The Effect of Electronic Scaffolding for Technology Integration on Perceived Task Effort and Confidence of Primary Student Teachers

Charoula Angeli and Nicos Valanides
University of Cyprus

Abstract

Forty-one primary student teachers were divided into two groups and were instructed how to integrate certain Information and Communication Technology (ICT) tools in learning activities. Only one group was guided to use Filamentality, a fill-in-the-blank interactive Web site, and to organize Internet information in a Hotlist and a Scrapbook. Questionnaires were administered to collect data related to students' perceived task effort (PTE) as a result of integrating ICT in the learning environment, and their confidence levels in using ICT tools, while their initial attitudes toward ICT and its integration in the classroom were taken into consideration. The results indicated that Filamentality effectively scaffolded particular aspects of ICT integration in learning and instruction, and significantly reduced learners' amount of PTE, but there was not always a significant effect on learners' self-reported confidence levels. (Keywords: ICT integration, teacher education, scaffolding, perceived task effort, confidence.)

INTRODUCTION

Cognitive theorists unanimously agree that the capacity of working memory is severely limited in the amount of information that can be processed. This means that the amount of information presented to learners, the difficulty of the material, and the format in which the material is presented are factors that may inhibit or assist learners in cognitively processing the information (Baddeley, 1986, 1999; Chandler & Sweller, 1991; Mayer, 2001). In technology-enhanced environments, Information and Communication Technology (ICT[1]) is a tool with certain affordances that is used to present information to students and a tool that students can use to complete learning tasks. The notion of affordances is based on the concept of "tool mediation" that stems from Vygotsky's work (Cole & Engestrom, 1993). In the context of ICT, the concept of "tool" embraces both symbolic objects, such as language and mathematics, and physical objects, such as computers and associated software (Gibson, 1982). Thus, affordances are function-oriented properties that relate to properties intentionally designed into the object, or to properties that can be creatively attributed to the object in certain situations. Basically, affordances describe applications, limitations, and/or implications that relate to how a tool can be used. Technological tools that are employed in the learning environment may facilitate or inhibit students' cognitive engagement in the learning process, depending on their affordances (Gibson, 1982).

[1] We use the term ICT broadly to include the Internet, the World Wide Web, and all computer-based technologies.

For these reasons, the concepts of cognitive load and Perceived Task Effort (PTE) seem to be highly relevant to and important for the task of integrating ICT tools in an educational context. Cognitive load theory views the limitations of working memory to be an impediment to learning and attempts to improve the quality of instructional design by considering the role and limitations of working memory (Sweller, 1994). If the amount of cognitive load exceeds learners' mental resources, then learning will be impeded. Thus, when cognitive load is high, efforts should be directed toward instructional design manipulations for lowering cognitive load, so that it falls to a level within the bounds of learners' mental resources. PTE is closely related to cognitive load, and, as it is operationalized in this paper, represents the level of effort a learner estimates that he or she expended over a period of time in order to complete an assigned task (Locke, Shaw, Saari, & Latham, 1981; Mohr & Bitner, 1995). Whereas cognitive load is measured in terms of the mental effort a learner perceives at *an instance in time* as he or she is still learning, PTE is measured *in retrospect* as the learner estimates it after the completion of a task. The bottom line is that both the cognitive load and the PTE need to be considered when designing ICT-enhanced learning activities.

According to Chandler and Sweller (1996), the use of ICT tools creates an additional cognitive load related to the tools to be learned. If learners are not experienced users of ICT, then ICT integration will make considerable demands on learners' cognitive processing activities. Several other researchers (de Jong et al., 1999) define the total cognitive load imposed in an ICT-enhanced learning environment in terms of (a) subject matter difficulty (is the subject matter easy or difficult?), (b) ICT usage (is working with the ICT tools easy or difficult?), and (c) instructional use of ICT (do ICT tools make the learning task easier or more difficult?). Thus, three different sources of PTE are also present in a learning situation corresponding to each one of the defined sources of cognitive load.

Of interest to the issues of cognitive load and PTE is the Internet as a tool that a teacher can use to locate useful information and use it in the design of instructional activities. Jonassen (2000a) argues that the World Wide Web (Web) has so many interesting topics to explore that it is easy for learners to lose awareness of where they are in cyberspace. Hence, even though the Web offers individuals a wealth of information that can be used to support the curriculum, they often become frustrated with the quantity of resources and the time needed to actually identify the best Web sites to use in learning (International Society for Technology in Education, 2002). Similarly, when individuals use the Web as a tool of inquiry, they may experience a heavy cognitive load, because they may become overwhelmed by the vast amount of information they need to assimilate, or even accommodate, in their knowledge schemata. These individuals are expected to report high PTE after completing the task.

