INSTRUCTIONAL APPROACHES ON SCIENCE PERFORMANCE, ATTITUDE AND INQUIRY ABILITY IN A COMPUTER-SUPPORTED COLLABORATIVE LEARNING ENVIRONMENT

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ABSTRACT

This study examined the effects of an inquiry-based learning (IBL) approach compared to that of a problem-based learning (PBL) approach on learner performance, attitude toward science and inquiry ability. Ninety-six students from three 7th-grade classes at a public school were randomly assigned to two experimental groups and one control group. All groups received the same web-based curriculum on the scientific topic of the greenhouse effect. These IBL groups, though, were asked to actively participate in the processes of predicting, hypothesizing, and testing, while the PBL groups were instructed to follow a specific problem-solving process. The results revealed that all students performed equally in science performance despite of the treatment groups. In terms of attitude toward science, the findings indicated that students participated in IBL or PBL groups reported more positive attitudes toward learning science and resulted in higher inquiry abilities than those who were in the control group. This study concerns itself with the features of the experimental treatment that may have contributed to these results, the implications of which are also considered.

INTRODUCTION

Recently, the design and use of computer-supported collaborative learning (CSCL) has received a growing interest. Many authors have described the principles of learning and instruction that underlie the construction of such environments (Feltovich, Spiro, Coulson, & Feltovich, 1996; Hewitt, 2002). Although the terminology used to describe the principles varies among authors, a set of common ideas appears in most of their descriptions. These principles include the assignment of learning tasks that are relevant to learners, the encouragement of learners to take ownership of the learning process, the requirement of learners to work together to address the learning tasks, and the construction of learning tasks that are situated within a complex and realistic context (Koschmann, Kelson, Feltovich, & Barrows, 1996).

While a number of experimental and quasi-experimental studies have compared the effects of CSCL environments with traditional lecture and discussion-type instructional approaches, results have varied greatly. In some instances, students who were taught in accordance with traditional lecture and discussion practices demonstrated learning outcomes that were equal to those demonstrated by students who were placed in computer-supported learning settings (Tutty & Klein, 2008; Yildirim, Ozden, & Aksu, 2001). In other cases, students in computer-supported environments learned more and retained longer learning effects than did students who received a lecture and discussion approach (Yu, She, & Lee, 2010). When the computer-supported approach proved to be superior, however, the researchers were unable to ascertain which features of the computer-supported learning environment were primarily responsible for the improvement in learning and attitudes.

Given the mixed results and the difficulty that previous researchers have had in isolating the most important features of CSCL, we thought it would be beneficial to conduct a study that focused on how to connect the features of CSCL to maximize its instructional advantages. As noted above, one of these features involves the degree of contextualization in which a learning task is presented to learners. Contextualization, defined by Mazzeo, Rab, & Alssia (2003) as “a diverse family of instructional strategies designed to more seaminglessly link the learning of foundational skills and academic or occupational content by focusing teaching and learning squarely on concrete applications in a specific context that is of interest to the student” (pp. 3-4). Numerous terms regarding contextualization are used interchangbly with basic instruction or a specific content that is meaningful and useful to students such as contextualized instruction, situated cognition, problem-based learning, and inquiry-based instruction (Gijbels, Dochy, Van den Bossche, & Segers, 2005; Hattie, Biggs, & Purdie, 1996). Regardless of the term used, all of these applications center on the practice of systematically connecting instructional task to life goals, which places students’ interests and needs at the center of education (Dewey, 1966; Dowden, 2007). Perin (2011) reviewed sixteen studies on contextualized instruction and concluded that the outcomes of contextualized instruction were positive unless it is coupled with explicit strategy instruction. For example, De La Paz (2005) found that students received contextualized writing instruction with self-regulation and historical reasoning strategies showed greater gain on essay length, numbers of arguments in the essay, persuasive quality, and historical accuracy than those who received traditional instruction.

To take the full potential of contextualized instruction, learning tasks that encourage deep or meaningful learning are critical. However, the extent of how varying degrees of contextualized instruction affect the acquisition and transfer of skills and knowledge when coupling with other instruction appears to have little consensus within the instructional design community. Problem and inquiry-based instruction were of particular interest to the current study. This study focused on these two instructions that had not been rigorously examined in the context of computer-supported collaborative learning environment yet had been shown to enhance learning outcomes and affective changes.

