitutes the primary identity cue in VEs and, correspondingly, that the visual characteristics of one's avatar significantly impact online behavior" (5). By giving different test subjects randomly generated avatars Throne et al proved that one's virtual appearance alters one's online behavior. They noted that test subjects that were given more attractive avatars were more forthcoming and friendly. They also discovered that users with taller avatars were more confident. They named this phenomenon the Proteus Effect, where "an individual's verbal

behavior is affected by their digital self-presentation in ways that are independent of how others perceive them" (7). Virtual environments allow students to take on any role that they want, meaning that those students with low self-efficacy or confidence can now inhabit a confident and strong avatar, thereby lowering their Affective Filter. With the loss of the narrative, inhabiting the characteristics of the avatar is much more difficult. There is no longer a back story to identify with, only a 2D representation of a character whose name the player doesn't even know. The alternative to allowing players to skip content would be to force them to partake in the narrative.

Forcing the player to participate in content that they otherwise would skip is not the ideal solution for game design. Players should theoretically enjoy each aspect of the game and if not, if the content is only put in for specific types of players, i.e. completionists, competitive players, etc. the content should not be essential to the core experience of the game play. This is where *Parallel Hearts* falters. The core experience, that of emulating a girl's experience in high school, relies solely on the narrative. If the students do not have the patience for the cut scenes, journal entries or other narrative devices then they are missing this experience. Future iterations of the game would make considerable revisions to this aspect of the game.

The narrative of the game would benefit from emulating the educational content of the game in that the educational content appears in every aspect of the game. The cut scenes, tutorials, reward structures, and game play all include the educational content. This is done for two reasons. The first is to constantly drive home the lesson in every aspect of the game. The second is that if some players elect to skip certain parts they are not deprived of the game. In later versions of this game, the narrative would follow a similar structure. Instead of being isolated in the cut scenes that are easily skipped, it would be embedded into the game play as well, forcing the player to experience it, without having them sit through scenes they would

otherwise not enjoy. There would also be a drastic shortening of all of the narrative content. Currently, some cut scenes take upwards of two minutes to complete and are immediately proceeded by a page of text. This is problematic, as many players of this age prefer content at a more rapid pace. This would also help alleviate the time constraint that classroom game play put on the play experience.

The final important implication of this finding is that the educational content does not require a high degree of verisimilitude. A prominent goal for the design of *Parallel Hearts* was to create a game where the learning made sense within the virtual world. The goal was to maintain the magic circle (protected play space) so that when real world content entered a virtual game (that is, the mathematical content), the magic circle would not be broken and the player alienated.

I know! I'll treat it like a math problem. Math has always made sense to me. The key is to focus on the positive emotions, the ones that will help me conquer this, help me open up. Kind of like obtuse angles, greater the 90 degrees, open to the world.

If I avoid acute angles, less than 90 degrees and closed off (my usual self), maybe I can find my courage and find a new me!

Acute
<90

Obtuse
>90

Mae ♥

Figure 4.0.5: Establishing mathematics verisimilitude via the narrative

As figure 4.5 shows, the narrative was used to establish the verisimilitude of the mathematical content. The goal was for the mathematics to make sense in the virtual world so when the player had to jump on an angle, they wouldn't question why. They would understand that it is a conscious decision of Mae to try and relate her problems to mathematical concepts. Since the narrative was ignored by many students and the students reported having some degree of fun coupled with a sense of learning, the initial hypothesis, that verisimilitude/maintaining the magic circle are essential to learning, may be flawed. This would take a new study unto itself to fully explore but will definitely be addressed in a future playtest through more targeted questions concerning this topic.

Discomfort with Gender Identity

The final unexpected finding came about from a single comment from one of the male players. When the male student realized that the story was about a female protagonist who falls in love with a boy, he immediately stood up and said "I don't feel comfortable playing as a character who falls in love with a boy." The student had a class clown vibe to him and seemed to be seeking attention (a tendency the teacher confirmed), but it is still noteworthy. According to Carver et al in their essay "Gender Identity and Adjustment in Middle Childhood," "in middle childhood, children have a strong intrinsic desire to 'join in,' to feel they belong, and to see themselves as not terribly different from same-sex others" (97). This outburst could be attributed to the student's innate desire to identify with the hetero-normative standard of the room. Therefore, games that force new gender roles have the potential to alienate students. While this

was only one particular case, and was from a boy (the non-targeted demographic), it still remains an important consideration for future iterations of this game.

