Examining the Effects of Two Computer Programming Learning Strategies: Self-Explanation versus Reading Questions and Answers

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Abstract

The study described here explored the differential effects of two learning strategies, self-explanation and reading questions and answers, on learning the computer programming language JavaScript. Students' test performance and perceptions of effectiveness toward the two strategies were examined. An online interactive tutorial instruction implementing worked-examples and multimedia learning principles was developed for this study. Participants were 147 high school students (ages 14 to 18) of a computer introductory course in six periods which were randomly divided into two groups (n = 78; n = 69) of three periods each. The two groups alternated learning strategies to learn five lessons. Students' prerequisite knowledge of XHTML and motivation to learn computer programming languages were measured before starting the tutorial. Students largely expressed their preference toward self-explanation over reading questions and answers. They thought self-explanation incurred much more work yet was more effective. However, the two learning strategies did not have differential effects on students' test performance. The seeming discrepancy arising from students' preferred strategy and their test performance was discussed in the areas of familiar versus new strategy, difficulty of learning materials and testing method, and experimental duration.

Keywords: learning strategy; self-explanation; computer language; JavaScript.

Introduction

Computer programming has historically been difficult and frustrating for novice learners (Kelleher & Pausch, 2005). Studies show that 40 to 50 percent of first year programming students either had a below C grade or dropped out (Schuyler, 2011). Therefore, exploring effective instructional strategies is of prime interest among computer programming educators (Kert & Kurt, 2012; Renumol, Janakiram, & Jayaprakash, 2010). Teaching novice JavaScript learners is an even more intriguing undertaking because they are Web design enthusiasts coming into the new realm of computer programming mostly without prior knowledge. The supposed foundation of having learned Web design, along with the confidence it brings, could have falsely promised learners the same ease with learning JavaScript, which, on the contrary, presents a sudden surge of intrinsic cognitive load.

In the current study, a computerized interactive tutorial was developed to help students learning Web design tackle the challenges they are faced with learning JavaScript. The tutorial provided a multimedia learning environment that implemented multimedia learning principles (Mayer, 2009, 2011) and worked examples (Sweller, 2006). Online multimedia instructional tutorials that implement a worked-example strategy have been evidenced as effective (Kapli, 2011). In an online learning environment, the built-in interactive feature could afford students many opportunities for practising to acquire schema and encode it to long-term memory (Lee, 2008). Utilizing learning strategies to achieve desired learning outcomes is also important for learners (McNamara & Magliano, 2009). Even intrinsically motivated learners should be guided with learning strategies because they do not necessarily have an adequate strategy repertoire (Renkl, 1997).

The specific interest of this study lies in the added effect of utilizing self-explanation (Kalyuga, 2009; van Merrienboer & Sluijsmans, 2009) and reading questions and answers (Kinniburgh & Shaw, 2009; Pappa & Tsaparlis, 2011), two known learning strategies that have demonstrated positive effects in a variety of academic subjects, to determine which is more effective in learning JavaScript. This is the first study that sought differential effects of these two strategies in learning computer programming.

Self-explanation

Self-explanation takes place when learners explain concepts to themselves and verify their own understanding. Cognitive load theory proposes that self-explanation is effective because it generates germane cognitive load, which contributes directly to learning (Kalyuga, 2009; van Merrienboer & Sluijsmans, 2009). Self-explanation is a domain-general constructive activity that directs learners’ attention to the learning materials while checking on their understanding (Roy & Chi, 2005). Its process has been evidenced as helping learners comprehend unfamiliar text (McNamara, 2009; McNamara & Magliano, 2009) and developing computer programming concepts (Kwon & Jonassen, 2011).

Self-explanation engages learners to use their background knowledge to interpret the given instructional texts and examples (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Pirolli & Recker, 1994). Renkl (1997) observed that learners, drawing from their own background knowledge, used the self-explanation strategy to explain to themselves the solution steps in worked examples. Self-explanation techniques used alongside proper instructional support can improve transfer; for example, when combined with direct instruction, self-explanation became more effective and facilitated transfer with persisting benefits over a delay (Rittle-Johnson, 2006).

Self-explanation can be carried out in different formats such as thinking-aloud (McNamara, 2009; McNamara & Magliano, 2009) or typing one's thoughts (Muñoz, Magliano, Sheridan, & McNamara, 2006). Less-skilled readers are able to make more frequent bridging inferences with typing self-explanation text than with speaking their self-explanation when they are dealing with science texts (Muñoz et al., 2006).