Some theorists have emphasized the value of problem-based learning (PBL), in which content is presented indirectly through a rich simulation of a real-world, problem-centered environment (Hmelo-Silver, 2004; Lee, Shen, & Tsai, 2008). In the literature, PBL has been defined and described in several ways. Evenson and Hmelo (2000) state PBL is one of many contextualized approaches that much of the learning and teaching is anchored in concrete problems. In spite of many literatures on PBL, the core model of PBL is based on the ideas that learning should occur in concrete situations that have a relationship with students' prior knowledge and experiences (Barrows, 1986). Over the last five decades, PBL has been applied globally in many disciplines such as medicine (Barrows & Tamblyn, 1976), economics (Garland, 1995), business (Merchand, 1995), and psychology (Reynolds, 1997). One of the key features of PBL is collaborative problem-solving groups (Hmelo-Silver, 2004). Studies have found collaborative PBL alone does not help establish productive learning, but the learning should contextualize within the framework of higher order thinking and shared knowledge construction (O'Donnell, 1999; Palincsar & Herrenkohl, 1999). There is not yet evidence that PBL with contextualized instruction helps students become better collaborators or problem solvers (broadly defined). Therefore, the examination of PBL in the context of CSCL should shed lights on the overall effectiveness of contextualized instruction in PBL.

Others, have argued in favor of a highly contextualized inquiry-based learning (IBL), in which explicit prediction, hypothesizing, and testing is involved (de Jong, 2006; Oliver, 2008). In IBL, students learn content as well as domain-specific knowledge and skills by collaboratively engaging in investigations (Quintana et al., 2004). Frequently implemented in the science education, IBL focuses on enabling students to take ownership of learning through experimentation and exploration. Chang and his colleagues (2003) found that collaborative IBL facilitates college students' knowledge elicitation and exchange of inner thinking. Similar findings are discovered in many domains such as history (Yang, 2009), statistics (Schwartz & Martin, 2004), and social work (Plowright & Watkins, 2004). There is an extensive body of research on scaffolding learning in inquiry-based environments (e.g., Chen, Wu, & Lan, in press; Guzdial, 1994; Reiser, 2004; Toth, Suthers, & Lesgold, 2002). While many would agree that IBL with substantial student collaboration is effective at facilitating student learning, few studies in IBL has examined the activity of collaboration in the process of inquiry or acquiring new knowledge.

As noted by Hmelo, Duncan, and Chinn (2007), PBL and IBL are instructional approaches that situate learning in a practical task. In PBL, students learn by solving problems using their experiences or knowledge. In IBL, students learn by engaging in investigations of hypotheses, predictions, and evidence. Although PBL and IBL share several features, the distinctions between them have not been thoroughly examined. In a study that examined the introduction of PBL and IBL into the social work curriculum, Plowright and Watkins (2004) found that PBL is better at fostering the development of knowledge and skills within a professional discipline, while IBL divides the development of knowledge and skill into discrete units and imposes an assessment regimen that provides little opportunity for making connections between different subject areas.

Accordingly, research has shown that student performance and the transfer of newly acquired skills are largely affected by the degrees of contextualization in instruction and in the assessment or transfer environment. It has been found that contextualized instructional approaches, such as PBL, are most suitable for supporting the process of solving a problem and acquiring knowledge and that an active learning approach, such as IBL, is most suitable for supporting the acquisition of complex problem-solving strategies. Although no research has been published that compare the effectiveness of PBL to IBL, some research does support the notion that IBL increases certain aspects of motivation and engagement (Lynch, Kuipers, Pyke, & Szesze, 2005), while other research has pointed to PBL as a facilitator of future learning (Schwartz & Martin, 2004).

Despite steady growth in intellectual writing and theorizing on the impact of PBL or IBL approaches on instructional effectiveness, research in the area of CSCL environments remains very limited. Furthermore, most researchers have approached the issue by comparing the impact of a particular instructional strategy to instructional settings that are frequently characterized as traditional, classroom-based teaching. Research studies comparing the effectiveness of a particular instructional strategy in the public school setting often fail to acknowledge that the instructional strategies used by instructors may vary significantly from one case to another. As a result, these research studies provide little clarity concerning the measure of comparison used to determine the effectiveness of a particular instructional strategy.

