THE IMPACT OF STRUCTURED DISCUSSION FORUMS ON KNOWLEDGE ACQUISITION OF DIFFERENT KINDS BY COMPUTER SCIENCE STUDENTS

Moanes H. Tibi

Computer Science Department, The Academic Arab Institute for Education, The Academic College Beit Berl (ISRAEL)
tibi@beitberl.ac.il

Abstract

Asynchronous discussion forums have been examined for their usefulness in promoting online learning among students. This study proposed a structure for discussion forums and investigated its impact on computer science students' acquisition of different kinds of knowledge: know-*what*, know-*how*, and know-*why*. The study employed a field experiment using pre- and post-tests for evaluating the knowledge level by the students in the three knowledge kinds before and after the participation in the online course. One hundred twenty three students from two academic education colleges participated in seven computer science online courses. The main findings of the study showed that: (1) students of the structured discussion forum acquired more knowledge of the kinds "*how*" and "*why*" compared to the students who participated in the unstructured discussion forum; and (2) the obtained differences in knowledge acquisition were also dependent on the student's prior knowledge of subject matter. The findings of the study can contribute to the field of asynchronous online learning in providing a structure for discussion forums that has the potential to enhance knowledge acquisition of different kinds by the students.

Keywords: CMC, online learning, structured asynchronous discussion forums, knowledge acquisition.

1 INTRODUCTION

Online learning is already a fact of life for most universities and colleges in many parts of the world. The most widely used asynchronous tool for the purpose of increasing interaction and collaboration among participants in an online course is the discussion forum. Discussion forums allow the construction of collaborative knowledge since learners can work together, exchange information and ideas, and comment on each other's work ([1], [2]).

Researchers have reported that while online discussions can facilitate deep learning, that does not happen spontaneously; therefore careful and ongoing instructor mediation and support is required ([3], [4], [5], [6], [7], [8]). It has been also argued that without proper structure and management of the discussion forum, students may not achieve the expected learning goals ([7], [9], [10]).

Recent research has shown that structured discussion forums are more effective for the improvement of critical thinking skills than are unstructured discussion forums ([11], [12], [13]).

The current study addressed the problem of how to organize and manage structured discussion forums for facilitating online collaborative interactions among students in online computer science courses in order to enhance the acquisition of the three different kinds of knowledge (learning *what*, *how* and *why* of the subject).

2 BACKGROUND

The constructivist learning theory places a great emphasis on interaction and claims that knowledge is actively constructed by the student. The pedagogical approach underlying online learning is commonly based on constructivism, where students actively create knowledge in a personally relevant and meaningful manner ([14]).

Researchers, including Huang ([15]), Monteith and Smith ([16]), Sims ([17]), and Alexander, Polyakova-Norwood, Johnston, Christensen and Loquist ([18]), have acknowledged that constructivism learning strategies should be applied in online learning. The literature has also documented that constructivism learning theory is an appropriate match for online learning because it

ensures learning among learners ([19], [20], [21], [22], [23], [24]). In addition, Web technologies can help to shift the focus from knowledge-as-transmission to knowledge-as-construction because of its versatility and accessibility ([25]).

Constructivist principles are also applicable to computer science education ([26]). Computer science education puts emphasis on collaborative learning since students are often learning in groups and are required to design algorithms and to develop software projects in collaboration. Thus, the social and knowledge sharing aspect among students is stressed in completing programming projects. Based on the theory of social constructivism, instructors are responsible for designing a concrete teaching model in the context of the discipline, whilst students are encouraged to work through the problem using collaborative group strategies ([27]). Collaborative learning processes encourage knowledge construction in an environment in which students share their own understanding ([28], [29]). According to this view, the constructivist approach seems to be appropriate for computer science education at all levels ([26], [27], [30], [31]).

2.1 Instructional Strategies

Problem-based learning (PBL) and project-based learning are two important strategies that support the development of key generic capabilities such as teamwork, communication, critical thinking and problem-solving ([32]).

Ellis et al. ([33]) argued that PBL is especially well suited to computer science. Studies ([34], [35], [36]) showed that the adaption of the PBL and project-based learning methodologies in computer science courses encouraged group work and some additional skills such as problem-solving and self-directed learning skills.

In addition, the computer science academic community regards project-based learning as an essential component of any degree ([37]). Project work is recognized as having several educational and social benefits, in particularly providing students with opportunities for active learning ([37], [38]) and creative thinking ([36]).

