Middle School Girls + Games Programming = Information Technology Fluency

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ABSTRACT
In this paper we describe an after-school program that aims to develop information technology (IT) fluency by teaching middle school girls to make computer games. We focus on IT fluency rather than IT literacy because to participate in the current and future world of technology, students must develop fluency in three kinds of IT knowledge: contemporary skills, fundamental concepts, and intellectual capabilities rather than just literacy skills. The acquisition of fluency is more likely to happen in the context of a program like ours because of its emphasis on project-based work and a collaborative learning environment utilizing pair programming. The details of how IT fluency knowledge was acquired in the game programming part of our program are published elsewhere, so we only summarize those results here. The focus of this paper is on how participants have made substantial strides toward IT fluency due to aspects of our program as a whole. In this paper we provide many examples of how our program leads to IT fluency by addressing not just contemporary IT skills, but also intellectual capabilities and fundamental IT concepts.

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education – *Computer science education, Literacy;* K.3.1 [**Computers and Education**]**:** Computer Uses in Education – *Collaborative learning*

General Terms
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Keywords
IT fluency, pair programming, middle school girls, project-based program.

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1. INTRODUCTION
According to the National Research Council Committee on Information Technology Literacy, information technology (IT) fluency requires the acquisition of three kinds of knowledge through project-based work: contemporary IT skills, fundamental IT concepts, and intellectual capabilities. We will show how middle school girls participating in an after-school program involving pair programming and a variety of other peer support activities to create interactive 'choose your own adventure' games have made substantial strides toward IT fluency. Because we have already reported on details of the IT fluency knowledge acquisition from the game programming part of our program [1], we only summarize those results here. In this paper we focus on the exposure to IT fluency knowledge areas from our program as a whole - providing a more comprehensive discussion of how we are moving our girls toward fluency and not just literacy. Most students develop contemporary IT skills in computer literacy programs that are commonly found in our country's public schools. Our program's findings suggest that most of our participants developed contemporary IT skills in graphics, use of a database, use of the internet, use of basic operating system features, use of the computer to communicate with others, and the use of instructional materials. They also developed intellectual capabilities such as sustained reasoning, managing complexity, managing problems in faulty situations, testing of solutions, learning to expect the unexpected, the ability to navigate information structures and evaluate information, collaboration, and communicating with others. And they developed fundamental IT concepts such as algorithmic thinking and programming, information organization, fundamentals of computers, digital representation of information, limits of IT, and modeling and abstraction. We give examples of exposure and practice with each of these contemporary IT skills, intellectual capabilities, and fundamental IT concepts in the context of our program.

Our program includes a 12 week project-based learning environment using a collaborative learning strategy called pair programming and a variety of pair and other group activities. We believe that a program such as ours that focuses on IT fluency and not just contemporary IT skill acquisition is important for both male and female students to succeed in the changing world of technology. This paper focuses on female students because we are reporting on the results of a program designed for middle school

girls. The program, Girls Creating Games (GCG), is supported by the National Science Foundation's (NSF) Program on Gender Equity in Science, Technology, Engineering, and Mathematics (GSE). GCG's mission is aligned with GSE's mission to help young women become leaders and to pursue careers in IT. We can speculate that the program strategies would also increase the participation of young men. However, we predict that these strategies are particularly relevant to middle school girls because our strategies include a broader framework of interacting with computer technology, one that incorporates social interaction and encourages girls to discover and pursue their own role with technology-related tasks and interests [2]. The inclusion of fundamental IT concepts and intellectual capabilities in addition to contemporary IT skills provides us with insight into how girls can be leaders and pursue careers in IT.

The participants in the GCG program create interactive computer games, which provide them with the opportunity for an active role in relation to the computer. Previous research suggests that this approach is most likely to improve spatial and problem-solving skills, and act as a gateway into careers in technology [2, 3]. Currently, the design and use of computer games is dominated by males [4]. To increase girls' involvement in technology-related fields, the GCG program helps girls to design and produce their own interactive computer games. In this paper, we describe the program and explain what we mean by IT fluency and the three IT fluency knowledge areas of: contemporary IT skills, fundamental IT concepts, and intellectual capabilities. Within each knowledge area we include data from our previous paper which looked at participants' games. In addition, we describe and provide examples of how our program as a whole, with its emphasis on peer support, supports the acquisition of the IT fluency knowledge areas of intellectual capabilities and fundamental IT concepts by providing exposure to these areas. Finally, we discuss next steps for researchers and educators.