Research and theory on learning also emphasize the relationships between attitudinal and knowledge components, and the fundamental role played by attitudes and perceptions in facilitating ICT literacy, which entails a "collection of skills, knowledge, understanding, values, and relationships" (Watt, 1980, p. 3) that allow a person to deal effectively with ICT. In other words, dealing effectively with ICT relates not only to knowledge about the affordances of ICT, but also to individuals' attitudes and perceptions regarding ICT tools. Attitudes and perceptions act as a filter through which all learning occurs (Marzano, 1992), and are considered as a constituent part of learners' "self-esteem" that oversees all other systems (Markus & Ruvulo, 1990). Thus, learners continually filter their behaviors through their self-belief system to the extent that they even attempt to modify the "outside world" and make it more consistent with the "inside world" (Glaser, 1981).

From this perspective, researchers have studied several factors that seem to play an important role in affecting how individuals use ICT. These factors include not only ICT knowledge and the amount and nature of prior ICT experience, but also ICT-related attitudes and learners' beliefs in the ability to work successfully with ICT tools (self-confidence or self-efficacy) (Levine & Donitsa-Schmidt, 1998; Liaw, 2002; Murphy, Coover, & Owen, 1989). Attitudes and beliefs are also considered as predictors of behaviors and behavioral intentions that are linked to self-confidence. Beliefs about an object usually lead to attitudes toward it, and, in turn, attitudes lead to behavioral intentions regarding the object, which affect actual behaviors toward the object. Finally, there is a feedback loop where behavioral experience modifies pre-existing beliefs about the object. In terms of ICT use, attitudes toward ICT affect users' intentions or desire to use ICT. Intentions in turn affect actual ICT usage or experience, which modifies beliefs and consequent behaviors or behavioral intentions (future desire) and self-confidence or self-efficacy in employing ICT in learning.

In this study, we intended to manage the amount of cognitive load and PTE by integrating (or not integrating) ICT tools in the learning environment for management of the cognitive load and PTE related to ICT that may adversely affect learners' processing capacity. For example, there exist several Web-based tools, such as Filamentality (http://www.kn.pacbell.com/wired/fil), that can be incorporated into the learning environment to help manage the additional cognitive load and PTE that are caused by searching the Web. Thus, we hypothesized that the task of designing instructional activities using materials from the Web can be optimally managed by integrating Filamentality in the learning environment. This does not imply that Filamentality, or other ICT tools, will make the task easier, but that it may help learners manage the cognitive load and their PTE related to the ICT tools more efficiently and effectively, and, consequently, it may influence their confidence in using ICT tools. A successful attempt to lower the cognitive load will have implications on learners' PTE and may result in more successful performance. Such a performance will positively affect learners' confidence levels in employing similar tools and strategies in new learning situations. Learners' initial attitudes toward ICT and its integration in the classroom may also have implications on learners' behaviors and behavioral intentions, such as their PTE and confidence levels.

Thus, the study was undertaken to examine whether integrating, or not integrating, Filamentality in a science education method course would affect primary student teachers' PTE (as a result of the perceived difficulty) in learning with these tools and learners' perceived confidence levels in employing them for new learning. Specifically, the study set out to provide answers to the question: Does learning with certain ICT tools, such as Filamentality, affect learners' self-reported PTE and self-reported confidence levels in using ICT tools, after adjusting for the effects of their initial attitudes?

METHODOLOGY

The Context of the Study

Forty-one primary student teachers, who were enrolled in a science education method course, participated in the study. Prior to taking this course, students completed two basic computing courses in which they learned Word, Excel, PowerPoint, Internet, and Hyperstudio. The objective of these courses was mainly to raise students' skill proficiency level. The science education method course was designed around three major objectives: (a) to familiarize students with current trends in science teaching, (b) to capitalize on the interrelationships among science, ICT, and society, and (c) to integrate ICT tools for designing and developing interactive instructional activities. The instructor of the course (second author) in collaboration with an expert in instructional technology (first author) jointly redesigned the course in an attempt to integrate ICT tools in certain instructional situations.

Filamentality and Hyperstudio

Filamentality is a fill-in-the-blank interactive Web site that assists learners in defining a topic, and guides them through searching the Web and collecting appropriate Web sites. Thereafter, it assists with turning these online resources into different types of learning activities. The creators of Filamentality saw the process of learning and teaching with Filamentality as a three-step process, namely, gathering and analyzing input (i.e., different types of online resources), transformation of input (i.e., through different strategies and activities), and production, during which learners' investigations can be published on the Web (Chylinski, 1999). In essence, Filamentality provides electronic scaffolding through a simple template design, which offers the capability of organizing online information, and, thereafter, creating one or more of five types of activities, such as Hotlists, Scrapbooks, Treasure Hunts, Samplers, and WebQuests.

