Minesweeper and Hypothetical Thinking Action Research & Pilot Study

by
Jacob J. Walker

Effective Education Project
5/2/2010

Abstract

This Action Research project and Pilot Study was designed and implemented to improve students' hypothetical thinking abilities by exploring the possibility that learning and playing the computer game Minesweeper may inherently help improve hypothetical thinking. One objective was to use educational tools to make it easier for students to learn the logic of the game Minesweeper. The second objective was to determine if learning Minesweeper would help students to gain the Cognitive Asset of Making inferences and hypothetical thinking. The third objective was to determine if learning Minesweeper would help students to be better computer users.

Students were presented a PowerPoint presentation that discussed the thinking involved in the game Minesweeper. Students also participated in an exercise that simulated how Minesweeper determines information presented in the game. Students also went through a simulation program about the game. Further, students played the game Minesweeper, and had one-on-one assistance during part of the process.

Participants documented their Minesweeper playing results, were assessed with a pretest and posttest about their logical hypothetical thinking, and were assessed about what they learned in the computer course. The results of participant Minesweeper playing ability were compared with the assessment of logical skills and the assessment of computer knowledge and skills. These comparisons found a potential positive correlation at an alpha of 0.10. Causation could not be determined.

Results of the pilot study suggest that further study may lead to results confirming the hypotheses, and as such a future fuller study is being considered by the writer. Educational issues with Minesweeper were discovered, suggesting that it may be better to use a variant of the game in the future study. Methodological problems which prevented the evaluation of causation were discovered, and can be addressed in the future study. It is unknown whether the research is applicable to children, but the methodology of this research may be used with any grade level to determine effectiveness.

Contents

Introduction

I was introduced to the game Minesweeper by a math teacher when I was in high school as software that is included with Microsoft Windows. The game involves a square grid of cells, where the player attempts to click on every square except those that contain a mine (bomb). If a beveled square is clicked, and does not contain a mine, it will show a number (or be blank if the number is 0). This number is the exact number of mines adjacent to that particular square. Using these numbers, the player must use deductive logic (and in some cases probabilistic thinking) to hypothesize about where the mines exist by flagging them. Then by using this knowledge, the player continues until they accidently click a mine or they win the game. An example of the game is shown in Figure 1.

Figure 1. Three screenshots of Minesweeper showing from left to right a new game, a game after a few clicks, and a completed game

I have believed that part of my generally strong math ability, success as an A+ certified computer technician, and scoring in the 99th percentile on the Watson-Glaser Critical Thinking appraisal is due to my skill in logical thinking, which I think has been honed partly by playing Minesweeper. But I had not done formalized research to attempt to confirm this belief.

Because of my experience with the game, as a computer instructor, I have included winning the game as a prerequisite to a technician work-study program that I have led. Several students who wanted to join did not pass this prerequisite, or did not wish to attempt the prerequisite. They questioned whether using a game as a prerequisite was appropriate.

Further, in my basic computer classes, I have wanted to teach my adult students how to play the game, and have attempted to do so on at least three occasions in the past. Most of my attempts were generally not very successful for most students, as judged by my informal evaluation at the time.

From these two experiences, I wanted to conduct more formalized research with Minesweeper to test my hypotheses and beliefs about the game. This paper details the process of using action research techniques in my introductory computer course for adults to start this process of verification. This action research is also a pilot study to determine whether my hypotheses have sufficient probability of being true and that further larger scale research was warranted.

I believe this research has value because if it shows the promise of Minesweeper as an educational tool that can help improve logical thinking (an important component of accurate hypothetical thinking) then it could be used to help these skills by anyone with a computer. On a global scope this could have major positive ramifications for humanity.

In the process of my action research, I investigated three questions:

1. Will using these educational tools make is easier for students to learn the logic of the game Minesweeper?
2. Will learning Minesweeper help students to gain the Cognitive Asset of "Making inferences and hypothetical thinking?"
3. Will learning Minesweeper help students to be better computer users?

To the first question, I hypothesized that I would be able to create educational tools that combined with various forms of instruction would make it easier for students to learn to play and win Minesweeper. To the second question, I hypothesized that there would be a correlation between the logical thinking involved in hypothetical thinking, and a person's ability to play Minesweeper. But, I was unsure whether I could show a causal relationship. To the third question, I hypothesized that learning Minesweeper would help students to become better computer users if Hypothesis 2 was correct. Although, I did not believe that my research methodology could show causality, so I addressed the hypothesis that there would be a correlation between Minesweeper skills and computer skills, instead of addressing the hypothesis of causality.

Review of Literature

Using Games to Teach Cognitive Skills

The use of games to attempt to teach cognitive skills goes back to ancient times. It is thought that the game now known as "Go," is possibly one of the first games that were used to teach mental ability. Although there are several theories, one popular myth suggests that a Chinese emperor around 2100 BC taught his son the game to help him improve his thinking (Fong & Brooks, 1994). Although the myths differ in the results of the son learning the game, and evidence is not clear on whether the myths are correct, it still shows that the idea of using a game for teaching extends back in history.

Chess also has a history of being used to teach thinking, one legend suggests that the philosopher Philometer created the game in the late middle ages to teach the king to live a virtuous life (Adams, 2006). While Chess likely existed previous to the time of this legend, the legends about Chess and Go both show that people have believed that these games had the ability to help a person learn things beyond the game itself.

Psychological and educational studies of Chess and Go, along with other games, have had mixed results as to whether they really have cognitive and educational value. Several studies with chess suggests that learning chess can help with math ability, although a study by Thompson (2003), which controlled for IQ showed no scholastic improvement. Further, research by Horgan and Morgan (1988), suggests that spatial abilities are more correlated to chess playing abilities than logical abilities. Other games have shown to be effective in helping people to learn mathematics, and at least one game has been shown to be at least equal in helping people learn logic as lecture methods (Hays, 2005). Video games have had only a small amount of research done to demonstrate a connection between playing specific games and gaining in logical abilities (Kirriemuir & McFarlane, 2004). It should be noted that different games have had different results based upon research, and that many of the studies into the educational value of different games may have had methodological flaws (Hays, 2005).

The game Minesweeper, and its variants, in contrast to many of the other games studied for cognitive effects, is recognized to utilize direct logical thinking (Mackenzie, 1999). In 1995, Allan Struthers started to use the game Mine Hunter, a Minesweeper variant, as an educational scaffolding technique to introduce proofs to students (Struthers, 1995). His success was later replicated by Patti Frazer Lock in 1999, to use the same techniques in her classes to help teach mathematical proofs (Lock, 1999). Further, Minesweeper may be a “content-free” method of teaching logical thinking, based upon the idea that the content of the educational tool is thought itself. This might be similar to Feuerstein’s Instrumental Enrichments which have shown some possibility of increasing intelligence (Blagg, 1991).

The Value of Logical Hypothetical Thinking

Wilson and Conyers suggest that Hypothetical Thinking is a "Cognitive Asset," which they define as skills that are related to thinking which are of extraordinary value. Wilson and Conyers have defined 26 such assets that they believe are important for students to posses to gain executive intelligence, which they suggest is what helps "exceptional leaders produce exceptional results" (D. Wilson & Conyers, 2006, p. vi). Wilson and Conyers define the cognitive asset of Making Inferences/Hypothetical Thinking as "The ability to solve problems and create new information by making inferences based on the information given. To go beyond what is said to a logical conclusion that is not explicitly given." (p. 143) Further, they state the goal of the teacher should be to "To create within students the understanding of the importance of making correct inferences and thinking beyond the given in a logical manner" (p.143).

Hypothetical reasoning is a central topic in cognitive science and is a major component of what is known in Dual Processing Theory as Type 2 Processing done by our brains. Type 2 processing is what allows us to generally analyze possibilities and make rational decisions, compared to what is usually our default thinking, which is called Type 1 processing. Type 1 processing is fast and automatic, but often leads to wrong conclusions. Research is showing that instrumental rationality, defined as behaving in the world so you get what you want given your resources, is reliant upon Type 2 processing, and having good logic skills combine with specific types of thinking dispositions. Further, research suggests that IQ does not have a major correlation with instrumental rationality (Stanovich, 2009).

Correlation of Logical Skills to Computer Skills

Several studies have found a positive correlation between a student's mathematical background and their success in an introductory college level computer science course (Campbell & McCabe, 1984; Coates & Larry Stephens, 1990; B. C. Wilson & Shrock, 2001). Specifically, Konvalina, Wileman, and L. J Stephens (1983) found that mathematical reasoning, including logical ability, was a key factor in predicting the success of Computer Science students.

It should be noted that a Computer Science course is generally at a higher mathematical and logical level than an introductory computer literacy course. Most literature about computer literacy has focused on attitudes and not pre-requisite skills or aptitudes, and not on skills.

The previous successful use of Minesweeper to assist in teaching logical proofs, and the importance of logic in hypothetical thinking and computer usage, suggests that learning Minesweeper may inherently help people to improve their hypothetical thinking and computer usage.

Design and Methodology

Participant Characteristics

The action research project/pilot study was conducted during and after an adult introductory computer course in a generally economically depressed area. It was conducted in a northern Californian suburban Adult School. The participants of the study were those who voluntarily joined during the fourth week of a six-week course. Several students were not in attendance during the times the pretest was administered, and did not join the study. There were a total of 19 participants who completed the pretest, although many did not complete other parts of the study.

Of the total participants, 68% are female, and 32% are male. The participant ages ranged from being in their 20's to 80's, with the majority (eight of them) being between 50 and 60 years old. A large minority (28%) of the students are first generation Americans, and many of them are still learning English. The educational level of the participants vary significantly with 22% not having a high school diploma, 33% having their high school diploma, 28% having some college or an Associates degree, 11% having a Bachelor's degree, and one participant (making up 6%) having a Ph.D. The vast majority of the participants (74%) are seeking employment and are specifically in the class to gain computer skills to improve their ability to get a job. Most of the other 26% are retired, and in the class for enrichment purposes, such as being able to better communicate with family and friends using the Internet.