Since this present study was concerned with the acquisition of different kinds of subject knowledge in computer science online courses, the PBL approach and the project-based learning approach were appropriate instructional strategies that were adopted in this research.

2.2 Subject Knowledge in Computer Science Education

Computer science students are required to obtain subject knowledge of different kinds since they need to design algorithms for given problems and then implement these algorithms by writing a computer program in a programming language. Successful computer programming requires not only knowledge of abstract mathematical thinking and logical reasoning ([39], [40]); it also requires problem solving and critical thinking skills ([41]).

To teach programming, instructors need not only to teach how to design programs and write code to process data, they also need to let students see, test and understand how the code executes and works with data ([40]). Davies ([42]) distinguished between programming knowledge (of a declarative nature, e.g., being able to state how a "while" loop works) and programming strategies (the way knowledge is used and applied, e.g., using a "while" loop appropriately in a program).

Broberg ([43]) pointed out that knowledge is a complex concept and one aspect of the complexity is the wide range of types of knowledge. According to Byrnes ([44], [45]), the term knowledge refers to three kinds of information structures that are stored in long term memory. Byrnes (([44], [45]) and Shavelson, Ruiz-Primo and Wiley ([46]) named these kinds of knowledge: declarative knowledge or "knowing *that*", procedural knowledge or "knowing *how*", and conceptual knowledge or "knowing *why*". Neef, Siesfeld and Cefola ([47]) distinguished between the following three kinds of knowledge: know-*what*, know-*how* and know-*why*.

Know-*what* refers to knowledge about "facts" ([47], [48]) and it is rich in information on activities and relationships ([49]). The know-*how* knowledge refers to skills, i.e. the capability to do something ([47], [48], [50]) and thus, it is a procedure-based mode of knowledge ([49]). Know-*why* knowledge is concerned with the understanding of reasons and principles underlying the performance of activities ([47], [51]). Broberg ([43]) claimed that there is a difference between knowing how to perform a process and understanding why the process leads to the particular effect.

In order to make computer science learning and computer programming more successful, students must acquire subject knowledge and skills of these three different kinds. Because of the complex nature of computer science education, computer science students were the population chosen for this research.

2.3 Related Research Studies

Discussion forums are tools that promote a collaborative learning environment where participants interact by negotiating, debating, reviewing and reflecting upon existing knowledge, and are able to build a deeper understanding of the course content ([10], [52], [53]).

Practitioners continue to question how best to integrate discussions into online courses to meet learning goals. Garrison ([54]) argued that collaborative and constructivist approaches to learning does not happen by simply making the technology available. Anderson [4] stated that one of the critical roles that an instructor performs in an online learning course is the creation and implementation of strategies that will encourage discourse between and among the participants and between students and content resources. According to Lall and Lumb [5], an effective online course includes the use of online teaching strategies that incorporate discourse as part of the pedagogical design. It is therefore important to structure the asynchronous discussion forums in order to provide a foundation for critical discussions and critical thinking ([6], [55]) and to enhance learning in online courses.

A discussion forum can be unstructured or structured. An unstructured discussion forum does not include planned discussions, neither does it provide rules for interaction and collaboration among the participants. It is primarily used for asking questions and obtaining answers and feedback from the participants rather than for posting discussion topics ([13]). Sometimes it is used by students for personal communication with their peers. In contrast, a structured discussion forum provides well designed, organized and planned discussions with specific topics and goals ([13]) and has clear interaction, collaboration and etiquette rules ([10], [55]).

Recent research has shown that structured discussion forums are more effective for the improvement of critical thinking skills than are unstructured discussion forums ([11], [12], [13]). However, it is not clear how to structure and manage discussion forums in order to make their use among the students more effective for the acquisition of different kinds of knowledge in computer science online courses.

2.4 Purpose of the Study

The purpose of this study was to increase the understanding of how asynchronous structured discussion forums influence student's learning in computer science fully online courses. The study proposed a design for structuring discussion forums that fosters interaction and collaboration among the students and aimed to examine the impact of the structured discussion forum on students' knowledge acquisition of the kinds "*what*", "*how*", and "*why*".