Research on self-explanation has been conducted on academic subjects like physics (Fukaya, 2011; van der Meij & de Jong, 2011) and mathematics (Durkin, 2011). However, studies examining effects of self-explanation on learning computer programming have been sporadic. The few studies consist of text learning of LISP in the early to mid-90's by Bielaczyc, Pirolli and their associates (e.g., Bielaczyc & Pirolli, 1995; Pirolli & Recker, 1994), an experiment on the controlled self-explanations with learning Structured Query Language (Yuasa, 1994), and recently one study regarding reflective self-explanations with learning JavaScript (Kwon & Jonassen, 2011). These studies demonstrated positive effects of self-explanation on learning computer programming.

Based on these previous works, this study required students to type their answers to the guiding questions and provided appropriate instructional support throughout the lessons. For example, after learners submitted their self-explanation answers, a window popped up with suggested answers as instructional support for the learners to verify their understanding.

Reading Questions and Answers

Reading is a prevalent learning method across subjects, such as English and mathematics, and across platforms, like textbooks and online tutorials. Conventionally, students have learned computer programming by reading materials from textbooks or electronic sources. Reading questions and answers helps students focus their attention (Raphael, 1982) and keep them on the right path of learning (Benito, Foley, Lewis, & Prescott, 1993; McIntosh & Draper, 1995, 1996). A similar, established learning strategy called question-answer relationship focuses on understanding the relationship between questions and answers derived from the learning materials. The effects of question-answer relationship approaches have been widely evidenced to be positive (e.g., Kinniburgh & Shaw, 2009; McIntosh & Draper, 1995, 1996; Ouzts, 1998; Pappa & Tsaparlis, 2011; Raphael & Au, 2005). The question-answer relationship leads students to identify sources of information (Raphael, 1984; Raphael & Wonnacott, 1985). Reading questions and answers on a Web page is a variation of question-answer relationship. Learning by reading questions and answers on a Web page, as the current study called for, is comparable to reading printed questions and answers in a paper textbook (Tillman, 1995) and should achieve comparable result.

The application of question-answer relationship has positive results with diverse learners such as skilled adults (Ouzts & Palombo, 2005), young children (Lawrence, 2002; Soptelean, 2012), older children in secondary education (McIntosh & Draper, 1995, 1996), and students with learning disabilities (Gavelek & Raphael, 1982). Examples of its effects included science instruction in which students' reading comprehension of science texts was enhanced, and consequently, students' test scores improved in both subjects of science and reading (Kinniburgh & Shaw, 2009) and a mathematical instruction in which students' increased ability to identify the question-answer relationship improved their mathematical reasoning skills and also expanded upon their existing strategies of successful test-taking (Mesmer & Hutchins, 2002).

The Study

The project is the first to study the effects of self-explanation on novice learning of JavaScript, differing from the study by Kwon and Jonassen (2011) which focused on students' prior JavaScript knowledge and reflective self-explanations after taking a test. The present research is also the first to examine the effect of reading questions and answers compared to self-explanation, and compares the effects of the two strategies, on learning computer programming.

Students' prerequisite knowledge of XHTML and academic motivation to learn computer programming were used as covariates to increase precision of results. Motivation is essential for learning computer programming because it imposes high intrinsic cognitive load (Garner, 2002) and requires extensive practice (Law, Lee, & Yu, 2010). Motivation change is positively related to change in students' achievement in learning computer programming (Su, 2008). For the purpose of the study a composite score of the following motivation variables showing strong, positive relationships with learning, were included: students' self-efficacy belief, effort investment, and task value (Bandura, 1997; Usher & Pajares, 2009; Zimmerman, 2008).

This study examined two research questions: (a) is there a significant performance difference in the end-of-lesson test scores between the two groups of students provided with instructions for self-explanation versus reading questions and answers strategies; and (b) which learning strategy is perceived by students as superior for achieving a better understanding of JavaScript? To capture student perceptions, both quantitative and qualitative analyses were conducted.