Sampling Procedures

The study included the majority of students in my introductory computer course. These students voluntarily joined the study, and signed a form stating that they chose to participate (See Appendix A). While I offered for all students to join the pilot study, I attempted to make sure that all students did so voluntarily, and were not required to join if they didn't want to, or felt uncomfortable. I further explained how any reporting of data I did would keep their identity anonymous with no personally identifiable information, but due to the small size of the class, that if someone gathered additional information beyond my report, they might be able to identify individual identities. This is a potential problem of any study, and never can be fully mitigated. I have attempted to follow all the guidelines of the APA and FERPA and other federal regulations. I believe that my research is within the boundaries of the Common Rule of the Federal Regulation for the Protection of Human Subjects, since it is "Research in educational settings involving educational practices."
(§ 101 (b) (1))

Measurement Approaches

Demographic information of participants was collected by a Scantron® registration form that all students submit upon entry into the school. The logical assessment pretest was administered in written form, and the posttest was administered online. Each logical assessment had 14 questions, each question having three components. First, each question included a piece of knowledge generally placed in an "if… then…" form, although some questions used a syllogism form ("All" or "Some" of x are y). The next component was a hypothetical situation that involved part of the knowledge. Then a question was asked based upon the knowledge and hypothetical situation, and the participants were given the multiple choices of "Yes," "No," and "Not enough info." The questions were modeled after the research done by Hadar (1975), in which she worked with fifth grade students to teach them valid and invalid logical inferences. I chose to have many different types of questions on the assessments to see if any one form of question had more of a potential correlation with Minesweeper than another, but this decision also reduced the reliability of the test results. The specific logical forms of the questions are shown in Table 1, and all questions are shown in Appendix B.

While each question related to computers and I attempted to have the knowledge piece being as accurate as I could, the tests questions relied solely on logic and could be answered correctly with only knowing logical forms without content. I made the decision to not review the pretest results until after the post test results, because I did not want to bias my teaching and study based upon what I learned from the pretest results.

Table 1. Logical forms used in the logic assessments.

Type of Question	Form of Question	Correct Answer	Total Questions
Modus Ponens	If A then B. A. Is B True?	Yes	Pretest: 1 Posttest: 1
Modus Tollens	If A then B. Not B. Is A True?	No	Pretest: 2 Posttest: 2
Affirming the Consequent	If A then B. B. Is A True?	Not enough info	Pretest: 3 Posttest: 3
Denying the Antecedent	If A then B Not A Is B True?	Not enough info	Pretest: 2 Posttest: 2
Logical Biconditional (Positive)	If and only if A then B B Is A True?	Yes	Posttest: 1
Logical Biconditional (Negative)	If and only if A then B Not B Is A true?	No	Pretest: 1
Logical Conjunction*	If A and B then C A Is C true?	Not enough info	Pretest: 1 Posttest: 1
Universal Affirmative (Modus Tollens)	All A is B Not B Is A?	No	Pretest: 1
Universal Affirmative (Denying the Antecedent)	All A is B Not A Is B?	Not enough info	Posttest: 1
Particular Affirmative	Some A is B B Is A?	Not enough info	Pretest: 1
Particular Affirmative	Some A is B A Is B?	Not enough info	Posttest: 1
Spurious Correlation*	A correlates to B A Is B?	Not enough info	Pretest: 1 Posttest: 1

Note: Those questions designated with an * are not reflected in participants' scores due to ambiguity in the question. See changes for more details.

Every participant was given a Minesweeper journal that included asking them if they had played Minesweeper previously, and if they played other logical games such as Sudoku. Then, for each date in the study, students could enter the approximate total length of time played for that day, the number of games played, the number of games won, how long it took to win the games, and a spot to enter any comments or thoughts that they wished. The participants were instructed that they could use more than one line for comments, just make sure they clearly indicated which date the comment belonged to.

Further, at the end of the introductory computer course (second week of study), I gave a final test to all of the students in the form of e-mails sent to and from the students. I measured the difference in timestamps between when the instructions were e-mailed for the second segment of the test, and when the students e-mailed back a correct answer. In the test, students were allowed to continue to work on the problem until a correct answer was achieved.

The second segment of the test involved students correctly entering a URL (web address) into their web browser, and then analyzing four claims that were presented to them that were "urban legends." The students needed to use Internet resources to determine whether the urban legends were true or false, and send back where they found the information. The students only needed to get the validity of two of the urban legends correct to continue in the test. (See Appendix C for full instructions given to the class.)

This segment of the test was chosen because the first segment could not accurately have its time measured as the first instructions in the test were given out on paper. The other segments that occurred after the segment chosen did not have sufficient people complete them within the original class time, or had a component that was more of a "trick" question, such that I did not feel they were accurate representation of students actual ability.

This segment also involved the most critical thinking since students needed to research whether something was true or false, with different websites sometimes having conflicting information, and then needed to use their own logic to determine the validity of the claim. The total time it would take a student to complete this section would approximately be the "sum" of their ability to enter URLs, speed in reading, ability to search the Internet for information, ability to rationally decide about information presented, ability to write an email, and speed in typing. Due to the multiple skills involved, it is not possible to know if a correlation exists between any specific skill, and a lack of skill in any area could dramatically change the amount of time required to complete that segment. But, since this was my standard test, and the time does not generally lower student scores, I did not wish to change it based upon the academic needs of my students, and must accept its limitations for the purposes of this pilot study.

I also kept a journal of my thoughts about the events occurring in the class, that included information from informal interviews and dialogue I had with the participating students. Due to the amount of outside events occurring, I would generally journal at least one day after the events occurred in class. While this gave me more time to reflect, and potentially subconsciously process the events before journaling, it may also have reduced the crispness of memory such that fewer details may have been included (See Appendix G).

Research Design

The action research project/pilot study occurred over an eight week time period, with two initial weeks occurring in the introductory computer course where the students were given approximately 30 to 45 minutes each day to play Minesweeper. Six weeks occurred in other courses, or outside of being in a course, depending upon whether the participants joined subsequent courses offered. Participants were not given time to specifically play the game in classes beyond the introductory computer course, as it could not be assumed that the majority of the students in the other courses were participating in the study, and it would not be fair to them to take time away from instruction that they paid for.

To answer the first question, will using these educational tools make is easier for students to learn the logic of the game Minesweeper? I created three educational tools to help the students to understand the game. I then shared these tools and observed the participants in the classroom and talked with the participants personally.

The first educational tool I introduced was an Excel spreadsheet that showed a simulated board (See Appendix D), with mines already placed and shown, and the participants needed to type in the numbers for the mines in each cell, just as Minesweeper would. It had been my past observations that many students could not play Minesweeper partly because they did not understand the rules of the game.

The second educational tool I introduced was a PowerPoint presentation about what I viewed as important components to winning the game (See Appendix E). These components were metacognitive in the sense that they were about the thinking process involved in the game Minesweeper, and about other types of problems. The specific points included in the presentation were:

1. One must understand the rules (system), otherwise everything is just "shooting in the dark"
2. The strategy is to eliminate possibilities where possible to reduce or eliminate the need to guess.
3. A wrong hypothesis (assumption) will lead to a wrong conclusion, and lead to failure.
4. Paying attention first to what is solvable, leads to more information that can be used to solve what originally was not possible.

The third educational tool I used was a stand-alone PowerPoint presentation that acted as a simulation and computer based training for Minesweeper (See Appendix G). This program walked students through a theoretical game of Minesweeper, and had the students attempt to take action at key places in the game.

In addition to these non-traditional educational tools, I also lectured and worked one-on-one with the students on a nearly daily basis for two weeks, giving the students between a half-hour to an hour each day to practice the game for eight days. Most of the lecturing and one-on-one help was focusing on tactics to take in the game and understanding the rules of the game.

To answer the second question, will learning Minesweeper help students to gain the Cognitive Asset of Making Inferences and Hypothetical Thinking? I compared the pretest and posttest scores of the participants, and also compared their average score of both tests combined to the average number of Minesweeper wins.

I realized that I could not fully answer my third question, will learning Minesweeper help students to be better computer users? While I would like to know if there is a causal relationship, due to the fact that I was teaching my students computer topics at the same time they were participating in the Minesweeper survey, any pretest and posttest methodology would not be appropriate, as it would be impossible to distinguish between what gains were due to normal instruction, and what gains were due to Minesweeper. As such I compared the average number of wins a student had compared to how fast they had correctly answered part of their computer course final exam, which could attempt to show a correlation.

Changes

My original plan was to use a Minesweeper variant that I had programmed called Phreatapolis to test out my hypotheses. While I programmed the basics of the game in time to do the pilot study for my Masters program, I did not have sufficient time to debug it to a level where it would be usable by the majority of my students. Thus I went back to using Minesweeper, which is what I used for the plan for this particular project.

The time line of my pilot study needed to change slightly, primarily due to unforeseen personal issues and large professional responsibilities which included coordinating a full accreditation, preparing to move facilities, and more. These issues caused me to need to not teach one of the computer courses that I had planned to teach, and also put me more out of touch with some of my participants than I would like to have been. These issues also resulted in the postponing of administering the posttest, and needing to give the posttest online instead of in-person.

Two of the question types on the test were not counted towards participants' grades on the pretest and posttest. The logical conjunction question was not counted due to the ambiguity on whether the second event did not occur. Because of this ambiguity, the correct answer should be "Not enough info," but one could also argue that since the question wasn't explicit about the second part, then it could be assumed to not have occurred, and thus the answer could be "No." I also decided to not count the answers to spurious correlation in my final determination of a participant's score, due to the majority of participants answering "no," which most likely meant "no, there is no correlation", instead of choosing "not enough info."

I also did more interviews/personal conversations with students than originally planned, to attempt to find specific cognitive problems participants may have been having with becoming competent in playing the game. Further, I created a new game called Deductive Squares (See Appendix F), which can be played purely with pencil and paper (similar to Sudoku or a crossword puzzle). Due to the before-mentioned issues with work, I did not have time to share this new game with the participants during the pilot-study, although I have plans to share it with them and others afterward.

Results

Due to the small sample size, and lack of a random sample of the population, the results of the action research can not accurately be generalized. But, as a pilot study, the results can help to suggest whether further study is likely to be fruitful. As such, in my statistical analysis I generally used a .10 alpha instead of the .05 alpha that is traditional for educational research. This means I would generally be 90% sure of my results instead of 95%. Although, with the small sample size, I believe there is greater likelihood of bias in the sample, which can not easily be adjusted for in the calculations, since I'm not sure what the specific biases may be.

Hypothesis 1

The quantitative and qualitative data paint conflicting pictures to the answer, will using these educational tools make is easier for students to learn the logic of the game Minesweeper? Based upon the overall win ratio of the game, it was clear that within the amount of time of the study that many participants did not learn to play the game well. To test what should be considered an expert winning ratio, I played the game on the beginner level 10 times in a 10 minute time-frame, and won 60% of the games. A past small study showed that an estimated average human performance at the game was a 35% win ratio for those who play the game on an 8 x 8 board with 10 mines (Castillo & Wrobel, 2003). It should be noted that the current game of Minesweeper uses a 9 x 9 board with 10 mines, and thus the current average win ratio should be higher.