Since both genders are developing their gender-identity during the middle school years, it is possible that this scenario could pop-up again if the gender roles were switched. While in my own personal experience, I have never heard a female complain about playing as a male character in a video game, that does not mean the students are not still feeling alienated. The potential for gender confusion is reinforces the decision of having a female lead character in a heterosexual relationship. If gender identity could cause potential issues, then it is best to keep these issues out of the game so as not to detract from the key experiences. The goal of *Parallel Hearts* is not to challenge gender norms but to create interest in the STEM fields amongst middle school females. By maintaining standardized gender roles, I hope to reduce the potential for increased anxiety and learning distractions. I do acknowledge that this could potentially lead to other students who do not identify as "man" or "woman" under traditional heteronormative construction to feel excluded or uncomfortable. I do want to consider multiple gendered identities in creating this game. However, when designing this game, I relied on other mediated representation of this demographic to guide me in my choice of representation, anxieties, and sense of accomplishments, relying mostly on teen fiction and teen television.

Because *Parallel Hearts* is so meticulous in its targeting of females, it does open itself up to problems for male students, as shown by this case. Males may find themselves uncomfortable while playing and if this case is repeated in further play tests, it may threaten the use of the game in the classroom. Educational games are useless if only half of the class is allowed to play them. Teachers are far less likely to let the class play if they have to supervise one half of the class while the other plays on the computers. If this problem does persist, a potential solution would be

to create a sister game that matches the lesson plan of *Parallel Hearts* yet targets the male demographic. Males may not need the extra motivation to pursue STEM as much as females, but it would give the other half of the class something to do and quell potential cries of sexism or preferential treatment.

Based on this one fringe case, *Parallel Hearts* will not be iterated to address this phenomena but the topic will addressed in later play tests. Targeted questions and active observation focused on the male players will investigate this further and identify whether this is a serious concern or simply a 7th grade student acting out (something that is not unheard of). Games that target both male and female audiences would particularly benefit from further study into this area. If a balance can be made that benefits male and female learners equally, it would be the ideal method for creating the widest appeal.

Utilizing these observations, it is possible to iterate on the design of *Parallel Hearts* to improve its overall effectiveness. Each of these issues detracts from creating a strong motivating force for females to pursue STEM. The loss of the narrative, the appearance of gender identity conflict, as well as an atmosphere of competition were all unexpected results of the play test but are important issues that need to be addressed. While *Parallel Hearts* may not be able to overcome each of these issues specifically, the overall implications of these findings can be beneficial to later games or to other designers pursuing a similar goal.

Chapter 5: Looking Forward

Parallel Hearts has shown to be an enjoyable game that appeals to middle school females but it has yet to prove its efficiency as a teaching tool. Its inefficiency may, at first, seem to be a detrimental aspect of the game, but again, the purpose of *Parallel Hearts* is not to be a teaching tool. The game is meant to advocate STEM to the middle school female population. In this respect *Parallel Hearts* does well. Girls are considerably more likely to take the game home and play than boys. If playing the game at home, girls will gain more exposure, reinforcing the positive example of women in STEM that the game portrays. Looking forward there are numerous changes that need to be made to both the game itself and the conditions in which it play tested.

Including Cooperation and Collaboration

Parallel Hearts itself currently lacks in complex social interaction. All social interaction takes place exclusively outside of the game space. Since female players have been shown to enjoy this sort of social interaction, it is important to include it in the game. Also, collaborative learning is a highly effective teaching tool as described in the earlier section of this paper entitled "Complex and Cooperative Learning." While some cooperation takes place outside the game space it lacks in that it takes outside of the magic circle.

By keeping collaboration completely separate from game play, *Parallel Hearts* loses the benefits that the magic circle has to offer. The idea of the magic circle, originally coined by John Huizinga in his book *Homo Ludens*, is that all play has "forbidden spots, isolated, hedged round,

hallowed, within which special rules obtain. All are temporary worlds within the ordinary world, dedicated to the performance of an act apart" (10). The magic circle acts as a means to isolate the play experience. According to games theorist Ernest Adams in his book *The Fundamentals of Game Design,* "within the magic circle, actions that would be meaningless in the real world take on meaning in the context of the game" (15). This means that when a serious game neglects the magic circle, the message the game is trying to convey becomes less powerful. Instead of abiding by the rules of the game space, they step outside of them, not allowing for the separation of the real and the game. In terms of collaboration, when the game uses it outside of the game context, it no longer holds as much power as it would have within the game. The actions that were previously of the utmost importance within the game are no longer as important. The game has finished and the rules no longer apply. The deeper learning takes place outside of game, taking the learning outside of the learning/game space. The player can no longer reflect and examine their experiences because they are no longer within the game.

