

Paper presented at American Educational Research Association conference, April 2009Information and Communications Technology Fluency:
Defining and Measuring Standards in Middle School

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The goal of this paper is to move the field closer to a developmentally appropriate model of fluency with information and communications technology (ICT) and to describe some tested strategies for measuring it in middle school. Most efforts to integrate technology into K-12 education have focused on literacy (knowing specific information technology skills) rather than on fluency (knowing how to learn about, problem solve, and design new technologies) (Goode, Estrella, & Margolis, 2006; Papert, 1993). The focus on literacy alone is problematic for two reasons: 1) learning and working in all disciplines now requires the capacity to think flexibly, critically, and creatively with technology, and 2) literacy-focused education has not engaged students in a sustained way as illustrated by declining interest in ICT careers.

Fluency with ICT involves the ability to “communicate, collaborate, think critically, deal with ambiguity, and solve problems” (National Research Council, 2006, p. 23). In addition, in one area of technology--computers--people who are fluent with ICT have “the ability to express themselves creatively, to reformulate knowledge, and to synthesize new information” with what they already know (National Research Council, 1999, p. 2). Skills such as “expert thinking and complex communication” (Levy & Murnane, 2005) have been identified as core skills needed for creative work, calling for a rethinking of education for learning and working in the 21st century. Being fluent involves not just using technological tools, but knowing how to make things with them. These descriptions map clearly onto the principles of learning that already have broad-based support in the disciplines of history, science, and mathematics (Donovan & Bransford, 2005). These include building on prior knowledge, having a conceptual understanding, and the ability to set and monitor learning goals.

ICT fluency is increasingly becoming a requirement for meaningful participation in our society. Indeed, ICT fluency is believed to promote self confidence, motivate students to explore, generate questions and find solutions, and to build an orientation that promotes lifelong learning and adaptation (National Research Council, 1999). Becoming fluent with ICT has broad implications for learning because it involves the ability to organize and access information, and monitor learning.

Despite the importance of ICT fluency, existing definitions are limited by their focus on college and high school students. The National Research Council (1999) identified three components of fluency for college students: intellectual capabilities, concepts, and skills. In 2006, a working group applied these components to the high school level, and concluded that they needed to be adapted, due to differences in what high school students understand, and to new technologies (National Research Council, 2006). However, we know of no comparable effort focused on how to define, measure, or promote certain aspects of ICT fluency in the middle school years.

This paper will contribute to our understanding of what ICT fluency looks like and how it develops in middle school. This information can help educators move beyond computer literacy to promote and measure fluency with ICT. The paper will also move the field closer to developing much needed assessment tools for the concepts and capabilities aspects of ICT fluency that are appropriate for use with middle school students. The following research questions will be addressed:

1. What does ICT fluency look like in middle school?
2. What are some tested strategies for assessing ICT fluency in middle school?

This paper will begin with an overview of what is known about ICT fluency in college and high school, and the limitations of applying existing definitions to middle school. In the next section, we will describe what is known about what ICT fluency looks like in middle school. To this end, we will summarize the findings of a survey of after school and summer programs that aims to identify how middle school students are using and building fluency with ICT. The survey is used to define four core uses of technology: computer programming, visualization tools, communication, and computational and analytic tools. The findings suggest that students are using and mastering a range of technology tools, including geographic information systems (GIS), HTML programming, robotics, 3-D animation, web design, and computer game design.

Finally, we will describe some existing assessments, and use a case study of a computer game design class to illustrate what ICT looks like in middle school, and different strategies for assessment. One assessment strategy is to use the students' final projects. The data include over 150 games created by girls and boys in after school and summer programs. We will describe our coding and findings with one software package, Storytelling Alice (SA), an object-oriented programming system used to make 3-D animations. SA engages a range of students because it has kid-friendly images and characters, and prevents frustrating syntax errors by giving students menus that allow only the selection of valid parameters, given an object and a chosen operation. Students can see the immediate effects of their programming by viewing the animated changes. The paper will conclude with a summary of the findings and implications for next steps regarding how to define and measure ICT fluency in middle school.

What Do We Know about ICT Fluency?