3 METHODOLOGY

3.1 Design of the Structured Discussion Forum: Summary

The first step in this study was to develop a plan for the structure of the discussion forum based on the theory of constructivism, on pedagogical principles and on principles of group interaction and collaboration. The plan of the structured discussion forum contains the following three elements: (1) preparatory instructions about individual participation, (2) instructions about group collaboration, and (3) instructors' role in organizing the discussion.

Following is a summary of steps that have been taken regarding the design of the structured discussion forum.

- In the first step, the instructor explained (through an assessment rubric) how students will be evaluated in the course, the purpose and the nature of the discussions in the discussion forums and requested the students to fulfill the rules set for the participation in the discussion forums in order to keep the discussions organized.
- The instructor then constructed heterogeneous small groups of three or four students with mixed knowledge levels according to the results of the pre-test. This way of forming the small group assures at least that the best students in the class do not cluster together, leaving the weaker ones to fend for themselves. Each group received a group name.

- In the next step, the instructor established a discussion forum for each constructed small group. The participation in a small group discussion forum was allowed only for the members of that small group and not for other students. The instructor's role in the small group discussion forums was to facilitate students' interaction with the materials and with each other in their knowledge constructing endeavor.
- Students were then informed about the objective of establishing small group discussion forums, encouraging them to use these forums for the purpose of enhancing their interaction and collaboration around the learning materials and the group learning activities.
- Students were requested to participate actively in two levels of discussion groups. The first level was the central discussion forum where students from all small groups were participants; the second level was the small group discussion forum. Students were also told about the role of the instructor in each one of these two levels of the discussions.
- The instructor was actively involved in the central discussion forum in order to create a learning environment that motivates the students to construct knowledge through meaningful interaction with each other as well as with their instructor. The instructor regularly posted questions on different levels of knowledge to the forum and gave feedback to students' posts. The increased number of postings to the central discussion forum all over the course can make it difficult for the students to find specific information. Therefore, for each central topic in the course a new central discussion forum was established in order to contribute to a clear and a better organization to the whole process.
- The instructor posted lists of questions and problems to be solved and related each question to a different student. Students then answered the questions directed to them and were requested to give comments on other students' answers within a given period of time. Other types of clarification and support, such as offering explanations, clarification of students' understanding and offering suggestions that guide and improve deeper and further discussions, were also made. This part of the discussion was continuous over the entire course and aimed to encourage more interaction among the participants in order to enhance knowledge acquisition on different levels.
- In the middle of the semester, the instructor organized a group activity that asks each group of students to study a different limited subject and to prepare a short learning unit (composed of four pages) about this subject including three questions, each one related to a different kind of knowledge (know-*what* question, know-*how* question, and know-*why* question).
- In the next step, each group was required to study and discuss a learning unit of a different group, specified by the instructor, and to posts the answers to the questions as well as comments on the learning unit within the specified deadline. Then, each group was requested to check the answers and feedback they received and to comment on them.
- Besides the continuous feedback and support throughout the whole course, the instructor also sent a monthly personal positive feedback to the students about their level of participation, motivating students with low participation to be more active in the discussion forums.
- At the end of the semester, each small group of students was requested to complete a final project which was clearly described by the instructor.

3.2 Research Questions

The following research questions were examined in this study:

1. To what extent does a structured discussion forum impact the acquisition of each of the following kinds of knowledge by computer science students:
   - **a)** know-*what* (refers to declarative knowledge)
   - **b)** know-*how* (refers to the acquisition of skills)
   - **c)** know-*why* (refers to the ability to take a particular theory and to apply it to a given problem)
2. To what extent do the following intervening variables affect the acquisition of knowledge by the students: (1) *academic year*, (2) *gender*, (3) *prior experience in online learning*, and (4) *prior knowledge of subject matter*?

3.3 Design of the Study

In this study an experimental design was used to determine the differences between the impact of structured and unstructured discussion forums on the acquisition of different kinds of knowledge by computer science students. The students in each online course were randomly divided into two groups. One group participated in an unstructured discussion forum and was considered as the control group. The other group participated in a structured discussion forum (i.e., the treatment) and was considered as the experimental group.

A Pre-and post-test design was used for evaluating the knowledge level by the students in the three kinds of knowledge before and after the participation in the online course. The collected data from the pre-test was used for the following two purposes: (1) to build heterogeneous collaborative groups in terms of their knowledge level in the experimental group, and (2) to provide a basis for determining the degree to which participation in a structured discussion forum was related to the acquisition of different kinds of knowledge. The post-test data was used for measuring and comparing the differences in knowledge acquisition between the participants of the structured and the unstructured discussion forum.