To better understand the phenomena, the effect can be compared to a trip to a museum. While at a museum visitors walk the halls, inspect the exhibits, and learning, theoretically, takes place. Now take two distinct scenarios. In the first, the visitor visits the museum in complete solitude. He/she looks at each of the exhibits alone, discuss them with no one whatsoever, draw their own conclusions, then leaves. This is the scenario that reflects most serious games. They are played in solitude, offering little to no means for discussion. If the visitor was then allowed to discuss with their class the exhibits they saw, outside of the physical museum, it would reflect games like *Parallel Hearts*. Despite the added benefit of this discussion, there are still some fundamental flaws with the museum experience.

Now examine the second scenario. In this scenario the museum visitors tour the museum in a group. They tour the museum together, and as they visit each exhibit, they discuss with each other their thoughts and feelings on each of the exhibits. If discourse arises during the visit the group can revisit the exhibit in question and form more informed conclusions. The latter scenario allows for a richer learning experience. It benefits from the fact that the collaboration takes place within the same context that the learning does. There is no separation, no breaking of the magic circle. In this scenario the museum halls are the magic circle. Like a game, the space offers "a protective frame which stands between you and the real world and its problems, creating an enchanted zone in which, in the end, you are confident that no harm can come" (Apter 15). Although Michael J. Apter is using these words to describe the magic circle in relation to play, the occurrence is the same. The museum offers a protected space with specific rules that allow for visitors to experience the exhibit outside of the real world. This is why maintaining the magic circle is so important.

Discussing a serious game after playing it is equivalent to discussing a museum after leaving. The player/visitor gains none of the positive effects of the environment and the magic circle. The protected space is gone and the context of the game/exhibit is no longer present. The player can no longer re-examine any area of the game in question and all actions and discussion hold less weight since the added significance of in-game actions is destroyed with the breaking of the magic circle. The key to maximizing the benefits of collaborative learning is to place this learning within the context of the *Parallel Hearts*.

A Revised Play Test

After the inclusion of cooperation in *Parallel Hearts*, the game would benefit from a better structured play test. The test population examined in this essay had far too many existing biases. The class was too advanced, scoring perfectly on the pretest, making it impossible to determine whether or not the game is an effective teaching tool. Their mastery is in part due to their advanced status but also because the class had been taught the subject matter in preparation for the game. An ideal population would be one that has not seen the content before. They would ideally score poorly on the pretest allowing for their posttest to identify if they had learned or not.

Parallel Hearts would also benefit from a longer play test period. Only one student reported beating the entire game, and only one half of the class reached the third level. This means that the students were not given ample time to complete the game and were unable to reach one third of the educational content. This shortage of time came about due to the teacher's desire to not give up a lesson for that day's class. She insisted that the class have time to continue on their regular curriculum so as not to fall behind. If *Parallel Hearts* was incorporated into the curriculum or if the teacher decided not to teach the content beforehand, this would easily be avoidable. For more cooperative teachers, simply an additional 10-15 minutes of game play time would allow for a more complete study.

Lastly, the sample size of the initial play test was far too small to prove anything with a large degree of certainty. With a sample size of only 22, none of the results have a statistical significance. All of the students could possibly be outliers, therefore by increasing the sample

size, the hypotheses presented in this essay would benefit. Furthermore, in order to tell if middle school girls are actually being motivated by the game and pursuing STEM field subject matter in high school or college, a longitudinal study is required. The enrolment statistics of the players of *Parallel Hearts* will have to be tracked, and then compared to their exposure to the game. While this particular thesis did not explore this option due to time constraints, the goal of the thesis would considerably benefit from such a study.

Despite the complications and shortcoming of the study surrounding *Parallel Hearts* the game itself was well received. During the play test students and teachers were asking for more levels to explore and for the game to be ported to tablet devices. Each student enjoyed their game playing experience and the female students said that they may even be interested in playing the game outside of class. Unfortunately, much work needs to be done to the study in order to prove anything more conclusively, especially *Parallel Hearts'* educational merit. While the players felt that they were learning something that does not mean that they were.