The National Research Council (1999) proposed that fluency with information technology, or FITness, be the minimum standard that college students should achieve by the time they graduate. FITness has three components: 1) *intellectual capabilities* for problem solving, such as managing complexity, testing solutions, and engaging in sustained reasoning, 2) *fundamental concepts* about how and why technology works and how information is organized, and 3) knowledge of current technology *skills*, such as using word processing and spreadsheet software. Like other forms of STEM learning, IT fluency involves both procedural and conceptual knowledge that includes higher order thinking, such as the ability to critically and efficiently sift through information, identify and test new ways to solve problems, and work effectively with others (Garmire & Pearson, 2006; National Educational Technology Standards for Students, 1998; National Research Council, 1999).

Despite agreement about the importance of IT fluency, current capacity to instill it into teaching and learning is limited, due in part to the lack of a developmentally appropriate definition for K-12. The National Research Council (2006) report focused on high schools and identified some of the strengths and limitations of the FITness model. The committee felt that

overall the three areas of fluency were relevant to the experience of high school students, but recommended adding more specific examples, particularly within disciplines. They suggested that “the focus at the secondary level should be on how you use the technology to learn—how you use it to deepen your knowledge, to work together, and to create.” (p. 62). Limitations of the FITness model include the need to account for more recent, interactive technologies (e.g., chats, IM), as well as the lack of attention to the social and learning contexts, which includes learning not only with, but from, other people.

In addition, the 2006 report suggests the need to include more recent aspects of fluency, such as those that involve user-generated content. In particular, they noted that the thirty characteristics of FITness showed a tension between two poles: “designer or builder view” and “sophisticated-user view” (National Research Council, 2006). One project has helped to distinguish between the “user” and “designer or producer” skills. The Information Technology Career Cluster Initiative was among the first to bridge skill sets of IT “users” versus IT “designers or producers” (Education Development Center, 2002). This initiative identified the core IT literacy and fluency skill/knowledge sets found to be common among the various technology initiatives (e.g., FITness, ISTE, and state-based skills models) and connected these basic competencies with skill standards needed by technical workers in the information technology industry (Northwest Center for Emerging Technologies, 1999). Representatives from 13 states and the major IT companies collaborated to design this overarching framework and sets of skills/knowledge that benchmark the skills progression from technology literacy/fluency through the skills/knowledge needed in careers as “producers” of technology (people who design, develop, manage and support the hardware, software, multi-media and systems integration systems). The differentiation between user and builder indicates the need for more work in this area.

A primary source for standards is the International Society for Technology in Education (ISTE), which released the 2007 National Educational Technology Standards (NETS-S) and performance indicators for students. These standards identify what students need to learn in order to work, live, and make an active contribution to their communities and society. The standards cut across the FITness components and include creativity and innovation, communication and collaboration, digital citizenship, and critical thinking and problem solving. ISTE offers examples of learning activities that might promote these indicators in different grades, and has set up a wiki to facilitate sharing and discussion about classroom activities (<http://nets-implementation.iste.wikispaces.net/>).

Two national organizations have made strides in identifying the components of a developmentally appropriate model of ICT fluency. Based on the previous version of the NETS, ISTE’s Kelly and Haber (2006) proposed a rubric that suggests what students should master at the end of each grade period. For example, to demonstrate proficiency in the use of technology research tools, students at the end of grade 8 should “know how to conduct an advanced search using Boolean logic and other sophisticated search functions; know how to evaluate information from a variety of sources for accuracy, bias, appropriateness, and comprehensiveness” (p. 35). The Computer Science Teachers Association (2003) also made suggestions about appropriate ICT fluency-related topics and goals for the middle school years. These include solving problems and communicating using a range of media, accessing and exchanging information, compiling, organizing, analyzing, and synthesizing information, and analyzing problems and developing algorithmic solutions. However, the focus is on computer science, which differs from IT in this way: “while IT concentrates on learning how to use and apply software as a tool, computer

science is concerned with learning how these tools are designed.” (Computer Science Teachers Association, 2003, p. 3). It is clear that more work needs to be done to describe what students today should know, understand, and be able to do with ICT.

What Does ICT Fluency Look Like in Middle School?