2. PROGRAM DESCRIPTION

Girls Creating Games is a voluntary after-school and summer program for 6th, 7th and 8th grade girls. Six implementations were completed over the course of two years: after school, and two during the summer at a local Boys and Girls Club. In the after-school program, participants met twice a week for two hours for a total of twelve weeks; during the summer they met four times a week for six weeks. The project-based program focused on the design and construction of interactive narrative computer games using Macromedia Flash MX – a web-based multimedia software program.

Most computer classes and programs for middle and high school students focus on computer or information technology literacy-related tasks. But increasing girls' skills or literacy is not enough to increase their role in producing technology [3, 5] The GCG program makes a unique contribution because it teaches information technology fluency rather than just IT literacy – something that is essential for success as a professional programmer. Girls participated in activities on and off the computer. For example, the girls first played other computer games to generate ideas for their own designs. Then they brainstormed story ideas, took notes on ideas they had, and wrote their game story on paper with different choices of which paths to take for different outcomes. These activities are very similar to those used by professional programmers during the design phase of a new computer game.

In addition, the girls received instruction on the use of Flash. Interspersed within the Flash instruction sessions, the girls constructed their games on the computer. Later in the project they often modified previously designed parts to incorporate new skills.

The program participants worked as "pair programmers" through all of the stages of game development and building both on and off the computer. Like other pair programming partnerships used in industry and in college [6, 7], girls worked together side-by-side at a single computer and gave each other support. One girl was the 'driver' who operated the keyboard and mouse, and the other was the 'navigator' who provided guidance and negotiated decisions with her driver. The navigator also watched closely what the driver was doing and looked for potential problems. Partners switched roles frequently; an average driving session lasted 15 minutes. Several different mechanisms were used to remind girls to switch roles, such as the use of mechanical timers and program leader announcements, and modeling the use of 'high-fives' during the switch. Most of the participants worked with a partner the entire implementation (85%). The remaining participants either worked alone (6%) or started with a partner and finished alone (9%).

Half of the program time focused on using the Flash software and to design, program, and debug their games. The other half focused on team-building, career exploration, and self-reflection activities. Throughout the building phase, the girls participated in peer-based activities such as the 'Gallery Walk' showcasing activity. For this, the girls divided into small groups and walked around the computer laboratory, looking at each other's games. We taught the girls how to give feedback in supportive and constructive ways. We had 'Affirmation' activities once every week where girls wrote an affirmation or positive statement about some technology related item they saw in someone else's work. These statements were written on pieces of paper and read out loud by the receiver. These activities made the girls feel supported and built a 'community-of-learners,' instead of solitary, competitive individuals.

This paper includes data and program examples from three implementation cycles of which a total of 33 games were completed. We only included these third, fourth and sixth implementations (after-school only, not summer) because of the consistency of attendance, program activities and learning environment. Ninety-eight percent of the participants attended 70% or more of the sessions (this excludes girls who dropped out of the program because they moved, quit because of disinterest, etc.) Our primary focus for this paper is on the program support activities such as the pair programming, pair support, team building activities; collaborative learning environment; and the relationship of these activities to IT fluency knowledge acquisition.

3. IT LITERACY VS. IT FLUENCY

Information technology (IT) fluency has been proposed by the National Research Council (NRC) as a minimum standard for college graduates [8]. The NRC states that IT literacy, or knowledge of the skills needed to use today's computer software

applications, is insufficient to prepare students for the computer software applications of the future. Because information technology is rapidly changing, the skills that are necessary to use today's computer software will need to be updated for the future. Our students need more than just skills to use current programs such as web browsers, email, and word processors. Instead they need to adapt those skills to use 'as yet developed' software. Therefore, being fluent in IT starts from the point of IT literacy but takes it to the next step of putting the person into a position to be able to adapt as IT changes. It is important that IT fluency "should not be regarded as an end state that is independent of domain, but rather as something that develops over a lifetime in particular domains of interest and that has a different character and tone depending on which domains are involved. Accordingly, the pedagogic goal is to provide students with a sufficiently complete foundation of the three types of knowledge so that they can "learn the rest of it" on their own as the need arises throughout life" [8]. This 'sufficiently complete foundation' is a proposed standard for college graduates [9]. The NRC's report suggests that IT fluency education should be part of K-12 education but does not contain guidelines for K-12 education [8].

The NRC bases IT fluency on three aspects of knowledge: contemporary IT skills, fundamental IT concepts, and intellectual capabilities. Contemporary IT skills are seen as today's IT literacy. The conceptual basis of IT is independent of current technology because the information technology of the future will be based on the current technology's conceptual basis. Many of the intellectual capabilities for IT are also relevant to other domains such as engineering and general education, and are also seen as important for information technology. Each list has been prioritized and only the top ten items in each knowledge area have been named by the NRC [8]. (See http://stills.nap.edu/html/beingfluent/es_b1.html.)