Parallel Hearts also proved to target the female population well. Overall, female students enjoyed the game more than males and were more likely to play it outside of class. This means that even if *Parallel Hearts* does prove ineffective at teaching it could still be used as a motivator for female students. If the game can spur interest in the STEM fields then its goal will be achieved. A new-found interest in STEM will help carry female students into the STEM subjects in high school, furthering their chance of pursuing the topics in college and eventually finding a career. In order to help end the gender gap it is essential to target the female population when they are most susceptible to losing interest. The middle school years are the formative years where one's interest in future subjects is highly influential. *Parallel Hearts* has the potential to make a large difference but will benefit from some revision.

Adjusted Game Mechanics and Polish

Parallel Hearts still remains at the first step in a long process of iteration and re-testing. For the game to be complete there are still many mechanics that need to be adjusted. Below is a list of changes proposed throughout this article:

- Shortening the narrative elements (including cut scenes and Nettle text bubbles)

- Incorporating narrative into the gameplay

- Multiplayer/cooperative gameplay

- Voice/text chat

- Adding sound

- More levels

- Alternative gender roles

- More diversified play testing

- Larger amount of playtesting

- Multiplatform support

Clearly, there is still much work to be done. *Parallel Hearts* is nowhere near completed and will take much revision to get there. Each of these new features will be added systematically to the game and then immediately play tested by the target demographic. Based on the results of these play tests, the game will be iterated on further, either including or rejecting the potential additions. Plans are also in motion port *Parallel Hearts* to multiple platforms including mobile and Mac.

Based on the results of the initial play test and the theory presented in this article, I would still adamantly advocate for the use of games in classroom. Not only are games excellent

teaching tools, but they can increase a student's interest in a subject area. Educational games need to focus less on the curriculum and more on the gameic elements. As soon as the lesson comes before the game play, the benefits of the game are lost. Students are then participating in a virtual environment that they do not want to be in and are not enjoying. Nearly all of the benefits from games stem from their enjoyable nature. If we take that away, we are doing a disservice to the educational gaming movement. *Parallel Hearts* attempted to do exactly this and found some success. All players considered the game more enjoyable than their classroom work, making it a perfect piece of a complete lesson. *Parallel Hearts* coupled with structured teaching, formalized assessment, and continued practice have to potential to make lasting educational change. While this study has shown that the educational game may not be the best teaching tool, it can still be used as a tool to add excitement to a lesson plan while reinforcing the teaching method. They can serve as motivation and inspiration to show students that not all STEM subjects are inherently difficult or boring. By targeting female students specifically, games have to potential to make lasting changes that may help close the STEM field gender gap.

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Anxiety Research Suggest?" *The Modern Language Journal* 75.4 (1991): 426-39.

Appendix A

Pretest

Below is the pretest given to the students before beginning their play session. There was no time restriction for completing the test. Most students finished within 10 minutes. The goal of the pretest was to establish a baseline knowledge before playing the game. Comparing the results of the pretest to that of the posttest will reveal how much learning took place through the game.

Name _____   Gender: M   F

Please answer the following questions to the best of your ability.

Multiple Choice:
1.

The measure of an angle is 100°. What kind of angle is this?

    A. right
    B. acute
    C. obtuse
    D. straight

2.

Which angle is **greater than** a
right angle?

A.

B.

C.

D.

3.

Which of the following shapes has **only** acute angles?

A.

B.

C.

D.
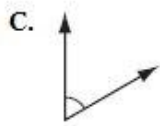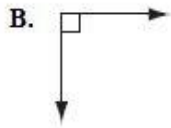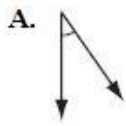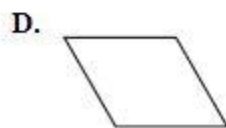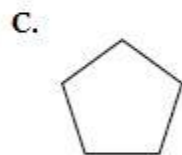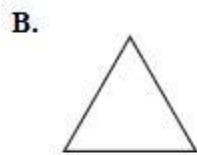
Short Answer:
4.