To address this question, we present findings on how youth are engaging with technology outside of school. In particular, we present new findings about the kinds of technology tools with which middle school youth are demonstrating mastery. The data were collected by the Innovative Technology Experiences for Students and Teachers (ITEST) Youth and Technology Working Group that includes projects that are funded through the National Science Foundation’s ITEST initiative. During the spring and summer of 2008, this group administered an online survey to principal investigators (PIs), staff, and educators of ITEST projects. As a follow-up to our first report—*Defining Information Technology Fluency: A Working Framework*—we designed the survey to answer the following question: *What do ITEST youth participants know about, and what can they do with, technology?*

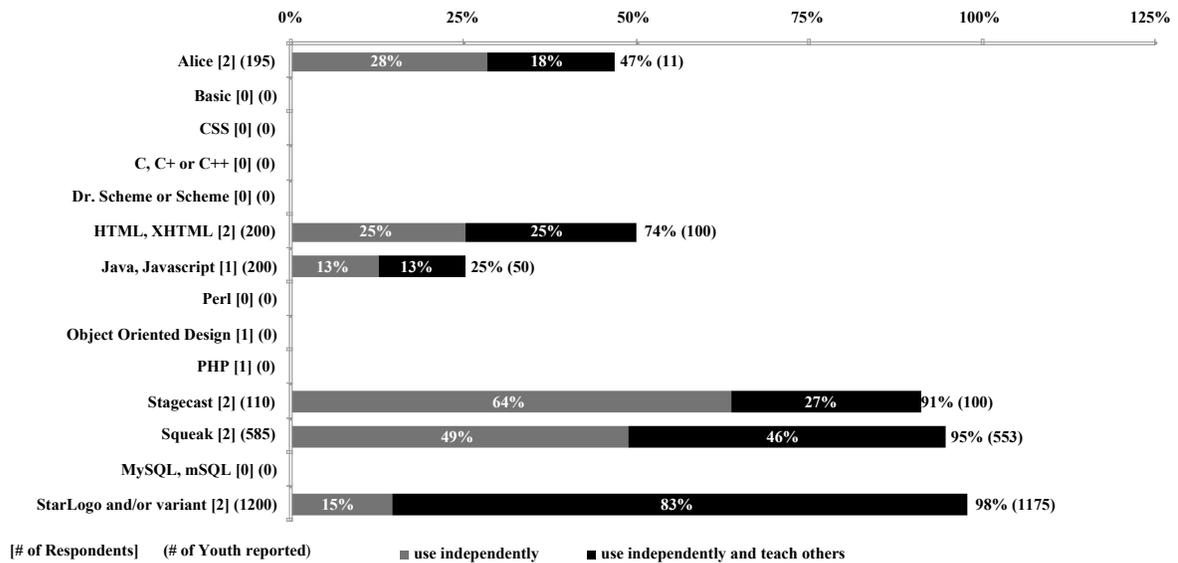
Respondents answered questions about the use of technology tools in their projects. The tools were clustered into five core applications: Computer Programming, Communication/Collaboration, Visualization, Computing and Analyzing Data, and Computer-Driven Equipment/Design and/or Building of Physical Objects or Environments. Three main groups of questions focused on the following aspects of technology use:

1. Whether a particular tool is used
2. Descriptions and examples of how that tool is used
3. Estimates of how well respondents believe youths use each of these tools on a scale from “don’t know” to “can use with help,” “can use independently,” and “can use independently *and* can teach others to use this tool”

These results provide an initial view of which tools are being used by middle school youth, as well as how these tools are being used—addressing numbers 1 and 2 above. With regard to mastery or “fluency” (number 3 above), the survey asked respondents to report youths’ skill levels with each technology tool by estimating the number of youth who: “don’t know,” “can use with help,” “can use independently,” and “can use independently *and* can teach others to use this tool.” Because project staff reported the mastery levels *based on their perceptions of youths’ skills* (number 3 above), it is difficult to determine the exact range in youth skills with these tools and technologies. Despite these limitations, these results offer a number of preliminary findings about the IT fluency of ITEST youth that, to date, have not been collected.