Methods

Participants

Participants (N = 147) were students at a high school located in a large, metropolitan school district of the southwestern United States. They were from diverse ethnic backgrounds with the vast majority being Hispanic-American (65% vs. school district average 42%) and African-American (17% vs. school district average 12%). The subjects were students of six periods of an introductory computer course with approximately equal numbers of students from freshmen to seniors. The ages ranged from 14 to 17 (n = 143) and 18 years old (n = 4) with the median age 16. Each group was randomly assigned three periods resulting in 78 students in group 1 and 69 students in group 2. The participating students had little to no previous computer programming knowledge. Earlier in this introductory computer course, all students were introduced to coding Web pages in XHTML. They were informed of this research study, and given the option to participate.

Materials

An online interactive multimedia tutorial with five JavaScript lessons was designed by utilizing worked examples and the cognitive principles of multimedia learning including the spatial and temporal contiguity, coherence, redundancy, and image and personalization principles (Mayer, 2009, 2011). The multimedia learning principles and worked examples were constant while the experimental variable was learning strategy.

To examine the second research question, all students were exposed to both learning strategies. After learning the first two lessons, group 1 self-explained to answer the guiding questions, whereas group 2 read the questions and provided answers. For the 3rd and 4th lessons, the two groups switched their learning strategies. For the 5th lesson, each group went back to its original learning strategy. As the first two lessons were the easiest and the fifth was the most difficult of the five lessons, this design configuration allowed materials of similar difficulty to be presented to each group.

The tutorial was hosted on an Internet Website but students had only restricted access from a classroom to control the place variable. The study took care to ensure that only eligible users were accessing the tutorial, all individual user received appropriate training materials intended for his or her group, and the learner activities (self-explanation narrations and testing) were recorded through the server.

Figure 1 is the flowchart of the instructional design. Each lesson was structured into five Web pages. Learners of both groups saw exactly the same pages except page 4. Each learner logged on through page 1, selected a lesson of interest on page 2, studied a demo and practiced on page 3, then practiced further on the upper part of page 4. The only difference appeared at the lower part of page 4. Students of the self-explanation group typed an answer to each of the guiding questions in the format of self-explanation then could compare it with the suggested answer in a pop-up window after submission. Students of the reading questions and answers group read a same question with its answer provided simultaneously in a pop-up window. Then all the learners encountered the same end-of-lesson test on page 5.

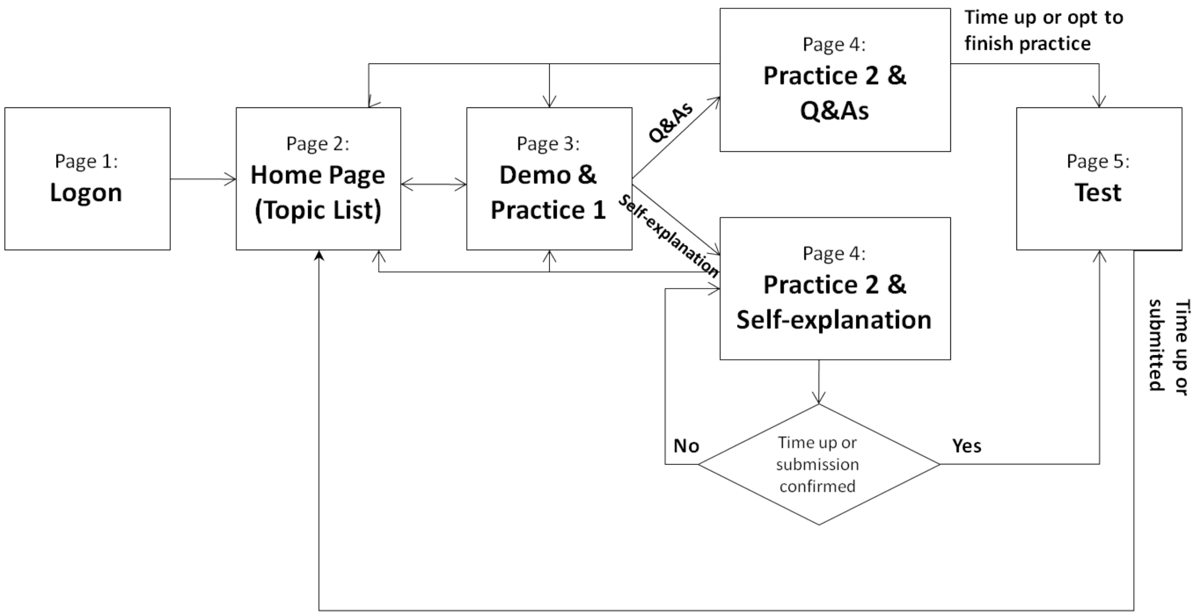

Figure 1: Overview of the instructional design in the format of a flowchart.