4. MEASURING IT FLUENCY ACQUISITION

In our earlier paper, we mapped aspects of IT fluency knowledge areas (e.g., NRC contemporary IT skills, fundamental IT concepts, intellectual capabilities) to Macromedia's Flash features included in the participants' games. We also argued that, if one of these identified Flash features is used in a game at or above our defined threshold level of three, the authors of that game have gained knowledge or have achieved a state of competency in the corresponding IT fluency aspect. We based our reporting of percentage acquisitions on this threshold level because it is our belief that the first time students use a specific Flash feature in their game the instructor could have walked them through the steps; the second time it is used suggests the students probably understood it without the assistance of an instructor, but we can not be completely confident; the third time we assume they did not need the assistance of an instructor and at that point have repeated it enough times to show mastery of the use of the feature. If mastery is achieved, then we argue that the corresponding contemporary IT skill, fundamental IT concept, or intellectual capability has been acquired. Based on this, we were able to show that many of the programming pairs acquired many aspects of IT fluency.

Measurement of IT fluency acquisition from our program as a whole is potentially difficult. We can not follow this same quantitative measure for knowledge acquisition as described above. Instead, our assumption is that if a girl was a participant during the time of the activity; she was exposed to the corresponding contemporary IT skill, fundamental IT concept, or intellectual capability. Some may not agree with this assumption, however, since acquisition of contemporary IT skills, fundamental IT concepts, and intellectual capabilities occurs at different levels over many years we argue that during this exposure in our project-based program, a minimal level of acquisition could occur [8, 9].

5. CONTEMPORARY IT SKILLS OR IT 'LITERACY'

From the games that the girls created we found that they acquired contemporary IT skills ("IT literacy") in the following areas: use of an artwork package to create images, use of a database to access information, and use of the internet to search for information. Macromedia Flash is designed with a full-featured artwork package that has drawing and text tools for manipulation of selected screen elements. We measured that all (100%) of the programming pairs reached a minimal competency level for the use of the artwork package. Flash has built-in libraries that provided our girls the opportunity to access databases almost every time they worked on their games. Again, 100% of the programming pairs reached a minimal competency level for the use of these databases. Also, 64% of the games contained images and sound that were downloaded from the internet using the Google search engine.

Additionally, there were elements of the GCG program that exposed participants to the following contemporary IT skills: use of basic operating system features, use of the computer to communicate with others, and the use of instructional materials. Every day participants utilized basic operating system features when they invoked applications (e.g., Flash MX, Internet Explorer), logged onto the secure server and then searched for their movie, graphics or sound files in folders. Throughout the program they learned the skill of using the computer to communicate with others by responding to questions in their electronic notebooks. Lastly, the skill of using instructional materials was exhibited by their use of skill instruction diagrams referred to as "flowcharts." Flowcharts are handouts with step-by-step instructions for each Flash skill taught throughout the program. Each programming pair had a set of flowcharts to refer to throughout programming their games.

6. INTELLECTUAL CAPABILITIES

By looking at the games the girls created, we can say that they acquired the intellectual capabilities of engaging in sustained reasoning and managing complexity. In general, sustained reasoning involves more than the one-time problem solving event. Instead, all stages of problem solving including problem definition, clarification, planning, designing, executing, and evaluation occur over a period of days or weeks. Rather than participating in a one-time activity, the girls in our program worked for twelve weeks designing and creating their games. They were all successful in completing a working game which allows us to say that 100% of them acquired the capability to engage in sustained reasoning. Additionally, the creation of a choose-your-own-adventure type of game required the girls to

manage the complexity of the design of multiple story paths. All but one of the pairs of girls created games with the minimum assigned complexity. Many of the games went beyond the requirements to include additional or varied story paths.

The girls took steps toward acquiring additional intellectual capabilities by exposure to the following capabilities throughout the GCG program: managing problems in faulty IT use, testing solutions, expecting the unexpected, navigating information structures and assessing the quality of the information, collaboration and communication. The girls first managed problems in faulty IT use when they encountered time and software constraints as they transferred their original design from paper to the computer. During the debugging activities in GCG, girls had another opportunity to acquire the capability of managing problems in faulty IT use. .The repeated activity included having another pair identify and record bugs in their game, reviewing the list of bugs, and then deciding how to proceed, including fixing the bugs. Sometimes fixing the bugs included looking at where in the chain of development something is broken. The girls sometimes used the flowcharts to retrace steps to see if something was missed. While programming and debugging their games, the girls also exhibited examples of the intellectual capability of testing solutions. Repeatedly they would test animations, buttons, and the movie file to see how it would work for someone playing the game and make necessary modifications based on the tests. Additionally, because our program leaders were not Flash experts, the program gave the girls ample opportunity to practice the above described intellectual capabilities. The girls had first hand experience with the intellectual capability of how to expect the unexpected when computers crashed and resulted in the loss of their files.