Based upon the documentation in their journals, four participants won less than 10% of the time, and based upon not keeping journals, but telling me that they never or rarely won, another five students are known to have won less than 10% of the time. Thus 9 out of 19 participants never learned to win the game more than 10% of the time. Only two students learned to win the game 50% to 60% of the time. I suspect that these two students would have learned to win at this ratio without the help of any educational tools. There were three participants who won the game 20% to 30% of the time. I believe these students likely directly benefited from the educational tools and help provided. Five of the participants did not keep journals of their wins, nor verbally shared with me how well they did.

While the quantitative data suggests that I was not successful in using the educational tools with nearly half of the participants, my qualitative data shows that my hypothesis may still be possible. First, it is important to understand why players lose a game. From my observations of others playing, my own experience playing, and my knowledge of the game, I propose that most games are lost for one of the following reasons:

- Players must randomly guess at first, which leads to a high proportion of games that are lost in the first few moves.
- Players often run into a situation at the end where they must guess the location of a mine.
- The players do not understand the rules of the game; specifically, they do not understand what the numbers mean, and/or they do not

understand what the beveled squares are vs. the non-beveled squares mean.

- Players focus on an unknown square instead of a square containing information about the unknown squares.
- Players do not understand the strategy of deductively eliminating possibilities, and instead guess.
- Players do not work on the parts of the board that are solvable, but instead focus on areas that can not yet be deductively solved.
- Players make a wrong hypothesis which leads to a wrong conclusion, which leads to a losing a game.
- Players click the wrong mouse button, or make another physical skill mistake.

The first two of these problems are simply part of the nature of the game and unavoidable. If I do a fuller study with different software (either Phreatapolis or Deductive Squares), I will make sure that these problems can not occur in the game, as they add an unneeded element of randomness to the study. The problem with clicking is likely a symptom of not enough practice, and would likely generally be reduced with sufficient practice. All the other problems that occur are problems caused by cognition of the players and thus can be reduced, or in some situations possibly eliminated.

I observed that by using a spreadsheet to teach the students what the numbers mean in the game, and having them practice three times in creating their own numbers based upon the rules, they more fully understood the rules than students did in the past. I also observed that several students didn't fully understand the rules with the practice, although they seemed to grasp them better than previous to doing the Excel practice. I believe if all the students had sufficient practice, they would get the rules. Further, a few students expressed that this exercise alone was an interesting game.

In my individual private dialogue with some students, I asked questions to attempt to determine what cognitive processes were occurring when they played the game, and in one case had a participant verbalize her thinking process. From these conversations I determined that many of my students, while understanding the rules of the game, struggled with the strategy.

There were two strategies they tended to struggle with. First, they would often focus on the unknown square and then look at the known information around it, as opposed to the effective strategy of focusing on the known knowledge, and deciding which squares with unknown information

Also, often in conjunction with focusing on unknowns, they would also focus on groups of squares that did not contain information that was useful in the moment. For instance, while one square on the right side of the board might contain information that would allow some unknown square to be deduced, the participant would be trying to focus on square on the left, that did not currently contain information that would allow a sure deduction. And if they had focused on the area that could be deduced, it would then often produce information that would allow the other unknown areas to be determined later in the game.

Students would also often make wrong deductions because of these first two problems, or simply from a mistake, which would lead to the game being lost later. Also, due to learning computer skills, some would often click the wrong mouse button, so instead of flagging a mine as an unsafe area, they would click on it thus losing the game.

From listening to my students, I realized that one of the problems with learning Minesweeper, is that once a wrong move was made, the game would be lost and the player would need to start from the very beginning again. In the version of Minesweeper that comes with Windows Vista and 7, a player can repeat the same level, but this was not the case in the Windows XP version of Minesweeper most of the participants played. Because of this "instant death" feature of the game, learning from experience by making a proper choice is often not possible. And research has begun to suggest that learning comes from success and not failure (Joelving, 2009).

Also, there is no built-in ability in the game to write out thoughts, unlike a pencil and paper logical problem like Sudoku. As such, players must only think inside their minds, or verbally think, but not being able to write out ideas. The past use of Minesweeper as an educational tool to teach mathematical proofs, was generally by showing students a virtual Minesweeper board, and by having them do pencil and paper exercises with these virtual boards. This brought me to the belief that if students could do pencil and paper practice with Minesweeper, that they might learn the game better, or gain the same logical skills as I believe Minesweeper teaches. I have named this new pencil and paper game, Deductive Squares. During the time frame of the action research, I was not able to share this educational tool with the participants, but plan to see its effectiveness with future research.

Hypothesis 2

While I set up my pilot study to attempt to show the possibility of causal relationship between learning Minesweeper and improving in logical skills, due several factors it was not possible for me to interpret the data in a way that would suggest whether my hypothesis was correct or not. But, I was able to successfully show the possibility of a correlation between general playing ability and logical ability.

After administering the pretest, I specifically did not look at the results to not attempt to bias my general instruction in a way that would cause me to inadvertently teach the skills I saw missing in my students. Also, the assessment was set up to be questions about computers that should all match reality. As an internal test of whether the assessment would accurately evaluate logical ability, or if the participants' knowledge of computers would also influence their answers, I had a trick question. This question stated the knowledge, "If the power button is pressed, then the computer turns on" and then stated the hypothetical situation "The computer is on" and asked "Was the power button pressed?" This question is in the form of the fallacy Affirming the Consequent, since it presents "if A then B" and then says B is true, which means that there is not enough information to know if A is true or not. Only 2 out of 19 participants got the answer to this question correct while on other Affirming the Consequent questions up to 5 participants got the questions right.

Although I can not be sure, especially since so many participants struggled with all the Affirming the Consequent questions, I believe that most of the participants probably believe that this is an if and only if question, as they don't know the possibility of other methods a computer can turn on (in fact there are two other obscure methods, including having a wakeup in the BIOS or having Wake on LAN set up) But research has shown that many people have problems with syllogistic reasoning when the answer conflicts with the beliefs of the students. For instance, in the syllogism "All living things need water" and "Roses need water" therefore "Roses are living things" is a logical fallacy because while roses are living, the premises do not support the conclusion. About 70% of university students answer that question wrong (Stanovich, 2009).

I also chose to use a different posttest than pretest, and while the number of types of questions were equivalent in the two tests, there were differences in the common sense answer. For instance the posttest had a similar question about the power button, with the same knowledge about the computer turning on if the button was pressed, and then gave the hypothetical situation that the computer was off, and asked if the power button was pressed. In this case the logical answer was No, as the question followed the logical form of Modus Tollens (If A then B, Not B, therefore Not A). For that question 90% of the participants got that question correct, while other Modus Tollens questions on the pretest as low as 42% of the participants got them correct.

Because of unknown variability of how much preconceived knowledge affected participant answers, and that the posttest and pretest were not the same, I do not feel that any comparison between the two could provide an accurate view of how students either improved or did not improve in their logical abilities. See Table 2 for results from both assessments.

Table 2. Correct Answers by Participants on Assessments of Logical Skills.

Question Type	Test Question	1	2	4	6	7	8	9	10	11	14	15	16	17	18	19	22	23	24	25
Affirming the Consequent	1.01	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●	●	○
	1.04	○	●	○	○	○		●	○	○	●	○	○	○	○	○	○	○	○	○
	1.09	○	○	○	○	○	○	○	○	○	●	●	○	●	●	○	○	●	○	○
	2.03		○	○		○		○		○	○	○			○	●		○		
	2.05		●	○		●		○		○	●	○			●	○		●		
	2.11		●	○		○		●		○	●	○			○	○		○		
Denying the Antecedent	1.05	○	●	○	○	○	○	○	○	○	○	○	○	●	○	○	○	○	○	○
	1.07	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●	●	○
	2.04		●	○		○		○		○	●	○			○	○		○		
	2.09		●	○		○		○		○	○	○			○	○		○		
Eliminating Possibilities	1.14	●	●	●	●	○	●	●	○	○	○	●	●	●	●	○	●	○	○	●
	2.14		○	●		●		○		○	●	○			○	●		○		
Logical Biconditional	1.10	●	●	○	●	●	○	●	●	●	●	●	●	○	●	○	●	○	●	○
	2.10		●	●		●		○		●	●	●			●	○		●		
Logical Conjunction	1.02*	○	○	●	○	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○
	2.02*		○	○		○		○		○	○	○			○	○		○		
Modus Ponens	1.06	●	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	2.06		●	●		●		●		○	●	○			●	●		●		
Modus Tollens	1.03	○	●	○	○	●	○	○	●	○	●	●	●	●	○	○	●	○	○	○
	1.11	●	○	●	○	●	●	●	○	○	○	○	●	○	●	○	●	○	●	●
	2.01		●	●		●		●		●	●	●			●	○		●		
	2.07		●	●		●		●		●	●	●			●	●		●		
Particular Affirmative	1.08	○	●	○	○	○	○	○	○	○	●	●	●	●	○	○	○	●	○	○
	2.08		●	●		●		●		●	●	○			●	○		●		
Spurious Correlation	1.13*	○	○	○	○	○	○	○	○	○	●	○	○	○	○	○	○	○	○	○
	2.13*		○	○		○		○		●	●	○			○	○		○		
Universal Affirmative	1.12	○	●	●	○	●	○	●	●	●	●	●	●	●	●	○	●	●	●	●
	2.12		○	○		○		○		○	●	○			○	○		○		

Note: Correct answers are marked with a ●, incorrect answers are marked with an ○. Blank spaces indicate that the question was not answered (Generally because they didn't take the posttest). Questions marked with a * were not included in test scores.

In addition to the problem with the pretest and posttest not being comparable, it was also not possible to determine the improvement in game playing ability in all participants. The average percentage of games won per day did not consistently improve for all participants, and for some participants the percentage of wins per day changed apparently randomly (although some of this was due to playing a small set of games in a session, for instance Participant 4 played several sessions with just 1 game, and won, thus having the maximum ratio for that session.) See Figure 2 for full chart of percentage of games won per day for each participant.