At the completion of all five lessons, students took the end-of-study questionnaire to express their learning strategy preference and provide reasons for the choice.

Measures

XHTML pretest. An XHTML test was administered to students before they were introduced to the online tutorial to evaluate their Web design background knowledge. The reliability estimate (Cronbach's alpha) was .85.

Motivation questionnaire. A 23-item questionnaire was used to assess students' motivation levels in self-efficacy, effort expenditure, task value (attainment, utility, and intrinsic value) regarding computer language learning, and distractor items. A modified version of the Self-Assessment Questionnaire was utilized. Items in this questionnaire were modified to accommodate the current study from a well-established instrument on motivation and metacognition (see Hong, O'Neil, & Feldon, 2005, and O'Neil, Sugrue, Abedi, Baker, & Golan, 1992, for the history of instrument development and validation results). The reliability estimate was .90.

End-of-lesson tests. The tests at the end of the lessons were developed to assess the level of a student's acquired topical and procedural knowledge. Students' answers were rated on a 5-point grading scale. The reliability estimate was .76.

End-of-study questionnaire. The six items in the questionnaire inquired students' perceptions about the effectiveness and preference of either learning strategy and to explain why. The reliability estimate was .73.

Procedure

Participating students and their parents (if students were under age 18) signed a consent form provided in both English and Spanish. The study was conducted during regular school hours with 50 minutes in each period. A period was devoted for one lesson. Data were collected on an XHTML test and a motivation questionnaire prior to starting the tutorial. During the study, the answers to the end-of-lesson test questions from both groups were collected. The responses to the end-of-study questionnaire were collected after all lessons were completed.

Data analysis. To examine the first research question, two analyses of covariance were conducted with a between-subject factor (group) and two covariates (XHTML test scores and motivation scores). Practical significance (η^2) was reported, along with statistical significance for each statistical test. Before testing research hypotheses, data was screened and statistical assumptions were tested. For end-of-lesson test scores, skewness of lessons 1, 2 and 5 and of lessons 3 and 4 were smaller than $|1|$, approximating normal distribution. Individual z-scores were all smaller than $|3|$. Homogeneity of variance/covariance assumption was met, $p = .71$, for end-of-lesson test scores of lessons 1, 2 and 5. For lessons 3 and 4, although the probability level for the test of homogeneity of variance/covariance assumption was .032, the slight departure from the homogeneity assumption would not pose a problem on the robustness of the hypothesis testing as the group sizes were similar and the data approximated normal distribution. The assumption for the homogeneity of regression coefficient was met, with p values ranging from .34 to .82 for two dependent variables for the two groups.

Students' preference choices were counted and frequency differences were examined with chi-square tests. Students' narrative responses were analyzed to elicit categories using the following procedure: (a) listing and compiling participants' responses; (b) category elicitation by judging, tentatively labeling, and inspecting tentative labels to determine common categories; (c) mapping all participants' responses onto the tentative categories and inspecting categories for further revisions; (d) re-evaluating responses and mapping onto the final categories as necessary.

Two coders independently conducted category elicitation and mapping students' responses. An inter-coder agreement for elicited themes yielded an acceptable rate of 92.3%. After discussing the coder discrepancy, students' individual responses were remapped. For each theme elicited, students' reasons for their preferences were counted.

Results

To determine if student performance at the end-of-lesson tests were significantly different between the two groups, two analyses of covariance (ANCOVA) were performed. One on the mean end-of-lesson test scores of lessons 1, 2 and 5, and the other on lessons 3 and 4, and both with two covariates, XHTML and motivation scores.

The means, standard deviations and adjusted means and standard errors for students' end-of-lesson tests scores are presented in Table 1.

Table 1: Means and adjusted means of end-of-lesson tests by two groups.

Lessons	The Self-explanation Group	
	M (*SD*)	Adjusted *M* (*SE*)
Lessons 1, 2, 5	2.30 (1.24)	2.31 (0.13)
Lessons 3, 4	2.28 (1.32)	2.28 (0.17)
	The Q&A Group	
	M (*SD*)	Adjusted *M* (*SE*)
Lessons 1, 2, 5	2.50 (1.19)	2.49 (0.14)
Lessons 3, 4	2.37 (1.52)	2.36 (0.16)

n = 78 (self-explanation); *n* = 69 (Q&A).
Q&A = reading questions and answers.