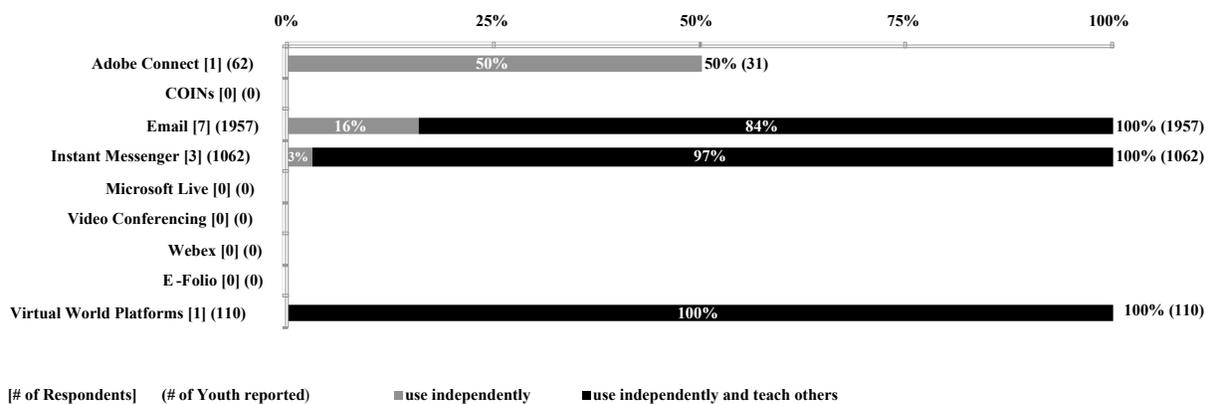
Eight different ITEST projects described the tools being used by middle school students. As shown in Figure 1, in the area of Computer Programming, there were six tools and technologies. These activities ranged from basic uses (e.g., retrieving or uploading data or information) to more sophisticated activities (e.g., building dynamic webpages, or programming interactive games, software, or hardware).

Figure 1. Middle School Youths’ Mastery of Computer Programming Tools



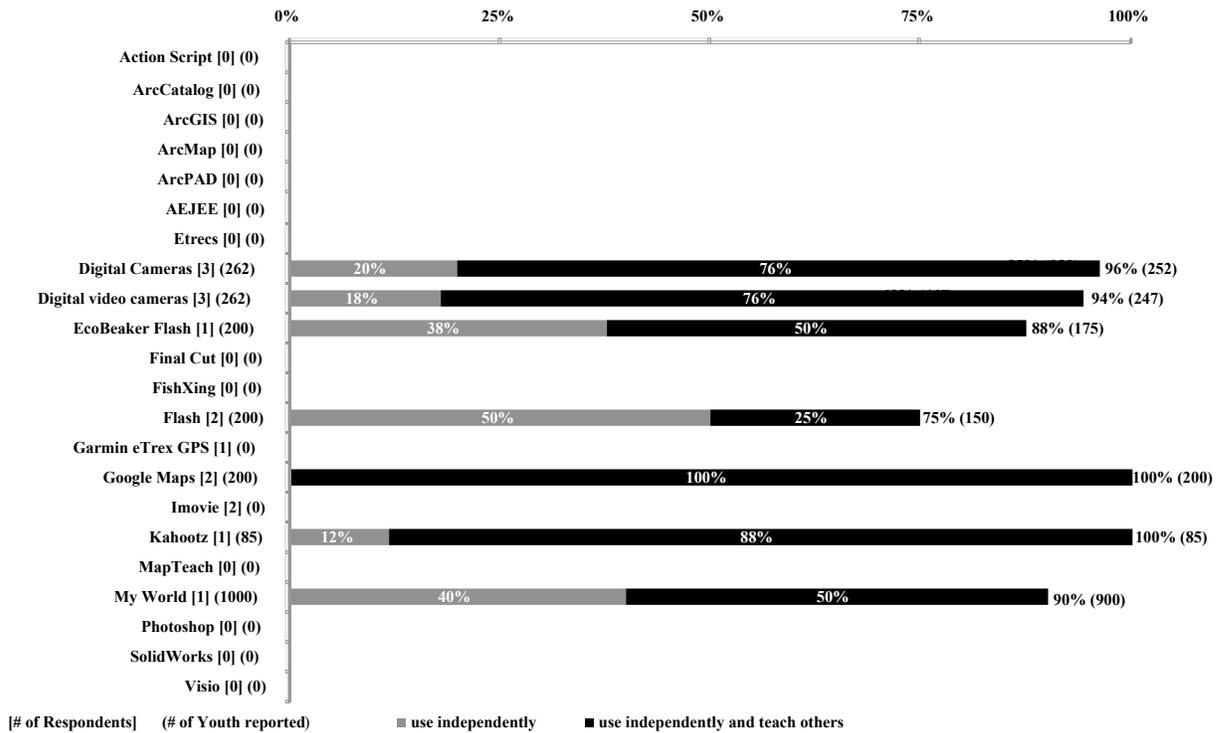
Various technology tools related to communication/collaboration were cited by respondents. As shown in Figure 2, e-mail and instant messenger were the most frequently cited among these items, and those who indicated that youth used these technology tools in their projects reported very high levels of mastery (100% use them independently and/or teach others to use these tools). These activities were mostly related to general communication, social networking, and data management.