THE PURPOSE OF THE STUDY

The purpose of this study was to determine the impact of varying degrees of contextualization of instruction on learner performance, attitude toward science, and inquiry ability. Specifically, the study compared the performance, attitudes, and inquiry abilities of learners who received instruction through one of two different approaches while engaging in the CSCL context. The first instructional approach was problem-based learning (PBL). The PBL simulates the complexities of real-world settings in which the learner might be expected to apply the skills and knowledge acquired through the instruction. Learners were required to gather necessary information from the material presented and collaboratively solve the problem as given by following a step-by-step problem-solving procedure (e.g., representation of problem(s), development of solutions, and monitoring and evaluation of a plan of action). The second instructional approach was inquiry-based learning (IBL) with content presented in a contextualized manner. Information was first presented through a description of abstract concepts and conceptual relationships, and then it was placed in context through a series of guided examples. The practice activities provided as part of this strategy were of gradually increasing levels of complexity and contextualization. The first activities were largely contextualized in nature, whereas the final practice activity simulated the ill-structured, complex nature of real-world problems.

METHOD

Participants

The participants in the study were 96 7th-grade students, who were attending a middle school in Taiwan. The participants were from three different classrooms, and all three classrooms were taught by the same instructor for the nature science subject. This study took place during the students' regularly scheduled science period. The average age of the children was 12 years and three months (SD=1.3). In total, 45 of the children were male and 51 were female. The level of science achievement among the participants was typical of their level in the school.

Materials

Instructional website. Regardless the treatment group, all students had to access the instructional website on nature science (see also Figure 1). The instructional website contains five elements: (1) News, (2) Resources, (3) Courseware, (4) Simulation, and (5) Evaluation and Survey. News reports what was happening at the time of data collection. Resources include the internet resources that students can find relevant information on the topics of the study. Courseware is educational material intended as kits for students to use. Courseware encompasses the topics related to the greenhouse effect. As illustrated in Figure 2, topics such as greenhouse effect and solar radiation and the earth are listed in the left hand side, and students can click on the topic(s) to study further. The design of the courseware content was in reference to Gagne's events of instruction. For example, a list of learning objectives (inform objectives), description of the relationship of the instructional contents (present stimulus material), a case study that is related to the subject (provide learning guidance), and a series of self-guided activities (elicit performance). Simulation page directs students to access a free online physics, chemistry, biology, earth science, and math simulations created by the University of Colorado called PhET. Evaluation and Survey page links to the database, where students were asked to complete pre/posttests and all of the questionnaires.

Figure 1. Instructional website

Figure 2. Screenshot of e-learning courseware

Problem-based learning (PBL) booklet. PBL booklet was the instructional manual that taught students how to solve problems step-by-step, following the processes of problem-solving which involve constructing problem space, choosing and generating solutions, monitoring and evaluating (i.e., Chen, 2010; Ge & Land, 2004; Sinnott, 1989). Booklet included external scaffolds aligned with the processes of problem-solving were designed by the researchers and content experts. Scaffolds included thirteen questions, and the sample questions were "what have caused the greenhouse effect?", "where do you gather information on the causes of greenhouse effect".

Inquiry-based learning (IBL) booklet. IBL booklet was the instructional manual that taught students how to perform scientific inquiry like those of experts. Scientific inquiry involves predicting, hypothesizing, and testing. Booklet included external scaffolds following the steps of inquiry were designed by the researchers and content experts. The sample questions were "what happened if the factory reduces energy fuel?", "what is the possible sources of methane?".

Instruments

Pretest and posttest. A 20-item multiple-choice question test was developed to assess student performance. The test was developed by the teachers who taught earth science class for more than five years. The test was also evaluated by college professors to ensure that they were appropriate. The test included declarative knowledge (10 items) and application knowledge (10 items). Each item was worth 5 point, and the maximum score was 100. Sample item for declarative knowledge was "Which of the following best explains the source of methane? (A) forest fire; (B) fossil fuel; (C) animal; (D) air conditioning." Sample item for the application knowledge was "Which of the following cannot prevent global warming? (A) recycling; (B) eliminate energy fuel reduction; (C) raise cattle and sheep in the farm; (D) ride bicycle. The split-half internal consistency for the test was .81. The test was distributed prior and after the study as reference to pretest and posttest.