Of interest to this study were the activities Hotlist and Scrapbook. A Hotlist is a Web page with links to text-based materials for a topic that are organized meaningfully into categories. According to the International Society for Technology in Education (2002), this focuses the search and minimizes the time needed to locate relevant information. A Scrapbook is a Web page with links to a variety of media, such as images, sound, video clips, and virtual reality tours as these relate to a topic. Learners can use a Hotlist to read about a topic, and, thereafter, a Scrapbook to explore aspects of the topic they feel are important.

The process of creating an activity in Filamentality begins with the registration of a new topic. As it is shown in Figure 1, the registration procedure requires the title of the activity, the creator's name, and a password. The next step, shown in Figure 2, is to add Internet links to the activity. Filamentality provides users with direct access to the most well known search engines to help with the identification of appropriate links.

Once the links are collected and their URLs are recorded in the template, the user chooses one of five possible instructional templates, corresponding to Hotlists, Scrapbooks, Treasure Hunts, Samplers, and WebQuests, to fill in. Then, Filamentality prompts the user with questions and task descriptions that need to be filled in appropriately. At the end, the activity can be published on the Internet with a click of the mouse, and the URL of the published Web site is displayed on the screen.

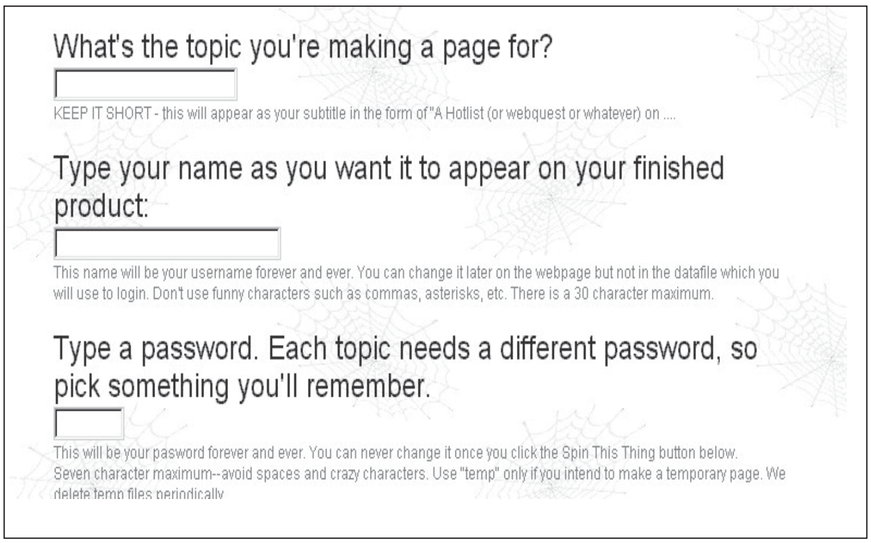

Figure 1. Defining a topic in Filamentality

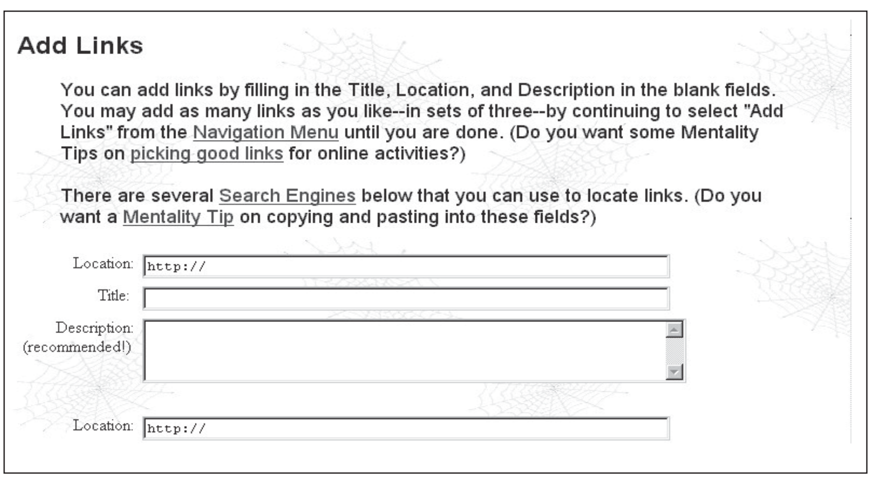

Figure 2. Adding links in Filamentality

In summary, Filamentality enables a user to create a Web page, to selectively record the results of a search of resources available on the Internet, to meaningfully organize them into categories, and, thereafter, to use these resources to create instructional activities. The resources found in a Hotlist and a multimedia Scrapbook can be downloaded, for example, into a Hyperstudio stack and manipulated accordingly by the learner. Hyperstudio is a well-known multimedia-authoring tool that is widely used by teachers and students to communicate ideas in multimedia form by bringing together text, sound, graphics, and video.