Figure 2. Middle School Youths’ Mastery of Communication/Collaboration Tools



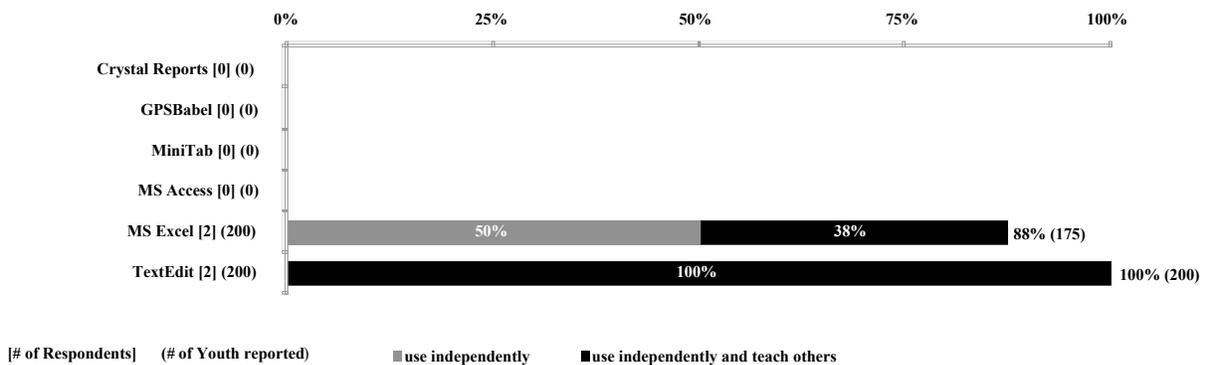
The visualization tools were generally related to mapping, creating or editing movies or public service announcements, and editing or manipulating photos or images. The most common visualization tools were digital still cameras and video cameras (Figure 3).

Figure 3. Middle School Youths' Mastery of Visualization Tools



Respondents identified two technology tools related to computing and analyzing data: Microsoft Excel and TextEdit, an open source text word processor and text editor. In both of these instances, the two respondents reported high levels of mastery, as shown in Figure 4. Respondents described most of the activities associated with computing and analyzing data as modeling, and also indicated that youth used these tools for graphing and gathering data.

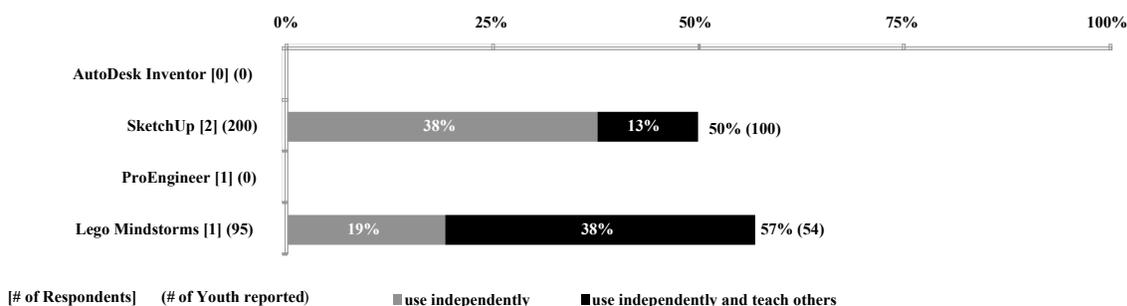
Figure 4. Middle School Youths' Mastery of Computing Tools



There were few responses in the section of the survey that covered Computer-Driven Equipment/Design and/or Building of Physical Objects or Environments. This might have been due to the options listed or the particular interests and resources of the respondents who completed the surveys. With both of the tools, respondents reported slightly lower proficiency than in other areas cited on the survey. As shown in Figure 5, 50% of the youth can use

SketchUp independently and/or teach others to use this tool; 57% can do the same with Lego Mindstorms. Most activities had to do with building and/or programming robots, product design, and construction and modeling.