Line *m* and line *n* are parallel lines
intersected by transversal line *l*, as
shown below.
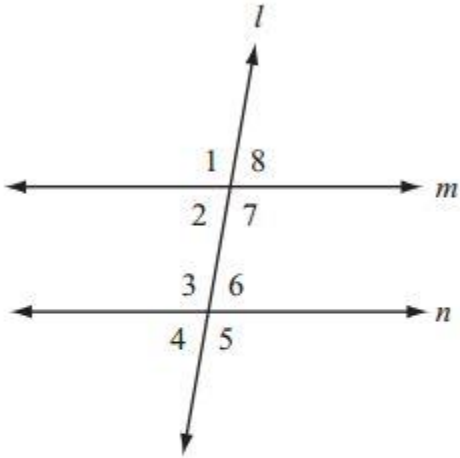
Which of the following pairs of angles
must have the same measure?

A. $\angle 1$ and $\angle 8$

B. $\angle 2$ and $\angle 6$

C. $\angle 6$ and $\angle 7$

D. $\angle 8$ and $\angle 5$

5.

In the figure below, parallel lines *l* and *m* are intersected by transversal *p*.
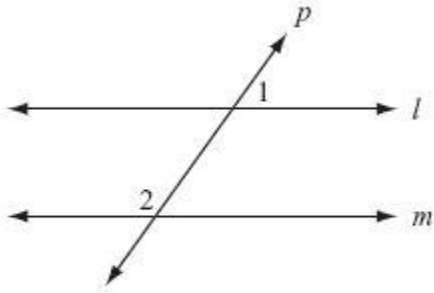
If the measure of ∠1 is 50°, what is the degree measure of ∠2?

6.

Find the missing angles

68°

Answer: _____

90°
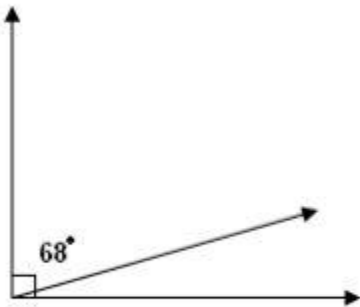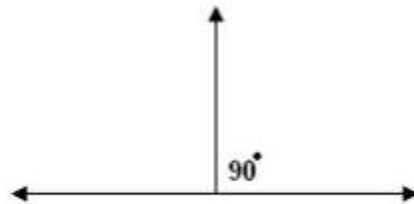
Answer: _____

7.

The figure below shows two intersecting lines.
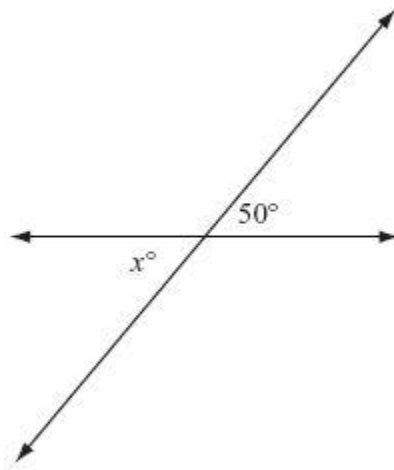
Based on the given angle measure, what is the value of x?

Appendix B

Posttest

Below is the posttest given to the students after completing their play session. There was no time restriction for completing the test. Most students finished within 10 minutes. The goal of the posttest was to establish a student's knowledge after playing the game. Comparing the results of the posttest to that of the pretest will reveal how much learning took place through the game.

Name _____   Gender: M   F
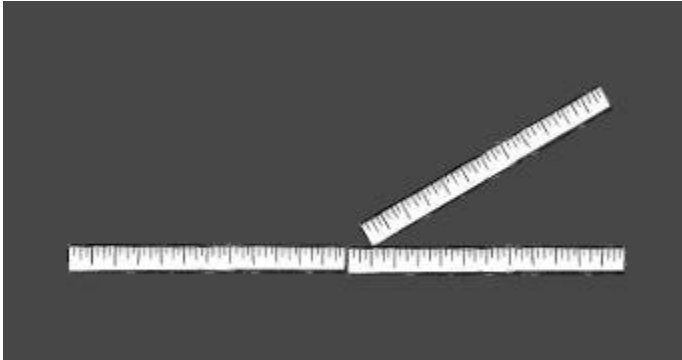
Please answer the following questions to the best of your ability.

Multiple Choice:

1. Which angle is safe for Mae to jump on?

A.