There was no statistically significant group difference in the adjusted means of end-of-lesson test scores for lessons 1, 2 and 5, $F(1, 143) = .940$, $p = .334$, $\eta_p^2 = .007$. Neither were those for lessons 3 and 4, $F(1, 143) = .105$, $p = .746$, $\eta_p^2 = .001$.

The end-of-study questionnaires were analyzed for students' perceptions on the two learning strategies. Although students consistently selected self-explanation (SE) over reading questions and answers (Q&A) as their preferred method of learning throughout the six items, the statistically significant difference was found only in Item 6 (Which method of learning helped you learn JavaScript better?), $\chi^2 = 6.37$, $p < .02$. Elicited themes and sample student reasons for their preference choice are presented below.

Item 1: Which method helped you understand JavaScript concepts better? Fifty-eight percent of group 1 students, who had started learning the first two lessons with the self-explanation method, chose SE, while the rest 42% chose reading Q&A. Students in group 2 also preferred

SE (55%) over Q&A (45%). Sample responses are presented in Table 2. Due to space limitation, tables are provided for the first and last items. For Items 2 to 5, summarized results are presented (request for tables for these items can be directed to the authors).

Table 2: The elicited themes and sample reasons of students' preference for Item 1.

Elicited Theme	Sample Student Reasons for Preference	
	SE	Q&A
It shows me what to do exactly	(None)	"… I understand better when someone is telling me what to do"; "…when I don't know the answer, it shows and I learn it" (and 18 additional answers).
It helps me think	"To think about it"; "It made me think harder about the information from the lessons"; "It made me have to understand it enough to be able to explain it" (and 3 additional answers).	"Q&As helped reiterate what I already learned and tested me on the depth of my JavaScript knowledge"; "Because I can read the question and try to answer then I check if I got it right."
It provides more information	"Because it explains more of JavaScript."	"… when I don't know the answer, it shows and I learn it."
Doing nothing /easier than typing	(None)	"Because I understand better when someone is telling me what to do."
It is easier to understand	"I say self-explanation because it is way easier to follow along than to just read Q&As"; "I understand better," (and 5 more).	"Well if I do it and it shows me how to really do it, it helps me understand something"; "Reading questions and then reading the answer helps me the most because it's logical"; "I know how to learn by reading it" (and 12 more).
I learn better with examples	"The way it helped me understand is because the example and display examples help me then I try" (and 1 more).	"Because the way I learn is very unique. I learn by looking at examples."
It affords (allows/forces) me to take the initiative to learn and express my knowledge	"…you can explain it on how you learned it"; "… because being able to learn on our own by answering questions let us understand the concepts more comfortably"; "It made me have to understand it enough to be able to explain it" (and 1 more).	(None)
It helps me remember better	"It helped me remember some of the JavaScript concept by using self-explanation." (and 2 more).	"Helps me remember more."
I get to learn and practice on my own / challenge myself	"…because being able to learn on our own by answering questions let us understand the concepts more comfortably"; "It made me have to	(None)

	understand it enough to be able to explain it" (and 9 more).	
New, interesting, less stressful	(None)	(None)
The prompted answers enlighten me	"I was getting my question answered by the prompted answers"; "Self-explanation because when information was given, I could read it and know what I am doing."	(None)
"Just because"	"It was better"; "It's better than Q&As"; "I always learn better like that"; "Self-explanation works best for me" (and 2 more).	"Because it explains to you the answer and question"; "It was better for me because I am a question and answer type of person"; "Because I learn better like that" (and 7 more).
Obscure, incorrect or irrelevant	"Self-explanation is a domain general constructive activity" (Author notes: Such explanation was not provided to students therefore is deemed irrelevant to reason of preference) (and 11 more).	"Some people can't remember the material and therefore cannot answer questions (Some answer for all)" (and 2 more).