Figure 5. Middle School Youths' Mastery of Computer/Driven Equipment



In summary, these results provide an initial view of what types of tools and technologies are being used with middle school students, how they are being used, and the levels of mastery. However, because the findings are based on a small number of programs, and on staff report of youths' mastery levels, it is difficult to determine the exact range of youth skills. Overall, however, these results indicate that youth in this national sample of programs are achieving high levels of mastery of these tools and technologies. That is, according to the adults, the youth in these programs are building ICT fluency by learning to use a range of technology tools independently and teaching them to others. But this is only one part of the puzzle. In the next section, we describe strategies for measuring ICT fluency by collecting data from the youth.

Assessment Strategies

Currently, there is no standardized measure of ICT fluency in middle school. There are, however, many new assessments for college students, like the Information and Communications Technology assessment from the Educational Testing Service (ETS). The ETS test and other assessments of college fluency included on www.Educause.edu focus on students' ability to diagnose and solve problems, assess the credibility of online information, make ethical decisions about how to use technology, and describe how technology works (e.g., how email is sent). However, the specific operationalization of these factors may not be developmentally appropriate for middle school. In addition, a standardized test cannot measure concepts and capabilities such as sustained reasoning or managing complexity.

The findings above are a first step toward understanding what ICT fluency looks like in middle school. However, additional research is needed, using a broader and larger sample, as well as additional assessment tools. In this section, we describe some resources for those who want to measure ICT fluency in their own classrooms and programs.

The developmental rubric based on the NETS (Kelly & Haber, 2006) provides a starting point for thinking about what to assess, but requires further development to be used as an assessment instrument. Kelly and Haber (2006) demonstrate how the NETS benchmarks can be used to develop tools for collecting a range of data. These include observations, portfolios, performance assessments, and surveys. For example, they describe an assessment rubric for middle school students' technology problem solving and decision making. The levels that can be

used to code observational data include novice, basic, proficient, and advanced. The levels move from knowing how to use spreadsheet data to the ability to develop strategies for use of data analyses, models, and simulations to make decisions about real-world problems.

These resources are useful guides for educators and researchers who want to develop their own assessments for a particular area of ICT fluency and the standards have guided our own assessment approach. For the last seven years, we have been teaching middle school students to program computer games with a partner during after school and summer programs. Our findings suggest that game design in pairs has real promise for promoting IT fluency in middle-school, and we have published the results of that work in several places (Campe, Denner, & Werner, 2005; Werner, Campe, & Denner, 2005; Werner, Denner, & Campe, 2006). In this paper, we will describe one example of how we assessed some aspects of ICT fluency by coding the student games and using logging data that documents each step of programming a computer game.

In the summer of 2008, we offered a 2-week course for students to create games using Storytelling Alice (SA) which is designed to help a broad group of students overcome barriers to programming (Kelleher & Pausch, 2005). SA is based on the Turing-complete programming language called Alice (Dann, Cooper, & Pausch, 2006). Alice is a 3-D animation tool that allows the user to write simple programs to animate pre-built objects (e.g., people, animals, vehicles) with existing methods. These methods can be used to create interaction between objects. Programming occurs by using a 'drag-and-drop' editing environment so students avoid syntax errors, which frees them to focus on the processes and concepts that underlie programming. The code and viewing windows are arranged so that the results of each program instruction are immediately visible. Over a two week (20 hour) period, we taught 31 students, who made 23 games (14 games were made by pairs of students, and 9 by solo students).

Game programming with SA appeared to have the most potential to build ICT fluency in the area of fundamental concepts, based on the FITness model. In particular, we focused on the concepts of modeling and abstraction, and algorithmic thinking and programming. Each game was coded for seven aspects of these fundamental concepts. For example, the concept of algorithmic thinking and programming was measured by how students used the five possible ways to control program execution in SA. Games that contain only sequentially executed statements are less sophisticated and can accomplish less than those that contain alternation (if-then-else), iteration (loops), parallelism (do together in SA) and events to control execution. With SA, understanding the concept of modeling and abstraction is shown with the use of programmer-defined methods and by the creation and use of parameters and local and global variables. We analyzed the 23 games and identified those containing student-added instances of these fundamental concepts. Since there are many predefined objects and methods in SA and Alice, we only counted instances of these fundamental concepts when students used them in student-created parts of their games.