B.
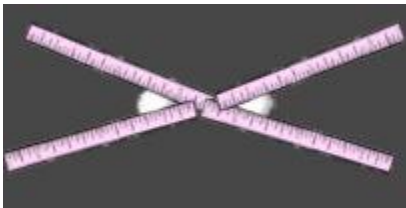
2.
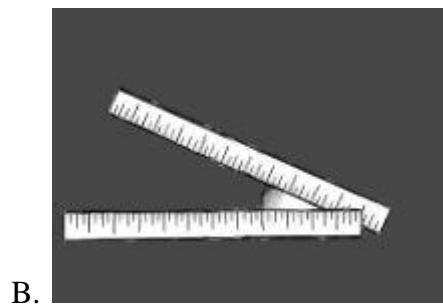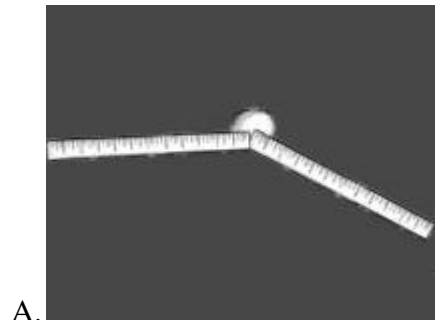
Stepping on this angle pair will cause Mae to:

  E. Be erased
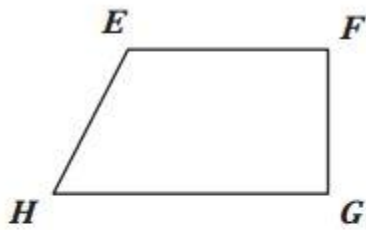 F. Bounce
  G. Fall Through
  H. Teleport

3.

Stepping on either of these angles will cause Mae to:

  A. Be erased
  B. Bounce
  C. Fall Through
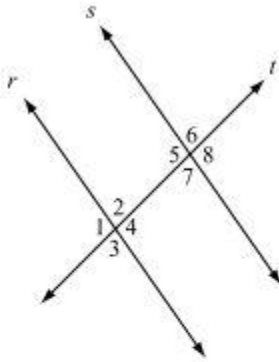 D. Teleport

4.

Elsa drew the quadrilateral shown below.

E   F

H   G

Which angle appears to be acute?

A. angle E
B. angle F
C. angle G
D. angle H

5.

Parallel lines r and s are cut by transversal t, as shown in the diagram below.

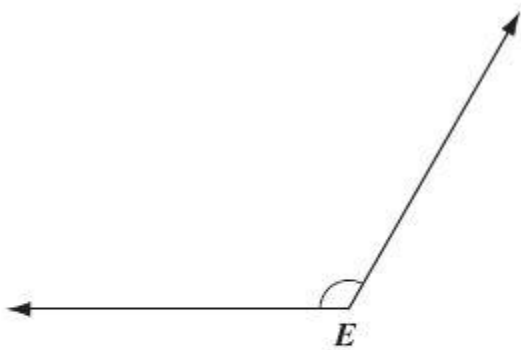Which of the following **must** be true?

A. $m\angle 1 + m\angle 5 = 180°$
B. $m\angle 2 + m\angle 8 = 180°$
C. $m\angle 1 = m\angle 7$
D. $m\angle 3 = m\angle 8$

6.

Angle *E* is shown below.

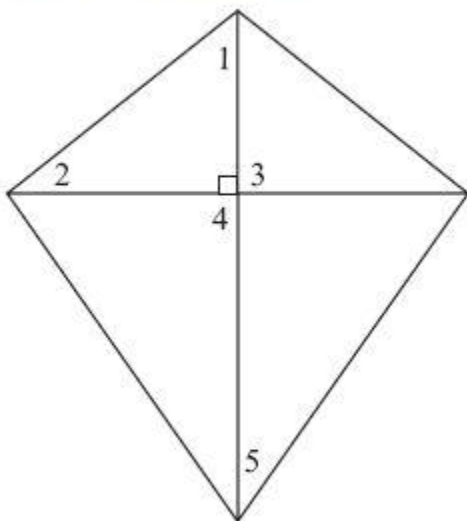Which of the following best represents the measure of angle *E*?

     A. 45°

     B. 80°

     C. 120°

     D. 200°
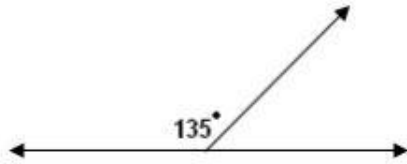
Short Answer:

7.

Gina drew the kite shown below.

Name two of the numbered angles that **must** be congruent to each other.

8.