Item 2: "Which method of learning helped you understand better the importance of utilizing JavaScript for Web development?" Group 1 students preferred SE (58%) over Q&A (42%); group 2 students chose Q&A (52%) over SE (48%). Sample responses for SE preference included: "If I explain it to myself in my own words, I will learn faster"; "If I read the method, I think I can get it myself instead of Q&As"; and "I understand better with my own explanation." Sample reasons for Q&A preference included: "Q&As because it had the answer there for you already"; and "Because when it asked me questions, it reminded me of what the topic was about and what to do."

Item 3: "After which exercise did you think that you could write your own JavaScript code?" Group 1 students preferred SE (54%) over Q&A (46%) and group 2 students also selected SE (57%) over Q&A (43%). SE preference sample reasons included: "Doing it yourself is better than just reading"; and "If I read it to myself & then re-read it & translate it in a way that I will understand & then think about it, I will get it." Sample responses for Q&A preference were: "It's way much easier for me to do because it's done for you already"; and "Q&As helped me write my own JavaScript code because it gave me review to what was coming towards me and gave me the understanding of what it was possibly going to ask me."

Item 4: "Which method of learning helped you visualize better what a given piece of JavaScript code will do in your Web page?" Group 1 students preferred SE (57%) over Q&A (43%); group 2 students also chose SE (55%) over Q&A (45%). Sample responses for SE preference included: "I would've read it myself and try to get it the JavaScript code"; and "Because I feel like it explained it good, to the point where I really understood it." A sample response for Q&A preference was: "Gives me the correct code."

Item 5: "Which method of learning helped you understand better the importance of the correctness of writing the JavaScript code?" Group 1 students selected SE (57%) over Q&A (43%); group 2 students also preferred SE (57%) over Q&A (43%). Sample reasons for SE preference were: “Because it was laid out clear on what you have to do”; “Because self-explanation helps me understand it a little bit more”; and “I understand this better with explanation.” Sample responses for Q&A preference were: “I would be able to understand it better”; “Easier to understand”; and “Helps me remember more, explains it better.”

Item 6: “Which method of learning helped you learn JavaScript better?” Group 1students preferred SE (64%) over Q&A (36%); group 2 students also chose SE (52%) over Q&A (47%). See sample responses in Table 3.

Table 3: The elicited themes and sample reasons of students’ preference for Item 6.

Elicited Theme	**Sample Student Reasons for Preference**	
	SE	**Q&A**
It shows me what to do exactly	(None)	“…Q&As made me reassured that I knew how to write JavaScript code…tested my immediate wit”; “…you can get exact information…”; “…it gave me a question and I wouldn't have to look for the answer”; “Because it tells me the questions I should be looking for and the answers I should say” (and 40 more).
It helps me think	“I think to myself”; “It got me to think harder” (and 3 more).	“I think to myself.”
It provides more information	“It explains more specifically” (and 1 more).	“Gives more info”; “…because it not only helped me review but gave me useful information, that could enable me get a full understanding”; “More detail was explained”; “Because there were more details.”
Doing nothing/no typing	(None)	“I only need to read…to understand the concepts.”
It is easier to understand	“…easier to understand”; “I can tell from my own wording that I understand more”; “Made me comprehend the material better”; “It's a lot easier to understand …”; “Self-explanation is more helpful to understand” (and 2 more).	“I say both but Q&As helps me understand it”; “It explains better”; “I only need to read the Q&As to understand the concepts” (and 4 more).
I learn better with examples	“Self-explanation clearly gave me examples”; “It helped me learn better by giving examples...”	(None)
Taking the initiative to learn	“I think both helped, but self-explanation helped more by practice” (and 1 more).	(None)

&express knowledge		
Helps remember better	"I remember better by explaining to myself."	(None)
I get to learn and practice on my own / challenge myself	"…because if put in your own words it's easier for you"; "I can tell from my own wording that I understand more"; "I can explain to myself what's going on"; "It gave me the code to study and type on my own" (and 9 more).	(None)
"…less stressful"	"…all I can say it was less stressful."	(None)
The prompted answers enlighten me	"Because it explains it like an adult/professional would"; "Because after you type, it tells you and explains it to you."	(None)
"Just because"	"…teaching me the best way to use JavaScript"; "Because it just helps you understand a lot more than Q&As" (and 4 more).	"Because questions and answers help me better."
Obscure, incorrect or irrelevant	"Am not sure which one may help me learn the JavaScript" (and 12 more)	"It helped me to interact." (Author notes: There is no interaction with Q&As.)