Attitude toward science. In order to better understand student science attitude, we adopted Cheng and Yang's (1995) Attitudes toward Biology Scale (ATBS) because this scale offers psychometric quality and provides both reliable (Cronbach alpha was between .87 and .92) and valid evidences allowing others researchers to apply to the context of this study. Before using the scale, minor modifications were made to accommodate this study's subject area (earth science) and participants. Reasons for using ATBS were its prior usage in the Cheng and Yang (1995)'s study shows stable reliability and steady construct validity. The instruction for completing the scale was given in the beginning: This survey contains a number of statements about science. You will be asked what you think about these statements. There are no "right" or "wrong" answers. Your opinion is what is wanted. For each statement, choose a specific numeric value corresponding to how you feel about each statement. 5 as strongly agree, 4 as agree, 3 as neutral, 2 as disagree, and 1 as strongly disagree. The survey with a total of 28 items includes five distinct science-related attitudes. The first factor is social implications of science. Here is a sample statement measuring it: "I think science is very meaningful to everyday life." The second subscale is career related to science: "I think science can be my future career." Enjoyment of science class is the third subscale: "I think science is an interesting subject to learn." The fourth subscale is normality of scientists: "The life of scientists is boring and lonely." Attitude to participating scientific inquiry activities is the fifth subscale: "When I encounter science related problem, I like to spend time to research and problem solve." The subscale reliabilities for this study were as follows: social implications of science (Cronbach's alpha = .84), career interest in science (Cronbach's alpha = .87), enjoyment of science class (Cronbach's alpha = .78), normality of scientists (Cronbach's alpha = .81), and attitude toward scientific inquiry (Cronbach's alpha = .86).

Inquiry ability. In addition to the measurement of students' performances and attitudes toward science, our study used 23 items from the Student Inquiry Ability Self-assessment Scale (SIASS) designed by Yang and Wang (2007) to assess students' inquiry abilities. Reasons that this scale was chosen were because it was used previously with fifth grade Taiwanese students and showed .84 internal consistency which is considerably high and stable. The scale included five factors: problem identification (3 items), information exploration (5 items), experiment validation (7 items), explanation (4 items), and transfer (4 items). Sample items for each factors were: "I can define the problem from observing the phenomena."; "I can utilize the library to collect information."; "I can design the steps of an experiment."; "I can predict the experiment outcomes."; and "I can use the collected information to solve the problem." The internal reliability of each subscale for this study was .88, .82, .87, .90, and .91.

Procedure

In this study, three intact classes of participants were randomly divided into three groups: the problem-based learning group (N=31), the inquiry-based learning group (N=33), and the control group (N=32). The members of three groups were equivalently sound. Each of the groups participated in the study for two days over a period of two weeks, dedicating one hour and 45 minutes of instructional time on each day. Only those students who were present all phases of the study, and for whom completed data were obtained, were included in the final analysis.

The actual study took place in the computer classroom with a teacher and three researchers present throughout. On the first day of the study, participants arriving in the computer classroom were told who their cooperative team members would be and were then seated in front of a computer. Once seated, participants were introduced to the research team, informed of the general purpose of the study, and given a description of the procedures and the lesson materials. After the orientation, students were given approximately 15-20 minutes to individually complete a pretest.

Upon the completion of the pretest, students assigned to PBL groups were oriented toward the instructional website and the paper-based PBL booklet. Students assigned to IBL groups were oriented toward the instructional website and the paper-based IBL booklet. For PBL and IBL groups, they worked collaboratively with their team members and wrote down the answers in the booklet. Students assigned to the control groups were oriented only toward the instructional website, and no further instruction or booklet was given.

The assessment procedures were identical for all treatment groups, and the assessment itself was carried out two days after each group received their treatment. All groups were told to individually complete assessments in the following order: posttest, attitude toward science, and inquiry ability questionnaires.