Each of the pre- and post-tests developed for all seven courses contained twelve questions, four questions about each kind of knowledge. The questions of the pre-tests covered material for a course that students were required to take as a prerequisite to the online course. The post-test covered core material included in the online course.

3.4 Participants

The participants in this study were 123 Arab students in computer science education from two different Israeli Academic Colleges of Education. They were divided into two groups: 60 (48.8%) students participated in structured discussion forums (experimental group) and 63 (51.2%) students participated in unstructured discussion forums (control group). In both groups most of the participants (95%) were female. 43.3% of the students in the experimental group were second year students, 46.7% of them were third year students and 10% of them were fourth year students. Likewise, 41.3% of the students in the control group were second year students, 42.9% of them were third year students and 15.9% of them were fourth year students.

3.5 Analysis of the Data

A t-test for two independent samples was performed in order to determine the differences between the control and the experimental groups in knowledge acquisition in the three different kinds of knowledge.

For the second research question a two-way ANOVA was performed in order to verify whether there is an interaction between each one of the intervening variables and the dependent variable achievement score, which refers to the total score of the student in the post-test.

4 RESULTS

4.1 Effect of Structured Discussion Forums on Knowledge Acquisition

The results showed that the mean of the total scores in the experimental group (M=75.05) is significantly higher ($p<.01$) than the mean of the total scores in the control group (M=68.28). Standard deviation for the experimental group was 15.60 and 15.75 for the control group.

Thus, results in the experimental group compared to results in the control group showed a significant positive difference in the content knowledge acquisition scores obtained in the post-test.

To find out in which kinds of knowledge there were differences in knowledge acquisition between the experimental and the control group, a t-test for independent sample was conducted (Table 1).

Table 1: Means of Scores and Standard Deviations of each Knowledge Kind in both Groups and the Results of the t-test between the Experimental and Control Group.

Variable	**Experimental (N=60)**		**Control (N=63)**		$T_{(121)}$
	Mean	S.D.	Mean	S.D.	
Score on know-what	17.85	3.23	17.90	3.38	-0.092
Score on know-how	31.47	7.38	29.00	8.03	1.770*
Score on know-why	25.73	9.73	21.38	9.46	2.514**
Achievement score (total score)	75.05	15.6	68.28	15.75	2.392**

*p< .05, **p< .01

The comparison between the means of scores obtained in each one of the knowledge kinds showed that the major contribution for this difference was caused by the knowledge kind "*why*" (see also Fig. 1). In this knowledge kind the difference between the means of the experimental and the control group was equal to 4.35 at the .01 level of significance. Likewise, a significant difference equal to 2.47 between the means of both groups was found in the knowledge kind "*how*" with an advantage by the experimental group at the .05 level of significance. For the knowledge kind "*what*", there was no significant difference in the means of the content knowledge acquisition scores between students who participated in the experimental group as compared to those who participated in the control group. In both research groups the means of scores in the knowledge kind "*what*" was approximately 17%. The maximum score for the questions about the knowledge kind "*what*" was 20% of the total score in the post-test. For the questions about each one of the knowledge kinds "*how*" and "*why*" the maximum score was 40% of the total score.

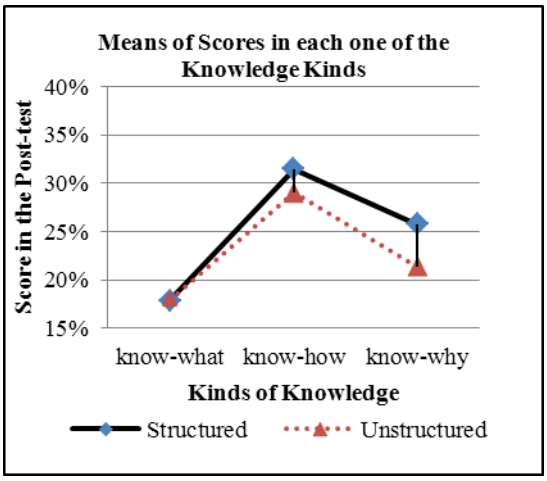

Fig.1: Means of scores in each one of the three knowledge kinds obtained in the experimental and control group.