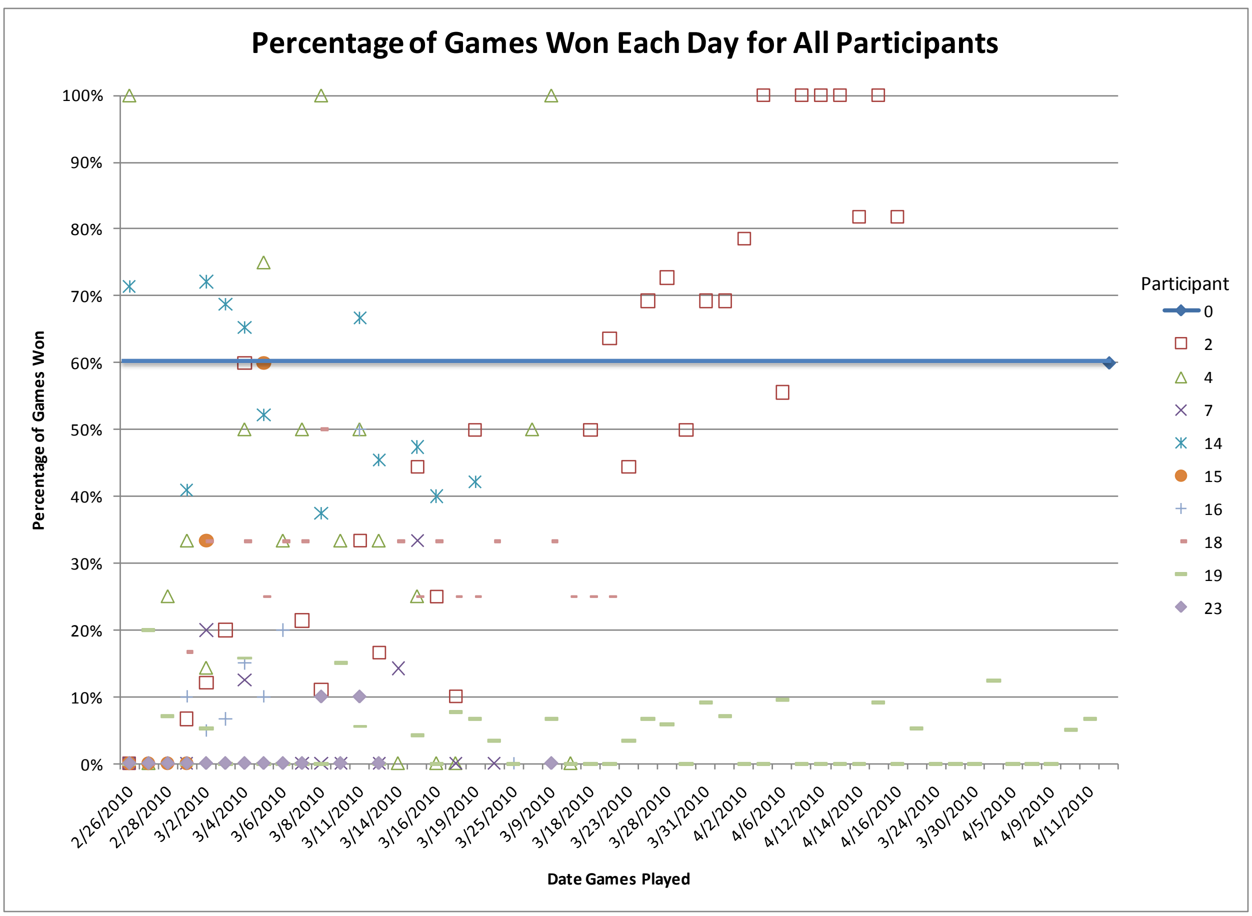


Figure 2. Chart of Percentage of Games Won for different participants based upon their journal entries. Note that participant 0 is me running a test group of games, and winning about 60% of the time.

Another measure that was more consistent was the change in speed that participants won the game as shown in Figure 3. But while many participants showed a trend of getting quicker at winning a game, some participants told me that they focused on speed (for example, Participant 14) while other participants focused on accuracy (for example Participant 2). While internally their changes in speed were fairly consistent, it would not be logically correct to compare the improvement in speed Participant 2 made with the improvements of Participant 14. Thus neither the measure of the percentage of wins in a session, or speed of wins provided a good measure to compare with the logical assessments to see if they correlated with improvement.

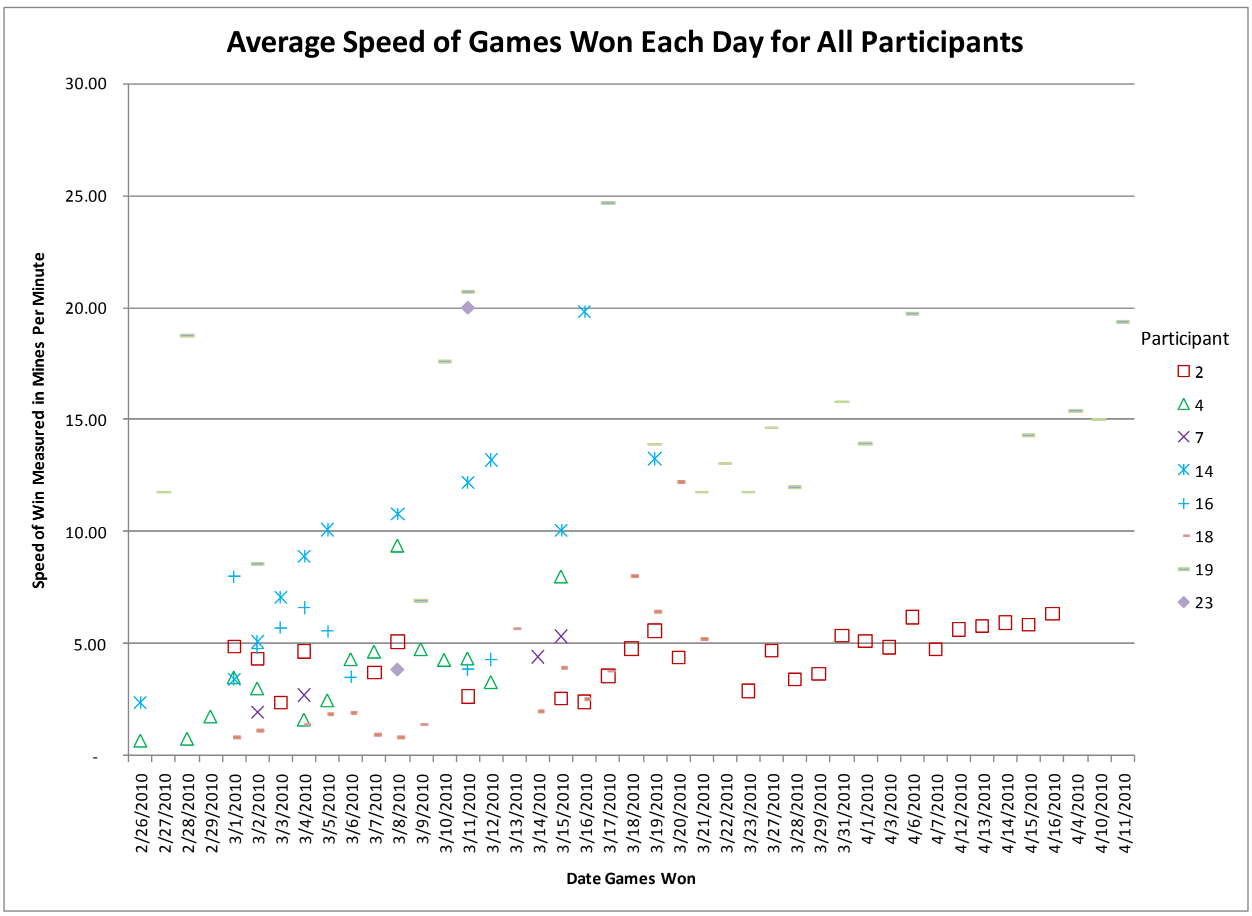


Figure 3. Average Speed of Games Won, measured in Mines Per Minute, for each day for all participants.

While neither percentage wins per day, nor speed of wins can be used to determine causation, it is possible to look for correlation by using the average percentage of wins for all days compared to the average overall score of the participant from the pretest and posttest of logical assessment as shown in Figure 4. By doing so, a potential correlation can be determined. In fact a linear relationship appears to exist with the equation

$y = 0.5x + 0.37$ where x is the percentage of Minesweeper games won, and y is the percentage of correct overall on the logical assessments. This had a coefficient of determination of .45, and with an alpha level of .10 the null hypothesis that there is no linear correlation is rejected, resulting in a weak positive correlation.

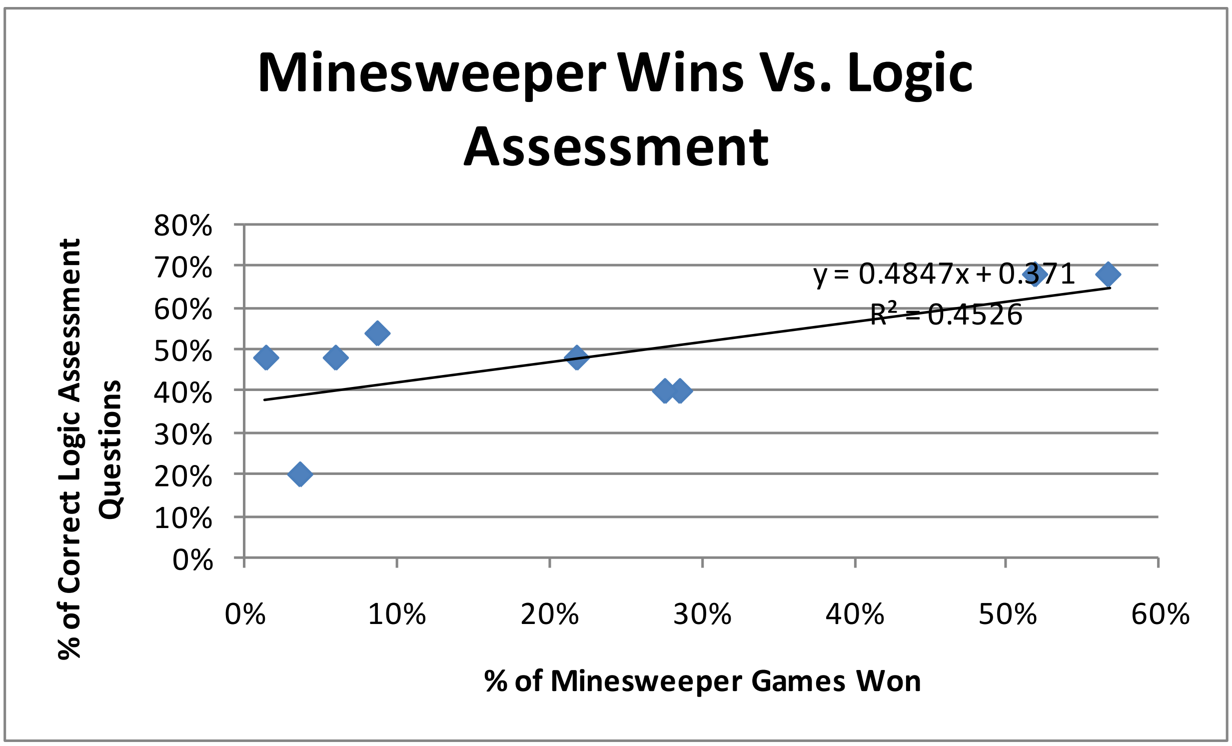


Figure 4. Individual participant results comparing overall percentage of games won with the percentage of correct answers on the logic assessments. The trend line shows potential correlation.