Research Procedures

Over the course of the semester, participants attended lectures and laboratory meetings. For the 13 two-hour lectures, students met as a group, whereas for laboratory meetings, they were randomly divided into two groups. Each group had 13 90-minute laboratory meetings. Laboratory work included experiments, ICT training, and design of ICT-enhanced lessons. Students' lab performance was assessed based on their performance on a design and development project, which required each student to: (a) select a different topic from the elementary science curriculum, (b) identify and evaluate Web sites suitable for teaching this topic, (c) use materials found on the Web to develop a Hyperstudio stack, and (d) integrate computer-based activities in an 80-minute ICT-enhanced science lesson for ages 7–12 to be taught in a real classroom setting in conjunction with other planned activities. Students were guided to design their lessons based on principles of learning theories that place the learner at the center of the learning process as the constructor of knowledge.

Of the 13 90-minute laboratory meetings, seven meetings were devoted to ICT training. Three kinds of ICT training sessions for each group were administered: (a) Hyperstudio training, (b) Internet training, and (c) design of ICT-enhanced activities. Even though students had been previously taught how to use both Hyperstudio and the Internet, they felt they needed further instruction about how to use and integrate them in a lesson plan. For these reasons, each group of students had two workshops about Hyperstudio and its added value in the teaching and learning process, three workshops about the Internet, and two workshops on how to design ICT-enhanced lesson plans. The first author conducted all ICT training sessions for both groups, while the second author conducted the remaining sessions of the course.

Internet training differed between the two groups. The control group learned about how to employ different strategies to effectively search the Web, and which engines were most appropriate for locating different kinds of information, such as images, video clips, sounds, animations, etc. These students also studied how to evaluate Web-based resources using different criteria, such as (a) accuracy, (b) depth, (c) breath, and (d) relevance to students' lives.

Students in the Filamentality group had the same basic Internet training as students in the control group, but they also learned how to use Filamentality. In their lab sessions, students were taught how to create a Hotlist, about a topic they themselves selected from the elementary science curriculum, using the tool of Filamentality. The lab instructor also explained the minor differences between a Hotlist and a Scrapbook, and assisted students with the creation of a Scrapbook about the same topic. Thus, students in the Filamentality group received instruction relevant to learning how to organize the results of their searches with Filamentality and how to create instructional activities using Filamentality. Students in the Filamentality group were encouraged to use Filamentality regularly, and students in both groups were encouraged to consult with the course instructors regarding the design of their ICT-enhanced lessons for elementary school children.

Instruments

At the beginning of the semester, a questionnaire was used to measure students' attitudes toward ICT and its integration in the classroom. The questionnaire consisted of 12 questions presented in Table 1, with a Likert-type scale from 1 to 5 (disagree a lot, disagree, neutral, agree, agree a lot). At the end of the semester, students were given two additional questionnaires. One questionnaire was used to measure different aspects of students' PTE. A Likert-type scale from 1 to 5 (very small, small, neither small nor large, large, and very large PTE) was used. There were two forms of this questionnaire, one for each group. The PTE for the control group was measured in terms of (a) the PTE to use Hyperstudio, (b) the PTE to use the Internet and collect quality information for their projects, and (c) the PTE to design instructional activities using Hyperstudio (instructional use of Hyperstudio). Similarly, the PTE for the Filamentality group was measured in terms of (a) the PTE to use Hyperstudio, (b) the PTE to use the Internet, collect quality information for their projects, and organize the information using Filamentality in a Hotlist and a Scrapbook for later use with their Hyperstudio stacks, and (c) the PTE to design instructional activities using Hyperstudio (instructional use of Hyperstudio). The difference between the two groups was that only the Filamentality group was deliberately instructed and guided to use Filamentality and organize the information in a Hotlist and a Scrapbook. The aspect of PTE related to subject matter difficulty was not measured, because students chose a topic of their liking, and thus probably a topic they understood best. In addition, at the end of the PTE questionnaire there was an open-ended question asking students to describe their experiences in learning with the tools, and, in particular, how the tools helped them to carry out their task and what difficulties they encountered.

The other questionnaire that was administered at the end of the semester was given to both groups of students and measured their self-reported confidence levels in using specific ICT tools in a classroom for instructional purposes. The questionnaire included six questions, presented in Table 3, and a Likert-type scale from 1 to 5 (disagree a lot, disagree, neutral, agree, agree a lot) was also used. These questions examined the extent to which learners felt confident in teaching their own students how to use Hyperstudio and the Web, and how confident they felt in integrating these tools in teaching and learning.