Find the missing angles

135°

Answer: _____

24°
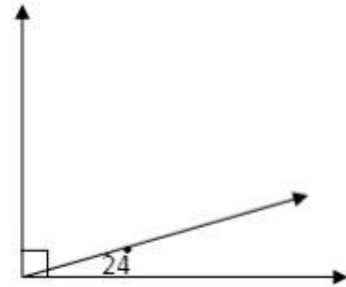
Answer: _____

9.

Six geometric terms are given in the box below.

acute	equilateral	isosceles
obtuse	right	scalene

David drew the six triangles shown below.

A

B

C

F

D

E
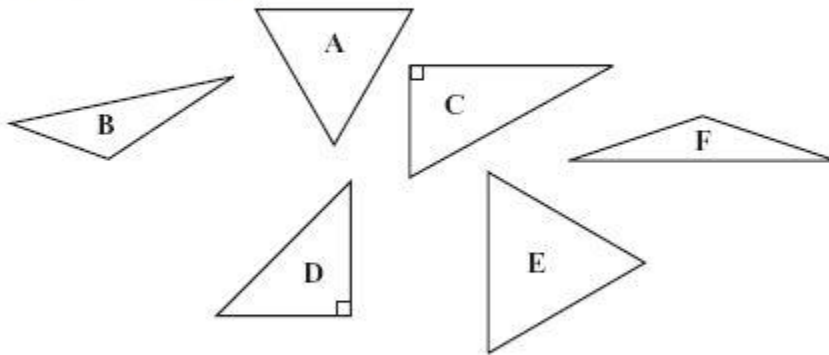
a. Identify one of the geometric terms listed in the box that can be used to describe triangle A. Explain your reasoning.

b. Which **two** of the geometric terms listed in the box can be used to describe triangle B? Explain your reasoning.

Appendix C

Survey:

Below is the survey given to the play test population after completing their play session. It was a take home survey and was collected the next day. The goal of the survey is to identify how the players felt about the gameplay experience. It measures qualitative reactions to the game.

Name_____   Gender: M   F

How often do you play video games?

    A. Several times a day
    B. Once a day
    C. 3-5 days a week
    D. 1-2 days a week
    E. Every few weeks
    F. Less often

How much fun was this game compared to normal class work?

    1   2   3   4   5

Less fun   The same   More fun

How much fun was this game compared to other video games you have played?

    1   2   3   4   5

Less fun   The same   More fun

How much do you feel you learned from this game?

| 1 | 2 | 3 | 4 | 5 |

None　　　　　　　　As much as class　　　Much more than in class

How likely are you to play this game outside of class?

| 1 | 2 | 3 | 4 | 5 |

Very unlikely　　　　　Neutral　　　　　　Very likely

Appendix D: PrePosttest and Survey Data

Pretest Scores:

Questions Wrong	Total	% wrong	Male	Female
Question #				
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	10	45	4	6
5	7	32	3	4
6a	0	0	0	0
6b	0	0	0	0
7	1	5	1	0

Posttest Scores

Questions Wrong	Total	% wrong	Male	Female
Question #				
1	0	0	0	0
2	9	41	4	5
3	3	14	3	0
Didn't get there	8	36	3	5
4	0	0	0	0
5	11	50	6	5
6	0	0	0	0
7	1	5	1	0
8a	0	0	0	0
8b	2	9	1	1
9	1	5	1	0

Survey Results

1. How often do you play video games?

	Male	Female
Several Times a Day	1	1
Once a Day	2	1
3-5 Days a Week	2	1

1-2 Days a Week	1	1
Every Few Weeks	0	3
Less Often	0	2
Average		

2. How much fun was this game compared to normal class work?

	Male	Female
1 (Less fun)	0	0
2	0	0
3 (The same	0	0
4	2	5
5 (More fun)	4	4
Average	4.67	4.44

3. How much fun was this game compared to other video games you have played?

	Male	Female
1 (Less fun)	2	0
2	4	6
3 (The same)	0	2
4	0	1
5 (More fun)	0	0
Average	1.67	2.44

4. How much do you feel you learned from this game?

	Male	Female
1 (None)	0	1
2	0	1
3 (As much as class)	6	6
4	0	1
5 (More than in class)	0	0
Average	3	2.73

5. How likely are you to play this game outside of class?

	Male	Female

1 (very unlikely)	3	1
2	2	2
3 (Neutral)	1	4
4	0	1
5 (Very likely)	0	1
Average	1.67	2.89