Hypothesis 3

The methodology of this study attempted to determine a possible correlation between Minesweeper skill and computer skills, but not causation. Nine of the participants took the final exam for the introductory computer course; eight of them completed the second segment of the final test within the allotment of time in the class. When comparing percentage of games won to test segment completion times, as shown in Figure 6, there are two ways to look at the data. It is possible that there are six points that correspond well with an equation, and two outliers which simply don't match the pattern for some reason. Or the outliers should not be removed from the pattern, and there is very little correlation between variables.

Given this is a pilot study looking for potential areas where future research could possibly find a correlation, I made the assumption that six of the participants followed a pattern, and the other two did not. (And in fact, with at least one of the participants that does not follow the pattern, I know there is a valid reason why) The six participants in the pattern have data that fits the equation $y = 0.06e^{-1.7x}$ where x is the percentage of wins with a coefficient of determination of .81. The t-test against the null hypothesis that there is no correlation with these six participants has a t (obtained) of 4.11, which gives an alpha level of .02.

While the direct correlation between Minesweeper ability and computer ability has the potential to be strong, my original hypothesis was that it would in fact be the logic ability of the participant that would cause the stronger computer ability. But analysis of comparing a participant's average score on the logic assessments they completed, and the time it took them to complete the segment of the computer final shows no apparent correlation with any logical equations as shown in Figure 5.

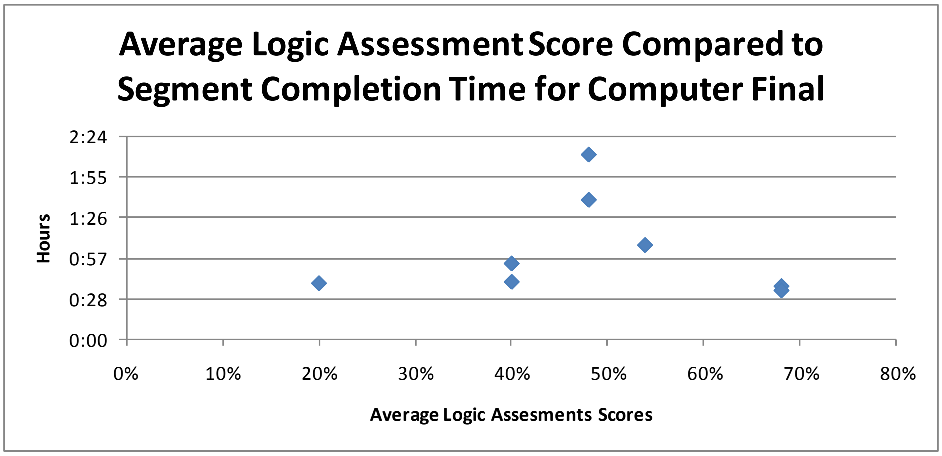


Figure 5. Comparison of participant logic assessments scores with the time it took to complete segment 2 of their computer final exam. No meaningful potential correlation could be found with data.

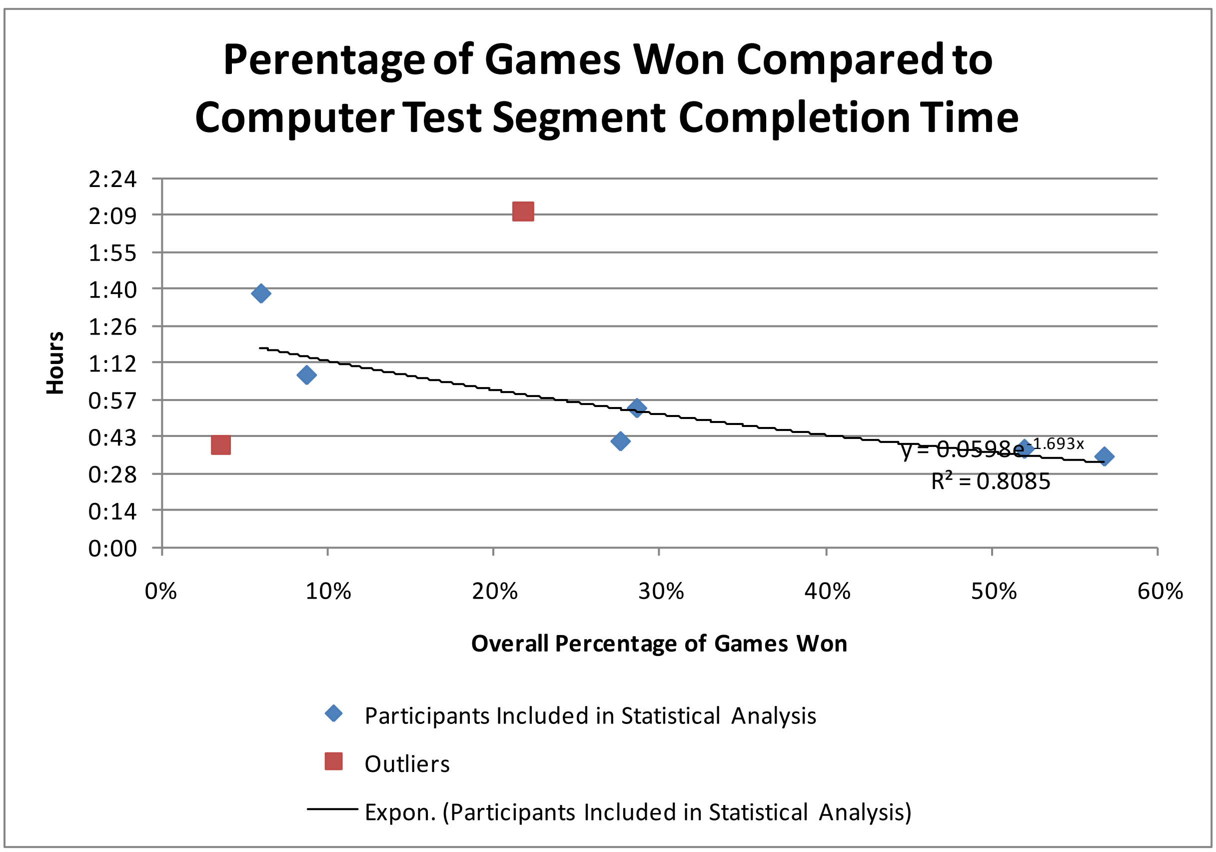


Figure 6. Percentage of overall games participants won compared with the completion time in hours for segment 2 of their computer final. Note the results that are being assumed to be outliers.

I also investigated the potential correlation between general education level and completion times of the segment as shown in Figure 7. This also had a well fitting correlation, without the need to remove any outliers from the data set to get the fit. Using regression analysis in Excel, an equation of $y = 0.24e^{-0.14x}$ where x is maximum grade level the participant achieved. This has a coefficient of determination of .47. With this coefficient of determination the null hypothesis is only precluded with an alpha of .10.

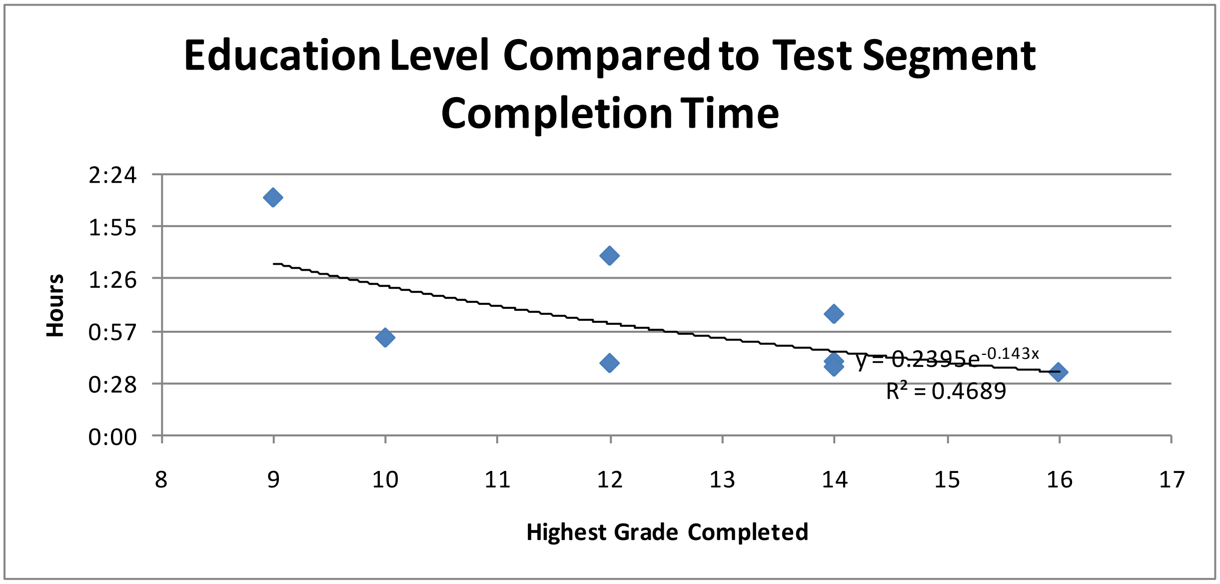


Figure 7. Participant education level compared to segment 2 completion time in hours of the computer class final exam.