RESULTS

Table 1 shows the frequencies of students' responses to the 12-item attitude questionnaire. There were no statistically significant differences between the two laboratory groups in terms of their responses to the attitude questionnaire. Thus, the results were collapsed over the two groups and attitude was not considered as a covariate in the subsequent analyses. The split-half correlation method, with the Spearman-Brown correction, gave a reliability estimate of .86.

Table 1: Students' Initial Attitudes about ICT (n=41)

Item	Disagree a lot %	Disagree %	Neutral %	Agree %	Agree a lot %
1. I feel comfortable learning the new technologies	2.4	9.8	9.8	39.0	39.0
2. Using the computer constitutes a skill that students must learn	0.0	0.0	0.0	17.1	82.9
3. The computer imposes stress on me, because, if anything goes wrong, I wouldn't know what to do	19.5	53.7	12.2	9.8	4.9
4. I feel comfortable with my abilities to be able to learn how to use the computer	2.4	9.8	4.9	58.5	24.4
5. The use of computers in education makes me skeptical	9.8	24.4	9.8	46.3	9.8
6. The use of computers in education makes me enthusiastic	0.0	2.4	7.3	53.7	36.6
7. The use of computers in education interests me	0.0	2.4	0.0	51.2	46.3
8. The use of computers in education scares me	26.8	41.5	14.6	14.6	2.4
9. Computers confuse me	34.1	48.8	7.3	9.8	0.0
10. I don't think computers will be valuable in my profession	82.9	14.6	0.0	0.0	2.4
11. I enjoy learning how to use the new technologies	0.0	2.4	12.2	39.0	46.3
12. Whatever the computer can do, I can do it equally well with another way	7.3	68.3	22.0	2.4	0.0

The results in Table 1 show that the majority of students felt the need for employing new technologies in the learning environment, felt comfortable in learning how to use new technologies, and were rather enthusiastic to learn how to integrate ICT in their teaching, although there were students who expressed some skepticism. In general, there was an overall positive attitude and a positive momentum toward ICT integration. Of course, even though ICT-related attitudes seem to play an important role in how ICT is used in teaching and learning (Levine & Donitsa-Schmidt, 1998), research has also shown that positive attitudes alone are not always good indicators of preservice teachers' eventual use of ICT in the classroom (Wild, 1996). Preservice teachers, for example, may have positive attitudes about ICT integration without realizing how difficult the task can be, or how much effort they may need to invest to successfully complete the task. Thus, despite preservice teachers' initial positive disposition toward ICT integration, they may still find the task of integrating ICT in the classroom difficult once they realize what it really entails.

Table 2 shows descriptive statistics on each aspect of students' PTE. Students in the control group reported a higher PTE on all aspects of the dependent variable, namely, (a) difficulty of Hyperstudio, (b) use of the Internet, and (c) instructional use of Hyperstudio.

Table 2: Descriptive Statistics of Students' Perceived Task Effort (PTE) (n=41)

Aspects of PTE	Group	*M*	*SD*	*n*
Difficulty of Hyperstudio	Control group	2.71	.78	21
	Filamentality group	2.35	.67	20
Use of Internet	Control group	3.29	1.00	21
	Filamentality group	2.35	.75	20
Instructional use of Hyperstudio	Control group	3.81	.68	21
	Filamentality group	3.25	.97	20
Total PTE	Control group	9.81	1.75	21
	Filamentality group	7.95	1.64	20

A multivariate ANOVA, using the three ratings of PTE and the total PTE as the dependent variables, was subsequently conducted. The results indicated that the ratings on the total PTE between the two groups were statistically significant, $F = 12.314$, $p = .001$. The ratings on use of the Internet and instructional use of Hyperstudio were also statistically significant, $F = 11.344$, $p = .002$, and $F = 4.634$, $p = .038$, respectively, but the ratings on Hyperstudio difficulty were not statistically significant between the two groups, $F = 2.545$, $p = .119$.

These findings indicate that students who were instructed to employ Filamentality in their work reported lower PTE related to the use of the Internet, design of instructional activities using Hyperstudio, and total PTE. The findings signify that Filamentality produced a facilitating effect in searching the Internet and organizing the information in a Hotlist and a Scrapbook, and in carrying out the design task. Interestingly enough, the PTE related to the difficulty of Hyperstudio was not significantly different between the two groups, but the PTE related to the design of instructional activities using Hyperstudio was significant. The results seem to indicate that the lower total PTE for the Filamentality group was attributed to a facilitating effect directly related to Filamentality.