The use of flowcharts throughout instruction and practice exposed girls to the intellectual capability of navigating information structures and assessing the quality of information. Throughout programming their games they decided which flowchart to refer to and if it would assist them in the problem they were trying to solve. This capability also suggests that one must be able to "evaluate information" and "structure information appropriately to make it useful" [8]. This was supported in our program when the girls searched the internet for images and sound that they found useful for their game stored files locally, and then later retrieved them for inclusion into their game files.

Another intellectual capability is to collaborate using IT. A strong focus of our program was the girls working in pair programming partnerships. The girls used pair programming for their game design and construction; however, they also participated in many other team-building program activities with their partners such as: Telephone Architects, Pattern Blocks, and Minefield. All of these activities contributed to more peer support within their programming partnerships.

Much of the GCG program, especially with the use of pair programming, focused on the intellectual capability of communicating with others by including 'team-building' activities that required the partners to talk and listen to each other. For example, in Telephone Architects, one partner, the "architect", constructed a structure with plastic building pieces that their partner could not see. Then the architect described how to build the structure to their partner who had an identical set of building pieces. The architect and builder worked on terminology and the sequence of steps to successfully complete a replica of the original structure. Communication is critical for successful completion of this type of activity. Additionally, communication is essential to problem solving on the computer because it requires one partner to discuss the problem with their partner, another pair, or a program leader.

7. FUNDAMENTAL IT CONCEPTS

As described in [8, section 2.5, paragraph 3], fundamental IT concepts "touch on ideas of computation, communication, and information that are deep and intellectually challenging. Although any of the topics could be the basis of years of graduate study for a specialist, the basic ideas are straightforward and accessible, having been regularly taught to non-specialists for years." It is important to expose our students to these concepts often so that fluency can be achieved and so that as IT evolves, our students can continue to acquire the skills to create and use these new technologies. From looking specifically at the completed games, the girls acquired the following fundamental IT concepts: algorithmic thinking and programming and information organization [1]. We reported that all of the girls acquired the minimum for the algorithmic thinking fundamental concept because all of the games contained uses of ActionScripting – the programming feature of Flash. Additionally, team-building activities (described above) enforced the precise language and sequence of instructions aspects of this concept and prepared the girls for actual programming activities. The fundamental concept of information organization was exhibited by the extensive use of the layering construct of Flash in 61% of the games.

In the NRC's IT fluency report [8], the fundamental IT concept of fundamentals of computers includes general knowledge such as computer programs are composed of precise sequences of instructions. Many of the 'team-building' activities required the use of precise language and steps similar to the precision required to program a computer. The extensive use of flowcharts also enhanced the girls' concepts of computers and reiterated how they are programmed as a sequence of precise steps.

Participants were also exposed to the fundamental IT concepts of digital representation of information and limitations of IT. Often images they retrieved from the internet and then enlarged resulted in poor quality images. The girls saw that computer images are 2-dimensional arrays of picture elements or 'pixels' where each pixel is defined by its location and color. Another fundamental IT concept that the girls had many opportunities to acquire was modeling and abstraction. They designed their games on paper with an instructional scaffolding tool we call 'story path diagrams' and then had to transfer this information to the programming of their games using Flash.

8. CONCLUSIONS AND FUTURE WORK

Our program description and qualitative and quantitative results indicate that the Girls Creating Games program provides opportunities for the acquisition of IT fluency through the exposure to contemporary IT skills, intellectual capabilities, and fundamental IT concepts. We reported on the acquisition of IT fluency from the game design and construction part of our program [1] and continued to outline the many examples in our program as a whole that support steps towards the acquisition of IT fluency . Given that contemporary IT skills are most

commonly acquired in public school programs, we have designed a successful program for middle school girls that encourages the acquisition of more than just contemporary IT skills, but also intellectual capabilities and fundamental IT concepts.

Although the findings presented in this paper advance the study of IT fluency, they are based on a small sample of girls in one school, and may not be generalizable to all middle school girls in the U.S. Next steps could include testing this model with a larger group of students, both girls and boys, in different types of schools. Another next step would be to apply this method of measuring IT fluency to programs where participants create a product other than a game, such as website or other application domain. It would also be of interest to investigate methods of how to more accurately measure the acquisition of intellectual capabilities and fundamental concepts. Additionally, we would like to investigate using different development software other than Macromedia Flash.

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