Other Results

As previously discussed briefly, it appears that different students had different types of learning curves with the game as measured by the speed that they won different games (mines discovered per minute). There seemed to be three major categories of how changes in playing speed correlated with the number of days they played, those participants that got faster over time, those who went slower as they played more, and those who fluctuated greatly in how fast they would win a game.

The majority of participants, who had sufficient data to be analyzable, became quicker at winning the game as they played more often. Most of these improvements in speed correlated very well to either an exponential, logarithmic, or fractional power curve (all of which look very similar visually). For instance, Participant 14, who was the strongest player in the pilot study, and also had the most data, had a curve of best fit represented by the formula $y = 0.88x^{0.56}$, where x is the number of days playing and y is the speed in mines/minute. This had a coefficient of determination of .66.

One participant slowed down as they played the game, possibly because they were becoming more careful in making choices. For instance Participant 16 had curves of best fit represented by the formula $y = 9.47x^{-0.38}$ with an R^2 value of .56 and also the formula $y = -2.1\ln(x)+8.7$ with a coefficient of determination of .59.

Still another student showed little correlation of change in their speed to any particular curve, with the best curve of fit only having a coefficient of determination of .14.

Reflections and Discussion

While I would like to finish debugging the game Phreatapolis to use in a larger online study, I am now equally interested in using the game Deductive Squares in a larger study. Phreatapolis has the same problem as Minesweeper that sometimes there will not be a solution that can be derived purely deductively, and random guessing must occur (although I may be able to program this problem out of the game). It also has the feature that a wrong guess instantaneously loses a game. In contrast Deductive Squares inherently takes into account determining whether a square can be deduced or not, and unlike Minesweeper, it is not lost with a wrong deduction but only won when all the correct deductions are made. I believe that Phreatapolis will appeal more to a generally younger age group that enjoys video games, and that Deductive Squares will appeal more to a generally older age group that enjoys crossword puzzles and/or Sudoku.

When I do a larger study on the Internet, I will make sure that the games themselves inherently collect data, so I do not need to rely upon participants creating a journal, and needing to document themselves, as participant documentation can introduce error, and is not likely as precise or accurate.

I plan to adjust my pretest and posttest, and will likely use an identical posttest as the pretest so that the two results are more comparable. I will analyze the results more from these assessments to determine what types of questions I may include. For example, since most participants got the Modus Tollens form of questions right (if A then B, A is true, therefore B is true) I do not see a need to ask this form of question in a future study, or if I do include it, only include it once.

I am glad that I did this pilot study. While causality was not possible to attempt to establish with my hypotheses about the benefits of Minesweeper, the fact that I had correlations with a .10 level of significance with such a small sample size is sufficient for me to believe that it is worth my time to do further investigation. Although, the fact that there was apparently no correlation between logic ability and computer ability was an interesting result that contradicts past studies, and also should have further investigation.

References

Adams, J. (2006). *Power play*. University of Pennsylvania Press.

Blagg, N. (1991). *Can we teach intelligence?* Routledge.

Campbell, P. F., & McCabe, G. P. (1984). Predicting the success of freshmen in a computer science major. *Communications of the ACM*, *27*(11), 1108–1113.

Castillo, L. P., & Wrobel, S. (2003). Learning Minesweeper with multirelational learning. Presented at the Eighteenth International Joint Conference on Artificial Intelligence, Acapulco, Mexico.

Coates, L., & Stephens, L. (1990). Relationship of computer science aptitude with selected achievement measures among junior high school students. *Journal of Research and Development in Education*, *23*(3), 162-64.

Fong, L. W., & Brooks, E. B. (1994). The game of Go: Speculations on its origins and symbolism in ancient China. *Changes*, *2008*.

Hadar, N. B. (1975). *Children's conditional reasoning: An investigation of fifth graders' ability to learn to distinguish between valid and fallacious inferences*. Retrieved from http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED118359

Hays, R. T. (2005). *The effectiveness of instructional games: A literature review and discussion*. Retrieved from http://stinet.dtic.mil/oai/oai?&verb=getRecord&metadataPrefix=html&identifier=ADA441935

Horgan, D. D., & Morgan, D. (1988). Experience, spatial abilities, and chess skill. Presented at the Annual Meeting of the American Psychological Association, Atlanta, GA. Retrieved from http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED305145

Joelving, F. (2009). Why success breeds success. *Scientific American Mind*, *20*(6), 8. doi:10.1038/scientificamericanmind1109-8b

Kirriemuir, J., & McFarlane, A. (2004). *Literature review in games and learning*. Futurelab. Retrieved from http://hal.archives-ouvertes.fr/docs/00/19/04/53/PDF/kirriemuir-j-2004-r8.pdf

Konvalina, J., Wileman, S. A., & Stephens, L. J. (1983). Math proficiency: A key to success for computer science students. *Communications of the ACM*, *26*(5), 377–382.

Lock, P. F. (1999). Using the game Minesweeper to introduce students to proofs. Presented at the Annual AMS-MAA Mathematics Meetings, San Antonio, TX.

Mackenzie, D. (1999, June). Addicted to logic. *American Scientist*, *87*(3). Retrieved from https://www.americanscientist.org/issues/pub/addicted-to-logic

Stanovich, K. E. (2009). *What intelligence tests miss*. Yale University Press.

Struthers, A. A. (1995). Introducing proof techniques using the logical game Mine Hunter. *PRIMUS*, *5*(2), 108-112. doi:10.1080/10511979508965778

Thompson, M. (2003). Does the playing of chess lead to improved scholastic achievement? *Issues in Educational Research*, *13*. Retrieved from http://www.iier.org.au/iier13/thompson.html

Wilson, B. C., & Shrock, S. (2001). Contributing to success in an introductory computer science course: A study of twelve factors. In *Proceedings of the Thirty-Second SIGCSE Technical Symposium on Computer Science Education* (pp. 184–188).

Wilson, D., & Conyers, M. (2006). *Thinking for results: Strategies for increasing student achievement by as much as 30 percent*. BrainSMART.

Appendix

Appendix A – Consent Signed by All Participants

Jacob J. Walker is conducting action research about the potential connection between learning to play Minesweeper and improving hypothetical thinking and computer skills. This is a pilot project which may lead to a full experimental study. While individual information will be collected, including demographic information, through the study, none will be reported in connection with your name or other personally identifiable information.

The general location and type of school, types of classes, and general demographic information will be reported, and publicly printed. Given this, and the small sample size, if someone worked to gain additional information, they may be able to successfully identify individuals. But all reasonable attempts will be made, which do not compromise accuracy of the study, to not have personally identifiable information be easily obtainable.

I understand the purpose and potential risks of this study, as stated above. I hereby grant Jacob J. Walker permission to have me participate in the study.

______________________________________ ________________________________
Signature Date

Appendix B – Logical Assessments Pretest and Posttest

Pretest

For each of the following questions, unless otherwise noted, assume the computer is not broken.

	Knowledge	Hypothetical Situation	Question	Answer
1	If the power button is pressed, then the computer turns on	The computer is on	Was the power button pressed?	❑ Yes ❑ No ❑ Not enough info
2	If a word is selected and copy is clicked on the screen, then the word goes into the clipboard	The word is selected	Is the word in the clipboard?	❑ Yes ❑ No ❑ Not enough info
3	If Minesweeper is clicked in the start menu, then the game starts	Minesweeper is not started	Was Minesweeper clicked in the start menu?	❑ Yes ❑ No ❑ Not enough info

4	If the power cable is not plugged in, then the computer will not turn on	The computer will not turn on	Is the power cable plugged in?	❑ Yes ❑ No ❑ Not enough info
5	If the memory gets filled, then the computer will run slow.	The memory is not full	Is the computer running slow?	❑ Yes ❑ No ❑ Not enough info
6	If spyware gets on your computer, then it watches what you do.	Spyware is on your computer	Is it watching what you do?	❑ Yes ❑ No ❑ Not enough info
7	If you type in www.ucdavis.edu in the address bar of a web browser, then you will go to UC Davis's web page.	You did not type www.ucdavis.edu	Are you at UC Davis's web page?	❑ Yes ❑ No ❑ Not enough info
8	Some new computers come with Microsoft Office	You have Microsoft Office	Did Microsoft Office come with the computer?	❑ Yes ❑ No ❑ Not enough info
9	If mute is selected, then you will not hear sound.	You do not hear sound.	Is mute selected?	❑ Yes ❑ No ❑ Not enough info
10	If and only if Microsoft Word is running, then it is memory.	Microsoft Word is not in memory.	Is Microsoft Word Running?	❑ Yes ❑ No ❑ Not enough info
11	If you have DSL, then you can get on the Internet.	You can not get on the Internet	Do you have DSL?	❑ Yes ❑ No ❑ Not enough info
12	All Microsoft Office Editions contain Microsoft Word.	You do not have Microsoft Word	Do you have Microsoft Office?	❑ Yes ❑ No ❑ Not enough info
13	Bill Gates is good at playing Minesweeper, and is very rich.	You get better at Minesweeper	Will you become wealthier?	❑ Yes ❑ No ❑ Not enough info
14	Viruses can only enter a computer through removable media, or the Network, or the console (keyboard/mouse).	You have a virus. You have not used removable media, and no one else has used your computer.	Did the virus come from the Network?	❑ Yes ❑ No ❑ Not enough info

Posttest

For each question assume the computer is not broken, unless otherwise noted.

1. Knowledge: If the power button is pressed, then the computer turns on.

Hypothetical Situation: The computer is off.

Question: Was the power button pressed?

- Yes
- No
- Not enough info

2. Knowledge: If a word is selected and copy is clicked on the screen, then the word goes into the clipboard

Hypothetical Situation: Copy was clicked on the screen.

Question: Is the word in the clipboard?

- Yes
- No
- Not enough info

3. Knowledge: If Minesweeper is clicked in the start menu, then the game starts

Hypothetical Situation: Minesweeper is started

Question: Was Minesweeper clicked in the start menu?

- Yes
- No
- Not enough info

4. Knowledge: If the power cable is not plugged in, then the computer will not turn on.

Hypothetical Situation: The power cable is plugged in.

Question: Is the computer on?

- Yes
- No
- Not enough info

5. Knowledge: If the memory gets filled, then the computer will run slow.

Hypothetical Situation: The computer is running slow.

Question: Is the memory filled?

- Yes
- No
- Not enough info

6. Knowledge: If spyware gets on your computer, then it watches what you do.

Hypothetical Situation: Spyware is on your computer.