RESULTS

This study included three classes of dependent measures: (1) performance, (2) attitude, and (3) inquiry ability. As a dependent variable, performance was measured in the form of scores on declarative and application knowledge. The measurements and standard deviations of the test scores for performance on the pretest and posttest are presented in Table 1, which shows that the total mean score for the posttest was 64.47. In treatment group, the mean posttest score for the IBL groups was substantially higher than the mean score for the control and the PBL groups. Two t-tests were used to determine the effects of the types of instructional approaches (IBL or PBL) on learner performance. For the scores from the posttest, a review of the distribution of the scores did not indicate any serious violation of the normality assumption. With the alpha set at .05, as well as with 32 participants in IBL groups, the probability of detecting a large effect size was .71. All three groups of participants made significant improvements after the completion of this study. For equality of means on the posttest scores, $F(2, 92)=2.49$, $p>.05$, ES=.05. This result indicated that there were no statistically significant differences between the performances of groups.

Table 1: *Mean scores and standard deviations in science performance by treatment group*

Group	Pretest		Posttest		t	p	ES
	Mean	SD	Mean	SD			
IBL	58.55	16.53	69.68	14.66	-4.76	.000	.71
PBL	55.61	19.44	63.13	16.43	-2.17	.020	.49
Control	54.53	14.39	60.61	19.87	-3.40	.040	.27

The dependent variable of attitude was measured in terms of the social implications of science, career interest in science, enjoyment of science class, normality of scientists, and attitude toward scientific inquiry. Means and standard deviations of these measures concerning all groups are presented in Table 2. Following the descriptive statistics, an ANOVA test was performed to evaluate the differences between groups. The results showed a statistically significant difference among groups on the following subscales: social implications of science ($F(1, 96) =7.18$, $p<.05$), normality of scientists ($F(1, 96) =3.28$, $p<.05$), and attitude toward scientific inquiry ($F(1, 96) =5.04$, $p<.05$). To further explore the trend shown in the means, a post hoc univariate test was conducted. The results showed significant differences between the social implications of science of IBL (M=3.83; SD=.43) and control (M=3.61; SD=.56) groups. The differences between the normality of scientists of IBL (M=3.84; SD=.64) and control groups (M=3.71; SD=.61) and those of PBL (M=3.83; SD=.54) and control groups were found to be significantly different. The results showed a statistically significant difference between the attitude toward scientific inquiry of IBL (M=3.66; SD=.74) and control groups (M=3.43; SD=.54), and those of PBL (M=3.64; SD=.45) and control groups.

The last dependent variable of this study concerned students' self-reported inquiry ability, which showed a significant group difference: $F(1, 96) =4.13$, $p<.05$. The IBL groups (M=3.73; SD=.58) reported significantly higher inquiry ability than did control groups (M=3.56; SD=.41).

Table 2: *Mean scores and standard deviations by treatment group*

Dependent variables	N	Mean	SD
*Social implications of science**			
IBL	31	3.83	.43
PBL	33	3.68	.56
Control	32	3.61	.56
Total	96	3.71	.52
Career interest in science			
IBL	31	3.25	.79
PBL	33	3.16	.57
Control	32	3.19	.55
Total	96	3.20	.64
Enjoyment of science class			
IBL	31	3.56	.85
PBL	33	3.54	.63
Control	32	3.55	.60
Total	96	3.55	.69

*Normality of scientists**			
IBL	31	3.84	.64
PBL	33	3.83	.54
Control	32	3.71	.61
Total	96	3.79	.59
*Attitude toward scientific inquiry**			
IBL	31	3.66	.74
PBL	33	3.64	.45
Control	32	3.43	.54
Total	96	3.57	.59
*Inquiry ability**			
IBL	31	3.73	.58
PBL	33	3.68	.44
Control	32	3.56	.41
Total	96	3.65	.47

*Note. *p<.05*

DISCUSSION

The purpose of this study was to examine the effect of PBL and IBL on learner performance, attitudes toward science, and inquiry ability. There were no statistically significant differences in the science performance of the IBL group, PBL group, and control group. Findings indicate that IBL and PBL groups, given their larger effect size, scored higher on the posttests than did the control group. The lack of statistically significant differences in learner performance as a result of either IBL or PBL may suggest that a critical factor in determining instructional effectiveness in the CSCL is not only the level of contextualization employed, but the type of instructional approaches is designed and implemented. Hmelo and her colleagues (2007) argue both PBL and IBL are not minimally guided instructional approaches but rather as extensive scaffolding and guidance to facilitate student learning. Our finding further supports that both approaches are effective in promoting student learning. The PBL or IBL provides open ended and complexity in a context which is personally relevant to stimulate real world experience (Harwell & McCampbell, 2002; Uden & Beaumont, 2006). As a result, students involved in PBL and IBL processes seem to find it more enjoyable and stimulating (Ma, O'Toole, & Keppell, 2008).