Due to the similarity of the themes elicited from student responses throughout all questionnaire items, they were combined to count frequencies and chi-square tests were performed to determine the differences between SE and Q&A preferences (see Table 4).

Table 4: The elicited themes and frequencies of students' preference.

Themes	SE	Q&A	χ^2
It shows me what to do exactly	0	140	140.00^{***}
It helps me think	26	8	9.53^{**}
It provides more information	11	10	0.05^{ns}
I don't have to do anything/Easier than typing	0	5	5.00^{*}
It is easier to understand	43	45	0.05^{ns}
I learn better with examples	10	4	2.57^{ns}

It affords (allows/forces) me to take the initiative to learn and express my knowledge	24	0	24.00^{***}
It helps me remember better	10	4	2.57^{ns}
I get to learn and practice on my own/challenge myself	66	0	66.00^{***}
It's new/interesting/less stressful to me	3	0	3.00^{ns}
The prompted answers enlighten me	10	0	10.00^{**}
"Just because"	36	30	0.55^{ns}
Obscure, incorrect or irrelevant	70	15	35.58^{***}

* $p < .05$. ** $p < .01$. *** $p < .001$. *ns* = not significant.

Several themes in students' reasons for preference demonstrated statistically significant differences between SE and Q&A. Those themes that demonstrated higher frequencies in SE included: "It affords (allows/forces) me to take the initiative to learn and express my knowledge"; "I get to learn and practice on my own/challenge myself"; and "The prompted answers enlighten me." The themes with higher frequencies in Q&A included: "It shows me what to do exactly"; and "I don't have to do anything / easier than typing." The following categories did not demonstrate statistical significance: "It provides more information"; "It is easier to understand"; "I learn better with examples"; "It helps me remember better"; "It's new/interesting/less stressful to me"; and "Just because."

Discussion

Both self-explanation and reading questions and answers strategies have shown positive effects on learning in previous studies (Durkin, 2011; Raphael & Au, 2005), however this study is the first to compare their effects on learning computer programming. To strengthen the understanding, students' preferences and reasons were examined. Furthermore, the current study, along with the study by Kwon and Jonassen (2011), filled the research gap after nearly two decades by examining the effectiveness of the self-explanation strategy in learning computer programming.

Differential Effects of Two Learning Strategies on Learning Computer Programming

Students' end-of-lesson test performance did not differ. However, the questionnaire data revealed that students from both groups had more favorable impressions toward self-explanation over the reading questions and answers method. The reasons expressed by students have informed why self-explanation was perceived as better. The major elicited themes and their response frequencies are discussed.

Elicited Themes

The elicited themes reflected students' attitude toward learning. Excluding the reasons that were "just because" or "obscure, incorrect or irrelevant," and only considering the reasons with more than zero count, the reasons among students' preference for self-explanation were more evenly distributed than those for the preference for reading questions and answers. Of nine themes with 203 counts of reasons for the self-explanation preference, the largest count was 66 for one reason ("I get to learn and practice on my own/challenge myself"). As for the reading questions and answers strategy, of the seven themes elicited with 216 counts, there were 140 counts toward one reason ("It shows me what to do exactly").

Students preferring the reading questions and answers method appeared to like to be shown what to do, which is aligned with one of the benefits of the question-answer relationship strategy as guiding students in the right direction of learning (Benito et al., 1993; McIntosh & Draper, 1995, 1996; Raphael, 1982). Nevertheless, their remarks demonstrated passivity in their learning approach. On the other hand, the two themes for the self-explanation preference that demonstrated statistically significant differences and accounted for over 40% of the counts were: "I get to learn and practice on my own/challenge myself"; and "It affords (allows/forces) me to take the initiative to learn and express my knowledge." They seemed to indicate that students liked the challenges brought forth by self-explanation, appreciated the opportunity to take charge of their own learning, wanted to be in control of the learning process, and were happy to give their input during learning. These themes showed that students enjoyed active participation in learning.

One theme revealed that self-explanation had appealed to some students because it was new, interesting, or less stressful. According to students' verbal and written comments, they had never heard of this learning strategy before the study. It is possible that there was a certain novelty effect. The conjecture for the "less stressful" comment was that the appearance of the reading questions and answers caused higher anxiety in the individuals. Not surprisingly, no students considered it a new experience to read questions and answers, attesting to their previous exposure to reading.