Question: Is it watching what you do?

- Yes
- No
- Not enough info

7. Knowledge: If you type in www.ucdavis.edu in the address bar of a web browser, then you will go to UC Davis's web page

Hypothetical Situation: You are not on UC Davis's web page.

Question: Did you type www.ucdavis.edu?

- Yes
- No
- Not enough info

8. Knowledge: Some new computers come with Microsoft Office.

Hypothetical Situation: You have a new computer.

Question: Did it come with Microsoft Office?

- Yes
- No
- Not enough info

9. Knowledge: If mute is selected, then you will not hear sound.

Hypothetical Situation: Mute is not selected.

Question: Do you hear sound on the computer?

- Yes
- No
- Not enough info

10. Knowledge: If and only if Microsoft Word is running, then it is memory.

Hypothetical Situation: Word is in Memory.

Question: Is Microsoft Word Running?

- Yes
- No
- Not enough info

11. Knowledge: If you have DSL, then you can get on the Internet.

Hypothetical Situation: You are on the Internet.

Question: Do you have DSL?

- Yes
- No
- Not enough info

12. Knowledge: All Microsoft Office Editions comes with Microsoft Word.

Hypothetical Situation: You do not have Microsoft Office.

Question: Do you have Microsoft Word?

- Yes
- No
- Not enough info

13. Knowledge: Bill Gates is good at playing Minesweeper, and is very rich.

Hypothetical Situation: You get better at Minesweeper

Question: Will you become wealthier?

- Yes
- No
- Not enough info

14. Knowledge: Viruses can only enter a computer through removable media, or the network, or the console (keyboard/mouse).

Hypothetical Situation: You have a virus. You have not used the Internet (network), and no one else has used your computer.

Question: Did the virus come from removable media?

- Yes
- No
- Not enough info

Appendix C – Computer Final Exam Instructions for Segment 2

Note: The computer final was in the form of a "treasure hunt" to be more interesting and light hearted to hopefully reduce test anxiety on the part of the students. Segment 2 consisted of two distinct set of instructions. The first set of instructions was emailed to the students, and the second set were on a website that the students were directed to go to from the first set of instructions. Students would then email me based upon completing the second set of instructions. The measure of time was based from initial email timestamp sent by me, to the timestamp of the email with an acceptable answer.

Initial Email Sent to Student (First Set of Instructions)

Yar must be in good shape matey!

If you hope to find the treasure without losin' a leg, or gainin' a hook, yar gonna need to keep safe habits. Practice some stretches, and make shar ya' stay upright in the chair.

After stretchin', we need to set sail to our next destination. Set sail to: www.effectiveeducation.org/tras/treasurehunt.htm

Boring Instructions if You Can't Read the Exciting Ones

- Do some hand, wrist, or neck stretches.
- Keep good posture throughout class.
- Go on the web and go to www.effectiveeducation.org/tras/treasurehunt.htm

Webpage of Instructions (Second Set of Instructions)

Here Be a Riddle of Four, Answer 2 But No More

Dead men tell no lies, but rumors abound all around!

- Tell me is it true there is a virus called "Join the Crew"?
- Do Pirate Chocolate Coins contain Melamine?
- A pirate will never tell a fib, or a myth an authority will give… But is it true that Snopes has said that Blackbeard used "Sing a Song of Sixpence" to attract new crew members, and is it really true he did? And why might truth stay hid?
- We be romanticized pirates, like those of Disney and books, but we know the real ones of Somalia are giving us a bad name. But thankfully I have heard of a cruise, you can find out about from http://www.tothepointnews.com/content/view/3617/85/ But is it true?

Email your captain with the answers, and then you will receive your next instructions.

Boring Instructions if You Can't Read the Exciting Ones

- Look up on the Internet the following claims, and see which are true or not. You only need to answer 2 to get this question right.
- Here are the claims:
  - There is a computer virus called "Join the Crew"
  - There was a recall of Pirate Chocolate Coins because they might have contained Melamine.
  - People have believed that "Sing a Song of Sixpence" was used by Blackbeard, because Snopes said it was true. Give the full story about whether "Sing a Song of Sixpence" is about pirates.
  - There is a cruise where you can shoot at Somalia Pirates
- Email your instructor with the answers, and he will send you more instructions.

Appendix D – Example of Spreadsheet Teaching the Rules of Minesweeper

The following grid was presented to students in Excel, and they were told that in each square surrounding a star to write a number that corresponds to the number of stars adjacent to the square.

Exercise

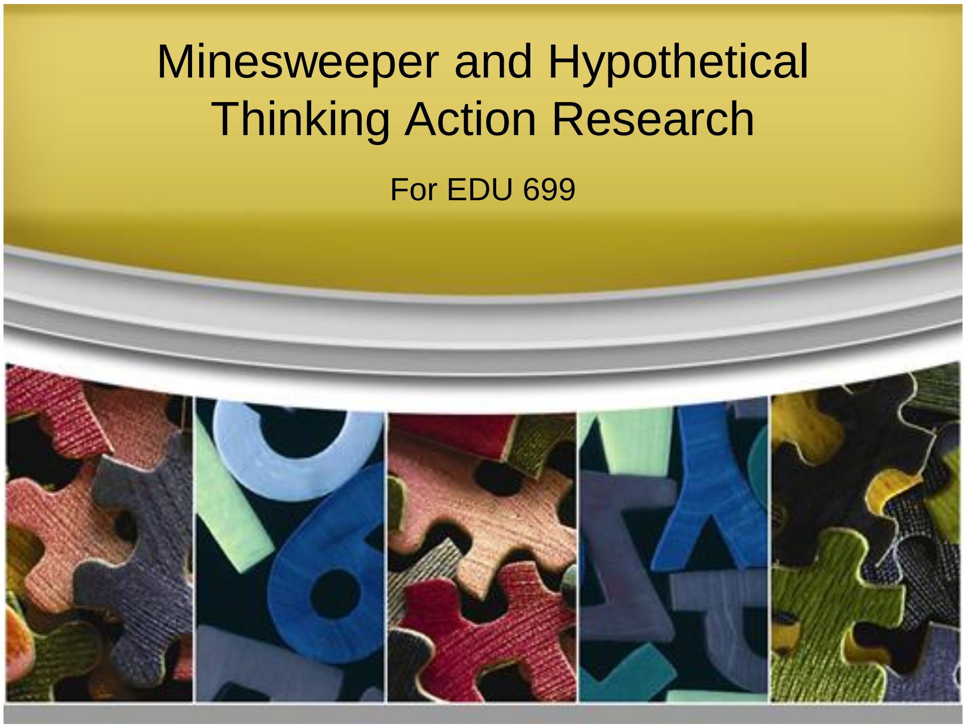
*				*			*	
	*							
*		*		*				
							*	
			*		*			

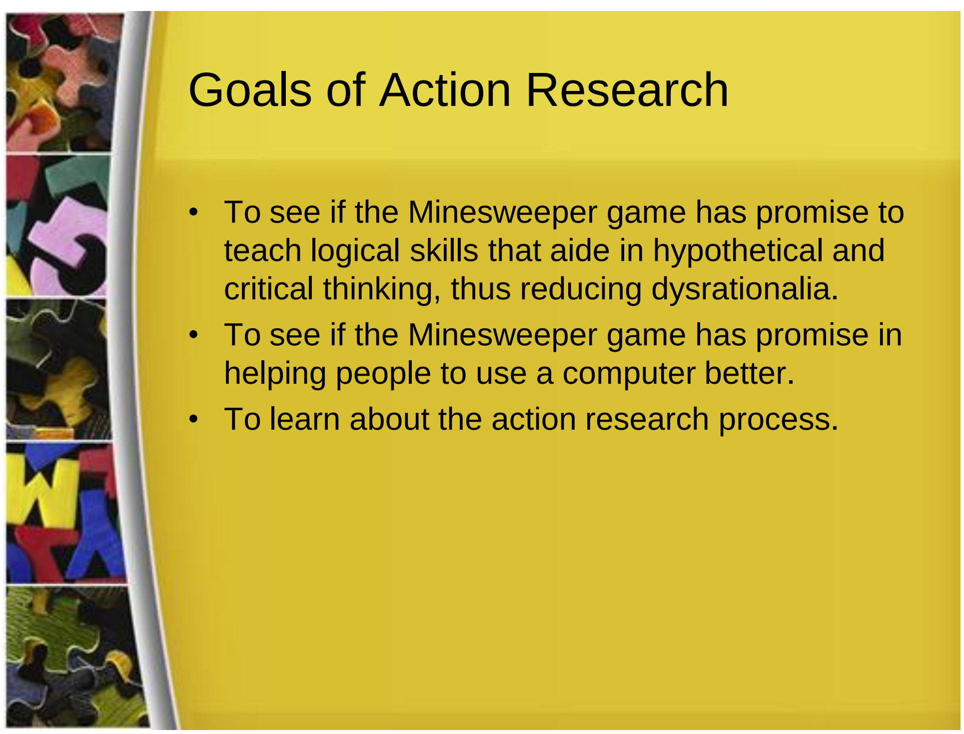
Solution

*	1		1	*	1	1	*	1
1	1		1	1	1	1	1	1
1	1	1						
1	*	1						
2	3	2	2	1	1			
*	2	*	2	*	1	1	1	1
1	2	2	3	3	2	2	*	1
		1	*	2	*	2	1	1

Appendix E – Metacognitive PowerPoint Presentation about Minesweeper

The following PowerPoint slides were shown to the entire class to explain the purpose of the action research and share some metacognition about the game.