Findings from students' attitudes toward the use of instructional strategies had relatively encouraging outcomes. Both IBL and PBL approaches were found to have a significant impact on several aspects of students' attitudes toward science except career interest in science and enjoyment of science class. This result indicates that learner attitude was impacted by the type of instructional strategy employed while engaging in the CSCL environment. An abundance of applied practice questions were employed in both of the instructional treatments. Motivational components were also incorporated into the design of both strategies through such factors as cooperative group work arrangements and numerous opportunities for learners to reflect and articulate. This study found that students who received IBL responded in a highly positive way to their perceived utility of science in daily life and society, normality toward scientists, and attitudes toward learning science through inquiry. This reiterates the effectiveness of instructional approaches in meeting the affective needs of learners, while pointing to the critically important merits of including a motivational design (Chen & Howard, 2010). This finding also supports the previous research contextualized in student-centered learning environments, showing that IBL that engages students in observing, inferring and measuring, and communicating can help them acquire inquiry skills (Pedaste & Sarapuu, 2006). Additionally, findings showed not all attitudes toward science were improved significantly after experiencing PBL or IBL. It is possible that PBL or IBL triggers uses of inner knowledge and ultimately, promotes deep learning, but such learning context induces heavy learning load which may hinder positive attitude for students who lack of adequate knowledge base (Simsek & Kabapinar, 2010).

IMPLICATION AND LIMITATION

The results of this study yield several theoretical and practical implications. Theoretically, this study extends the current literature on examining both PBL and IBL instructional approaches at the same time and their effects on student performance, attitude toward science, and inquiry ability. Although both instructional approaches present different degree of contextualization, the distinctions between them are very limited based on the results of this study. Practically, this study reassures PBL and IBL learning contexts offers meaningful learning experience that science teachers or curriculum developers can implement in their course design to support students at a metacognitive level as they engage in new learning. Teachers need to uniquely positioned and equipped to provide soft scaffolding to meet students' metacognitive needs.

One of the limitations of current research on the use of various instructional strategies is that it has focused on comparing the impact of a carefully-designed instructional strategy to a control treatment based on the teaching strategies employed by teachers on a daily basis. Under these conditions, inconsistent measures of comparison are used, thus yielding research results that often favor the instructional strategy of interest toward the researcher. In this research study, an effort was made to compare two distinct strategies that had both been developed according to specific instructional design approaches. As a result, a comparison of the impact of each of the strategies on learner performance indicated a lack of statistically significant findings, thereby suggesting that on average, both instructional strategies had a similar impact on learner performance.

Several limitations to the findings of this study merit special attention. In the first instance, participants in the study may not have performed at their highest ability level, given that student performance on the posttests was not considered to be part of the final science grade for the semester. In conducting the study, an effort was made to minimize the potential impact of this limitation in two ways. First, the 7^{th}-grade science instructor remained present in the computer classroom where students engaged in CSCL, thereby ensuring that students continued to feel accountable for their performance and attitude. Second, the instructor communicated to the students that their willingness to actively participate in the study was a factor in assigning their participation grade for the science class. This further encouraged students to put effort into their learning process while receiving their treatment.

Another limitation of the study was the administration of the instructional website. The greenhouse effect website contains instruction on the topic. Research has found that both learner performance and learner attitude are impacted in important ways by the use of different types of instructional media (Kozma, 1991). It is thus conceivable that the data gathered on learner performance or attitude may have been confounded by the use of different media. Furthermore, the administration of treatment was restricted by the regular class hours. The results of different instructional approaches on learner performance or attitude may be influenced by the participation time.

The conclusion of this study suggests more research in the area of examining different types of instructional approaches in the CSCL should be conducted, so that more conclusive findings in learner's performance and attitude can be ensured. The use of qualitative analysis methods could provide valuable insight into the differences in learning processes as a result of each of the instructional strategies. Additional research should also be done to determine the impact of cooperative group work arrangements on individual learning and performance in CSCL settings. Finally, further research could be done to determine whether the use of different media delivery systems in different instructional approaches confounded the research findings.

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