A qualitative analysis (Lincoln & Cuba, 1985; Merriam, 1988) of students' answers to the open-ended question at the end of the PTE questionnaire was subsequently performed. In qualitative analysis, the process of data analysis is recursive and dynamic, and aims at identifying emerging themes or categories (Merriam, 1988). The qualitative analysis of students' answers led to the identification of two emerging themes. First, the 20 students in the Filamentality group agreed that the amount of PTE was much lower than what it would have been without using Filamentality. They explained that Filamentality was easy to use and enabled them to organize the results of their searches into categories. Therefore, it was easy to access the information, when they needed it to design instructional activities using Hyperstudio. Second, the 21 students in the control group stated that they faced difficulties in integrating not only the Internet but also Hyperstudio in their design activities. Specifically, students in the control group stated that they felt frustrated integrating materials from the Web in their Hyperstudio stacks. Although they invested a tremendous amount of time searching the Web, they failed to organize the results of their searches electronically, and thus they spent extra time searching for them again when they actually needed to use them in their Hyperstudio stacks.

Descriptive statistics of students' self-reported (subjective) confidence levels are shown in Table 3. The results in Table 3 indicate that students in the Filamentality group tended to have higher confidence levels in almost every item of the questionnaire. A multivariate ANOVA, using the self-reported confidence levels on each item of the questionnaire and the total subjective confidence level as the dependent variables, was subsequently conducted.

Table 3: Descriptive Statistics of Students' Perceived Confidence Levels (n=40)

Aspects of confidence	Group	*M*	*SD*	*n*
1. I feel confident in designing ICT-enhanced activities for my students	Control	3.76	.70	21
	Filamentality	3.74	.87	19
2. I feel confident in integrating computers in my classroom practices	Control	4.05	.74	21
	Filamentality	4.11	.66	19
3. I feel confident in utilizing Hyperstudio for instructional purposes with my students	Control	3.33	.91	21
	Filamentality	3.89	.81	19
4. I feel confident in teaching my students how to use different search engines to efficiently search for information on the World Wide Web	Control	4.00	.71	21
	Filamentality	4.32	.48	19
5. I feel confident in teaching my students how to utilize Hyperstudio in their projects	Control	3.38	.92	21
	Filamentality	4.00	.82	19
6. I feel confident in using the World Wide Web in my classroom	Control	4.10	.54	21
	Filamentality	4.32	.67	19
Total	Control	22.62	2.48	21
	Filamentality	24.37	3.39	19

Note: One student was not present when the questionnaire was administered.

The results indicate that the students who were instructed to employ Filamentality reported significantly higher confidence levels related to only item 3, $F(1, 38) = 4.198$, $p = .047$, and item 5, $F(1, 38) = 5.017$, $p = .031$. The existing significant differences were related to students' perceived confidence in utilizing Hyperstudio for instructional purposes and their perceived confidence in teaching their own students to utilize Hyperstudio in their projects. Nevertheless, students in the two groups felt equally confident in designing ICT-enhanced activities for their students, integrating computers in classroom practices, teaching their students how to use different search engines, and using the Web in the classroom. The existing significant differences and other non-significant differences did not, however, add up to significant differences between the two groups in terms of their cumulative subjective confidence levels.

DISCUSSION AND IMPLICATIONS

In this study, two groups of primary student teachers were provided with opportunities for how to design ICT-enhanced learning, but only one group was intentionally instructed to use electronic scaffolding with the tool of Filamentality. The purpose was to investigate whether Filamentality could affect primary student teachers' PTE and confidence levels, after controlling for the effects of the differences in their initial attitudes toward ICT and its integration in the classroom. The results showed that students in both the control and the Filamentality groups had positive attitudes toward ICT and its integration in the classroom, and that there were no significant differences between the two groups in terms of their attitudes. Woodrow (1994) emphasized that positive attitudes are necessary but may be insufficient to instigate ICT-related behavior. Based on our results, we cannot provide any further insights related to the relative importance of attitudes toward ICT utilization.

The results indicate, however, that students who used Filamentality experienced, in general, a significantly lower PTE in completing their design task than those who completed the task without Filamentality. Filamentality served as a cognitive tool that helped students to effectively organize their thinking, and facilitated fast retrieval and use of information when students needed to use it at a later time. However, the differences were restricted to the use of the Internet and the design of instructional activities using Hyperstudio, and not to the difficulty of using Hyperstudio per se. The findings seem to suggest that adding tools to the learning environment, such as Filamentality, does not necessarily raise the PTE, and may even lower it. More importantly, the results indicate that students' PTE was not linked with technical skills, but rather with designing learning activities with ICT and integrating ICT in the classroom.