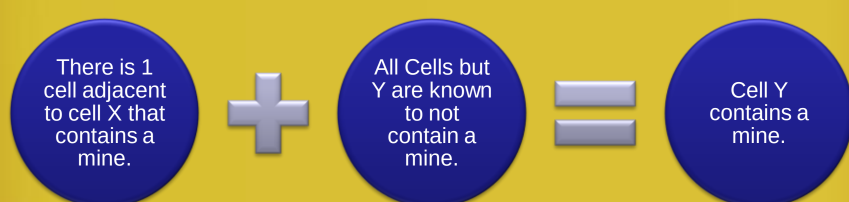


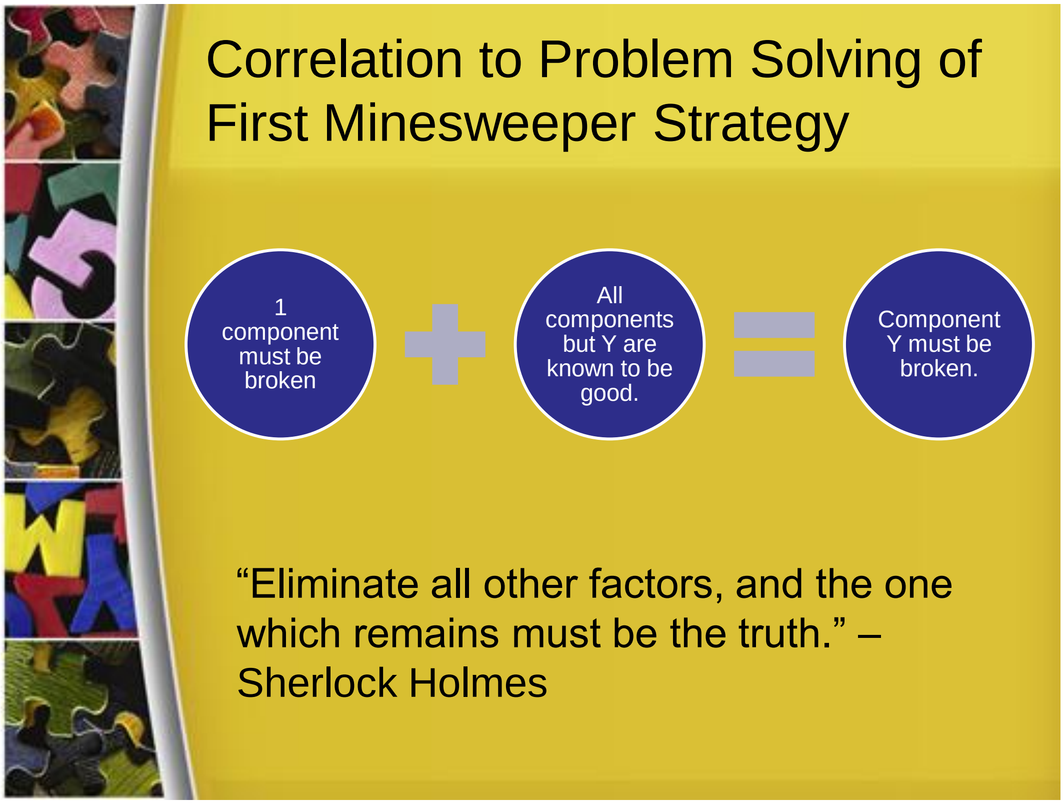


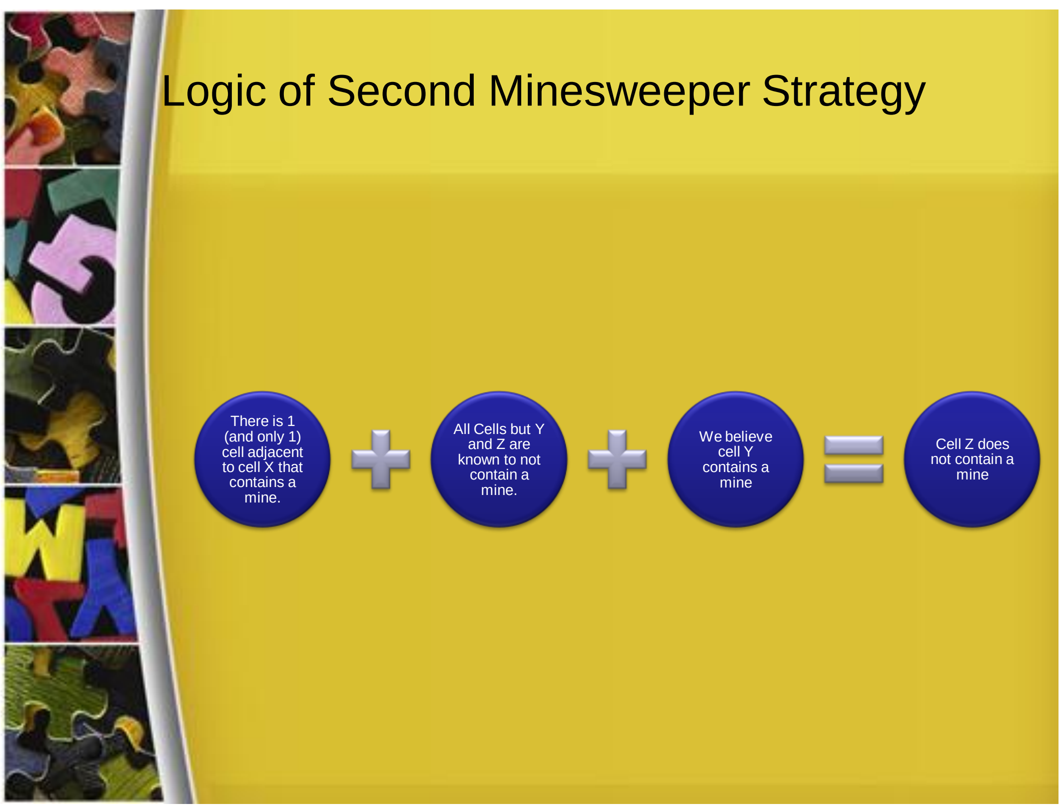
Metacognition about Minesweeper

- One must understand the rules (system), otherwise everything is just "shooting in the dark"
- The strategy is to eliminate possibilities where possible to reduce or eliminate the need to guess.
- A wrong hypothesis (assumption) will lead to a wrong conclusion, and lead to failure.
- Paying attention first to what is solvable, leads to more information that can be used to solve what originally was not possible.

Logic of First Minesweeper Strategy



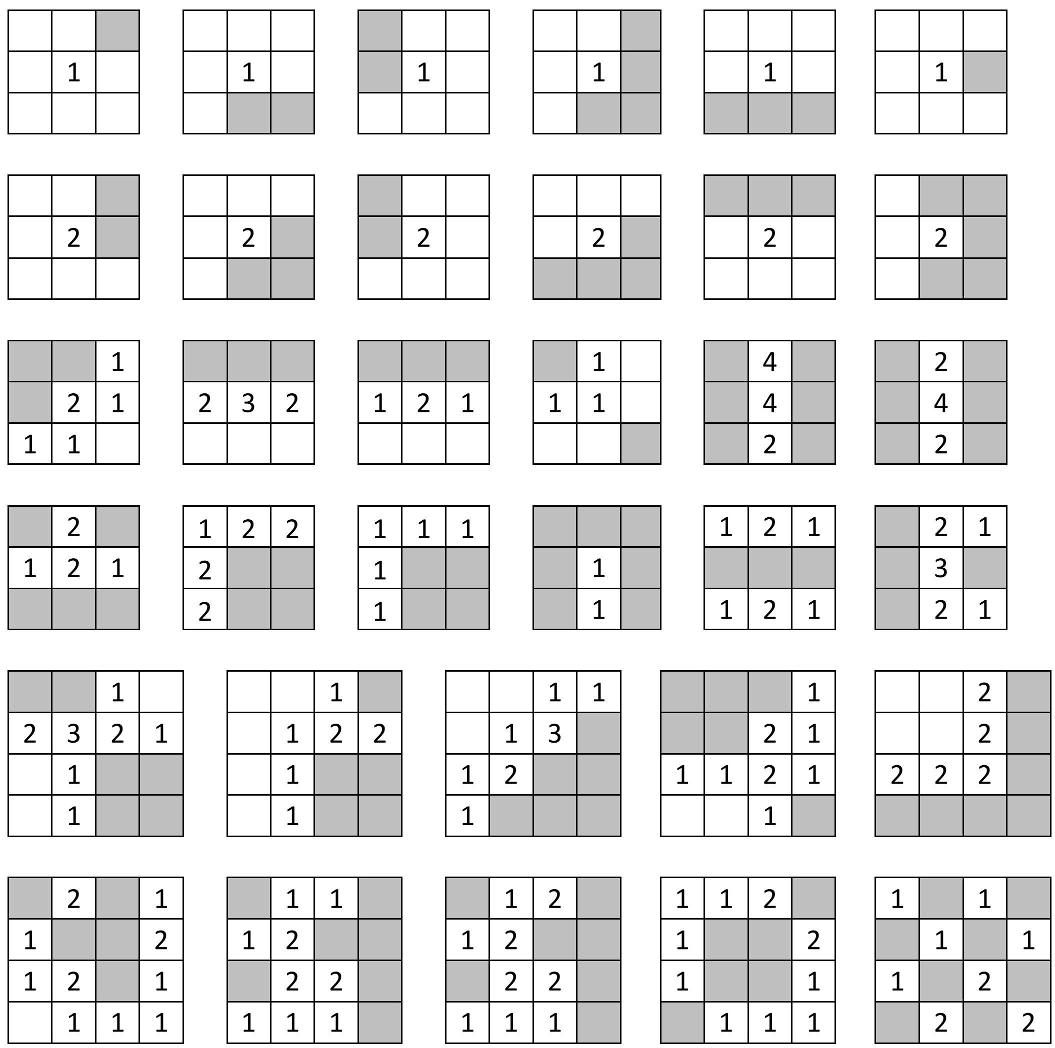

Correlation to Problem Solving of First Minesweeper Strategy
1 component must be broken
All components but Y are known to be good.
Component Y must be broken.
“Eliminate all other factors, and the one which remains must be the truth.” – Sherlock Holmes


Logic of Second Minesweeper Strategy
There is 1 (and only 1) cell adjacent to cell X that contains a mine.
All Cells but Y and Z are known to not contain a mine.
We believe cell Y contains a mine
Cell Z does not contain a mine

Appendix F – Deductive Squares Examples

Rules of Deductive Squares

Gray squares are either True or False (or can not be determined)
Numbers show the exact number of True Squares adjacent to that cell.
In each gray square, write a "T" if it is True, or "F" if it is False,
or a "?" if there is not enough information to determine the answer.



Appendix G - Supplemental Materials

The following additional supplemental materials are available online at http://www.effectiveeducation.org/MinesweeperPilotStudy

- Research Plan
- Instructor's Journal
- Excel Spreadsheet that teaches Minesweeper's Rules (Appendix D in Excel format)
- Metacognitive PowerPoint Presentation (Appendix E in PowerPoint format)
- Minesweeper Computer Based Training using PowerPoint
- Deductive Squares Exercises (Appendix F in Excel format)
- Participant Minesweeper Journals
- Analysis of Participant Data in Excel format