The two themes for self-explanation, "The prompted answers enlighten me"; and "It helps me think" appeared to support the premise that students would rather think about how to answer the questions on their own before verifying with the prompted answers, while still drawing upon the knowledge provided. Students seemed to enjoy knowing that they had understood it correctly by reading the prompted answers after some delay, instead of being fed with immediate answers. On the other hand, some themes with preference for reading questions and answers also demonstrated higher frequencies with statistical significance such as students expressed their pleasure of "not having to do anything" or "easier than typing" because typing was only required by the self-explanation method, indicating their reliance on being guided with their learning.

Some reasons were given for both preferences. For example, one student who cited the reason, "It is easier to understand" described himself as a "Q&A type of person," while another student citing the same reason but with the preference of self-explanation explained, "I understand better with my own explanation." The reasons: "It provides more information"; "I learn better with examples"; and "It helps me remember better" were also expressed for both strategies. Students seemed to share these same opinions toward their respective preferred learning methods. It appeared that students considered their preferred method as the one that provided them with more information because that method had a better appeal to their learner characteristics than the other method did.

This alludes to the conjecture that both methods could appeal to certain learner characteristics and favorably help learners process the information. An understanding of the learner characteristics of a target audience is essential for instructional design. Tailoring the instructional design to accommodate learner characteristics can help maximize student learning, especially for those who struggle. Teachers and instructional designers should strive to search for and use well-evidenced, effective learning and instructional strategies in developing instructional materials.

There were extraordinarily high numbers of the reasons of "just because" and obscure, incorrect or irrelevant answers, probably caused by the low academic standing of the participants. Students' poor reading comprehension could have hindered appropriate understanding for the strategies and their ability to reason (Schumm, Vaughn, Klingner, & Haager, 1992).

Proposed Suppositions for No Group Difference in Test Performance

Familiar versus new strategies. The reading questions and answers strategy had a wide and consistent application with success in various subject matter (McIntosh & Draper, 1995, 1996; Raphael & Au, 2005). The participating students had experience with reading and were more ready to take advantage of it, as compared to the unfamiliar concept and procedure of self-explanation.

Difficult learning material. Computer programming as a subject appears to have radical educational novelty (Dijkstra, 1989), imposing high levels of intrinsic cognitive load on novice learners (Garner, 2002). Additionally, the questions in the current study were open-ended, not multiple choice items, or those that require one correct answer (Pappa & Tsaparlis, 2011). For instance, the question that asked how to tell if there was embedded JavaScript code in a Web file was a "think and search" question requiring learners to understand the text and formulate an answer in their own words. Thus, the difficult learning materials and questions could have reduced the discriminating ability of the tests.

Short experimental period. Several 50-minute class periods spanning five days might be challenging for students to master a new learning strategy. More studies of a longer experimental duration are needed.

Limitations and Future Research

To answer the research questions, students had to experience both learning strategies. The design switched the subjects between the strategies due to the limitation of the subject pool and experimental period. We can refine this design to be more balanced by adding a fourth stage of learning, switching to the other strategy one last time. We can also add clarification on the difference between treatments versus no treatment by adding a control group that experiences neither strategy.

The nonsignificant test performance might have been partly due to variation in students' general academic differences. The current findings warrant the need for continued research, especially with difficult subject matter or underperforming participants. To accommodate learner characteristics, the multimedia pre-training principle that helps prime learners before a formal study and the signaling principle that assists in orienting the learners throughout the study can be utilized and will help maximize the understanding of learning strategy effects.

Conclusions and Implications

Although students' test performance did not differ between the two strategies, students preferred self-explanation, as it is interesting, challenging, and affords active participation in learning. It was also evident that learner characteristics played an important role in students' preferences. Future design and development of instructions therefore should utilize research findings on effective learning strategies in general as well as adapt to local needs like learner characteristics. More studies on the strategy of self-explanation with learning computer programming in appropriate lengths of experiments are warranted to help ascertain its potential effect.

The interactive online tutorial developed for the current study can be used for online or classroom teaching. When utilized in the classroom, students can learn at their own pace and teachers can provide personalized assistance. Students can further utilize the tutorial after school for extended practice. The tutorial provides performance-related feedback, along with the multimedia learning instruction guidelines such as the spatial and temporal contiguity principles (Mayer, 2008, 2009, 2011), and can keep learners interested and result in efficient instruction (Lee, 2008).

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