Nonetheless, the results of the study do not paint a clear picture in terms of the differences between the two groups related to their self-confidence in employing ICT tools in teaching and learning. There was, however, evidence suggesting that when students perceived a lower PTE, their self-reported confidence in integrating ICT in learning was higher than those students who reported a higher PTE. For example, students in the Filamentality group reported significantly higher confidence levels only in terms of utilizing Hyperstudio or teaching their future students how to utilize Hyperstudio for instructional purposes in their projects, and not in terms of just using the tools. Thus, the findings did not show any significant differences for items strongly linked with technical skills, such as using the Internet or the Web, or for items linked with a general perception of feeling competent in integrating ICT in instruction, such as designing technology-enhanced activities or integrating computers in classroom practices.

The cumulative evidence seems to suggest that engaging student teachers as designers of ICT-enhanced learning in a methods course can affect their perceived confidence levels about their future uses of ICT for instructional purposes. Jonassen (2000b) argues that when learners use ICT tools as designers they engage in "intellectual partnership" with them for "accessing information, interpreting and organizing their personal knowledge, and representing what they know to others" (p. 2). From this perspective, ICT tools, in and of themselves, are not so important, but the kinds of activities that they afford become crucial. The effects, of course, greatly depend on the mindful engagement of learners with the tools. "Effects *with* technology can redefine and enhance performance as students work in partnership with intelligent technologies—those that undertake a significant part of the cognitive processing that otherwise would have to be managed by the person" (Salomon, Perkins, & Globerson, 1991, p. 8).

The human partnership with ICT tools, such as Filamentality, usually entails a complementary division of labor, as tools with their powerful facilities assume part of the intellectual burden of information processing that shortcut the cognitive effort to produce a result. It seems that the electronic prompts provided by Filamentality would not be so successful if, for example, they were provided on paper, because Filamentality not only provided electronic prompts, but it also shared the intellectual burden of organizing and retrieving online resources. Thus, the electronic scaffolding provided by Filamentality liberated the learners to engage in cognitive activities that would, under different conditions, be out of their reach. It becomes rather obvious that once we couple technologies with people, then the technological component may decrease the intellectual share of the human partner, and any outcome should be treated as the joint product of person and ICT tools that become partners in what is called "distributed intelligence" (Pea, 1989).

In conclusion, the findings of this study indicate that ICT integration in teacher education programs should be carefully planned to ensure that student teachers' PTE decreases and confidence levels increase. Thus, it is crucial to carefully select appropriate ICT tools, so that students do not experience a high PTE related to the difficulty and instructional use of these tools. Similarly, we need to keep looking for ways to make our students feel confident about integrating ICT in their teaching practices, as it is a prerequisite for students to accept ICT as a powerful learning tool (Greenberg, Raphael, Keller, & Tobias, 1998; Zammit, 1992) and as an intellectual partner. Such partnerships are considered "joint cognitive systems" (Dalal & Kasper, 1994), where systems—not individuals alone—carry out intellectual tasks. Our results clearly relate to the changes in performance that learners display while employing ICT tools, such as Filamentality and Hyperstudio, or the effects when working *with* ICT tools. Nonetheless, the limitations of the present study (i.e., a small experiment, small sample, and small duration of the intervention) restrict the generalizability of the results and suggest that more robust research designs and coordinated research efforts are needed to systematically investigate the impact of ICT tools on human thinking, learning, and performance.

Contributors

Dr. Charoula Angeli is a lecturer in Instructional Technology at the University of Cyprus. She has undergraduate and graduate studies at Indiana University-Bloomington (BS in Computer Science, 1991, MS in Computer Science, 1993, and PhD in Instructional Systems Technology, 1999). Her research interests include the utilization of educational technologies in K–12, the design of computer-enhanced curricula, educational software design, teacher training, teaching methodology, online learning, and the design of learning environments for the development of critical and scientific thinking skills. (Address: Charoula Angeli, Department of Educational Sciences, University of Cyprus, P. O. Box 20537, CY-1678, Nicosia, Cyprus; cangeli@ucy.ac.cy.)

Dr. Nicos Valanides is an associate professor in Science Education at the University of Cyprus. He has undergraduate studies at the Aristotelian University of Thessaloniki (BA in Physics, 1969, and BA in Law, 1985). He has graduate studies at the American University of Beirut (Teaching Diploma, 1980, and MA in Education: Teaching Sciences, 1981) and at the University of Albany, State University of New York, SUNY—Albany (MSc in Instructional Supervision 1986, and PhD in Curriculum and Instruction and Educational Research, 1990). His research interests include teacher training, methodology of teaching and curricula for science education, development of logical and scientific thinking, science-and-technology literacy, the utilization of ICT in science education, blended learning, and the design of educational interventions and learning environments. (Address: Nicos Valanides, Department of Educational Sciences, University of Cyprus, P. O. Box 20537, CY-1678, Nicosia, Cyprus; nichri@ucy.ac.cy.)