The findings suggest that computer game design promotes some aspects of ICT fluency (Werner, Denner, Bliesner, & Rex, 2009). The percentages of games containing these fundamental concept aspects are: events – 100%, alternation – 26%, iteration – 17%, parallelism – 52%, additional methods – 48%, and parameters, local and global variables – 39%. We found that 30% of the games had four or more aspects and 74% had two or more.

Computer-logging data were also used to understand the process through which programming a game can promote ICT fluency. Similar to what Kelleher (2006) did, we determined the amount of time that the youth worked on three different actions: housekeeping (save and test), programming, and screen layout. For each pair or solo, we identified two dates

on which there were sufficient data to analyze: one at the beginning of the course, and one at the end. These data were parsed to reveal frequency of programming, scene layout, and housekeeping actions. The findings suggest that, on average, pairs spent more time on programming and housekeeping and solos spent more time on layout. These numbers combine the two dates of logging data for each solo/pair. When we compare the earlier date with the later date, for both pairs and solos, there was an increase in layout tasks and a decrease in programming tasks over time. However, we do not know if that decrease in programming is due to spending the early days working on exercises that teach important SA concepts, and spending the latter half of the project creating their game. In addition, we did not have enough data to investigate whether students who did more programming compared to scene layout had greater increases in IT fluency. We currently have a new grant to explore these questions with a larger sample and more detail.

Conclusion

As stated above, a focus on ICT fluency is important for two reasons: 1) learning and working in all disciplines now requires the capacity to think critically and creatively with technology, and 2) skill-focused education has not engaged US students in a sustained way, as shown by declining interest in IT careers. In this paper, we have begun to describe how middle school students are engaging with technologies in out-of-school settings, and strategies for assessing what they are learning. We have reported that there are many different technology tools being used and mastered by middle school students across the U.S.. In addition, we have taken a variant of one of the computer programming tools (Storytelling Alice is an extension of Alice) and described how we assessed the ICT fundamental concepts in middle school students' games, and what we learned by coding the games.

There is clearly more work to be done, as youth engagement with new technologies outpaces the research communities' efforts to understand what they are learning. Our findings reconfirm that middle school students are participating in innovative, technologically-advanced experiences that are grounding them in basic ICT literacy and fluency. The youth in this study are only one example of youth who are developing technology competencies in out-of-school time. The numbers of youth engaged in intensive technology experiences through informal learning has increased over the years as has their level of mastery of the technologies they use. By 2005, U.S. teens spent more than 6.5 hours per day engaged with media; 28% used computers and 22% played video games for more than one hour per day (Roberts, Foehr, & Rideout, 2005). That same year, The Pew Charitable Trusts reported that 21 million teenagers (87%) used the Internet, of whom 51% went online daily (Lenhart, Madden, & Hitlin, 2005). Today, Pew reports that 97% of teens use the Internet and calls 28% (mostly older girls) "super communicators." As youth develop greater expertise with technology tools, they are shifting from being simple consumers or technology "users" to content "producers"; 64% of today's online teens engage in content creation (Lenhart, Madden, Macgill, & Smith, 2007). This subtle, but important, shift reflects youth's growing mastery over technology and their desire and ability to use technology to create and innovate, both essential to the 21st Century workforce.

Today's youth are experiencing technologies in ways that push the limits of our current assessments of ICT literacy and fluency as they gather informally, in Internet cafes, after school clubs, at friends' houses and spend hours alone in their rooms learning about and/or becoming skilled at programming interactive games, software, or hardware, building and programming robots, building sophisticated quantitative models, performing higher order data analysis and

graphing, and creating media products. Our assessments have not caught up with their uses of technology and those that have are not age appropriate for middle school youth engaging in these activities. Clearly, more work needs to be done to understand the range of ICT fluencies among middle school students, and to measure the many other aspects of ICT fluency that cannot be assessed by analyzing a student created product such as a computer game.

Next Steps

We have identified several questions for future research:

1. What is the process through which ICT fluency develops?
2. What tools or activities are likely to promote it?
3. What types of instructional support are needed, if any?
4. Is exposure or mastery of concepts more important?
5. How can we increase the sensitivity of our assessment measures?
6. How can we increase the rigor of our assessment methods?

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