References

Baddeley, A. D. (1986). *Working memory*. Oxford, England: Oxford University Press.

Baddeley, A. D. (1999). *Human memory*. Boston: Allyn & Bacon.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction, 8*, 293–332.

Chandler, P., & Sweller, J. (1996). Cognitive load while learning to use a computer program. *Applied Cognitive Psychology, 10*, 151–170.

Chylinski, R. (1999). *Filamentality: A time-efficient way of producing Internet-based activities and publishing them on the WWW* [Online document]. Available: http://members.optushome.com.au/renatachylinski/filament.htm.

Cole, M., & Engestrom, Y. (1993). A cultural–historical approach to distributed intelligence. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 1–46). New York: Cambridge University Press.

Dalal, K. P., & Kasper, G. M. (1994). The design of joint cognitive systems: Effect of cognitive coupling on performance. *International Journal of Human-Computer Studies, 40*, 677–702.

de Jong, T., Martin, E., Zamarro, J.-M., Esquembre, F., Swaak, J., & van Jooligen, W. R. (1999). The integration of computer simulation and learning support: An example from the physics domain of collisions. *Journal of Research in Science Teaching, 36*(5), 597–615.

Gibson, J. J. (1982). *Reasons for realism: Selected essays of J. Gibson.* Hillsdale, NJ: Erlbaum.

Glaser, W. (1981). *Stations of the mind*. New York: Harper & Row.

Greenberg, R., Raphael, J., Keller, J., & Tobias, S. (1998). Teaching high school science using image processing: A case study of implementation of computer technology. *Journal of Research in Science Teaching, 35*(3), 297–327.

International Society for Technology in Education. (2002). *National Educational Technology Standards for Teachers: Preparing teachers to use technology*. Danvers, MA: ISTE.

Jonassen, D. H. (2000a). *Computers as mindtools for schools: Engaging critical thinking* (2nd ed.). Upper Saddle River, NJ: Prentice-Hall.

Jonassen, D. H. (2000b). Technology as cognitive tools: Learners as designers [6 pages]. Available: http://it.oe.uga.edu/itforum/paper1/paper.html

Lenine, T., & Donitsa-Schmidt, S. (1998). Computer use, confidence, attitudes, and knowledge: A causal analysis. *Computers in Human Behavior, 14*(1), 125–146.

Liaw, S. S. (2002). Understanding user perceptions of worldwide web environments. *Journal of Computer Assisted Learning, 18*, 137–148.

Lincoln, Y., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage.

Locke, E., Shaw, K. N., Saari, L. M., & Latham, G. P. (1981). Goal setting and task performance. *Psychological Bulletin, 90*, 169–181.

Markus, H., & Ruvulo, A. (1990). "Possible selves." Personalized representation of goals. In L. Pervin (Ed.), *Goal concepts in psychology* (pp. 211–241). Hillsdale, NJ: Erlbaum.

Marzano, R. J. (1992). *A different kind of classroom: Teaching with dimensions of learning*. Alexandria, VA: ASCD.

Mayer, R. E. (2001). *Multimedia learning*. New York: Cambridge University Press.

Merriam, S. B. (1988). *Case study research in education: A qualitative approach.* San Francisco, CA: Jossey-Bass Inc.

Mohr, L. A., & Bitner, M. J. (1995). The role of employee effort in satisfaction with service transactions. *Journal of Business Research, 32*, 239–252.

Murphy, C. A., Coover, D., & Owen, S. V. (1989). Development and validity of the computer self-efficacy scale. *Educational and Psychological Measurement, 49*, 893–899.

Pea, R. D. (1989, June). *Distributed intelligence and education*. Paper presented at the annual meeting of the Social Science Research Council on Computers and Learning, British Virgin Islands.

Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in cognition: Extending human intelligence with intelligent technologies. *Educational Researcher, 20*(3), 2–9.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*, 295–312.

Watt, D. H. (1980). Computer literacy: What should schools be doing about it? *Classroom Computer News, 1*(2), 1–26.

Wild, M. (1996). Technology refusal: Rationalizing the future of student and beginning teachers to use computers. *British Journal of Educational Technology, 27*(2), 134–143.

Woodrow, J. E. J. (1994). The development of computer-related attitudes of secondary students. *Journal of Educational Computing Research, 11*, 307–338.

Zammit, S. A. (1992). Factors facilitating or hindering the use of computers in schools. *Educational Researcher*, *34*(1), 57.