4.2 Effect of Intervening Variables and the Interaction of each one of them with Group Type on Knowledge Acquisition

To test whether the shown differences in knowledge acquisition between the experimental and the control group were dependent on any one of intervening variables (mentioned in research question no. 2), a tow-way ANOVA was performed. The obtained results are described in the following sub sections.

4.2.1 Effect of Prior Knowledge of Subject Matter on Knowledge Acquisition

The only found significant effect was of the factor students' *prior knowledge of subject matter* (Table 2) on the *achievement total score* ($F(2,117)=21.115$, $p<.001$) while the other intervening variables did not show any significant effect.

Table 2: The Effect of the Discussion Forum Type and the Students' Prior Knowledge of Subject Matter on the Achievement Score.

Source	Sum of squares	df	Mean Square	F
Group	1812.89	1	1812.89	9.76*
Knowledge Level	7844.163	2	3922.08	21.115**
Interaction	215.014	2	107.507	.579
Error	21732.51	117	185.75	
Total	661447	122		

*p<.002, **p<.001

In order to determine if there was a significant difference in the achievement scores between two prior knowledge levels beyond the group type (taking all students as one group), a Tukey post-hoc test was performed. The results indicated that there were significant differences (Table 3) between the three levels of prior knowledge at the level of significance lower than 0.1% (p<.001) which can be described as follows:

The mean of the achievement scores in the low knowledge level was equal to 60.59 (S.D. = 17.83) and was significantly lower than the mean of scores obtained in the group with the medium knowledge level (M=72.44, S.D. =12.81), where the latter also had a significantly lower mean than the mean of scores indicated in the group with the high knowledge level (M=81.75, S.D. =11.36).

On the other hand, it was found that the effect of students' *prior knowledge of subject matter* on the achievement score (see Fig. 2) was not dependent on discussion forum type (F(2,117)=0.579, NS).

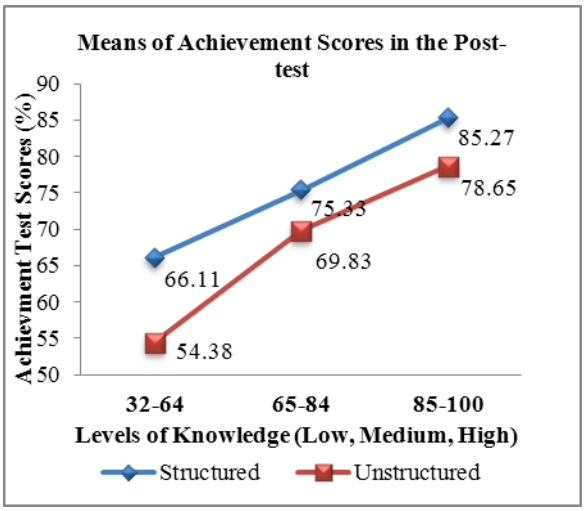

Fig. 2: Means in all three prior knowledge levels according to group type.

In order to examine the effect of the experiment on students' acquisition of knowledge in each one of the three prior knowledge levels, a t-test for two independent samples in each prior knowledge level was conducted (Table 3). The results showed that in each prior knowledge level the mean of achievement scores obtained in the experimental group was higher than the mean of scores obtained in the control group at the .05 level of significance.

Table 3: Comparison of Means between the Experimental and Control Group in each Prior Knowledge Level.

Prior Knowledge Level	Exp. & Cont.		Experimental			Control			
	Mean	S.D.	Mean	S.D.	N	Mean	S.D.	N	
32-64	60.59	17.83	66.11	17.7	18	54.38	16.33	16	$T_{(32)}=2^{**}$
65-84	72.44	12.81	75.33	12.55	27	69.83	12.68	30	$T_{(55)}=1.643^{*}$
85-100	81.75	11.36	85.27	11.74	15	78.65	10.38	17	$T_{(30)}=1.693^{*}$
Total			75.05	15.6	60	68.29	15.75	63	

*p<.05, **p<.03 (1- tailed)

The most prominent difference between both research groups (see Fig. 2) was obtained in the group of students with the low level of prior knowledge (**difference of means** =11.73, p<.03).

5 DISCUSSION

The findings showed that students in the structured discussion forum acquired more overall knowledge than the students who participated in the unstructured discussion forum.

5.1 Knowledge Acquisition of the Kind *"Why"*

The major contribution for the obtained difference in knowledge acquisition between both research groups was in the acquisition of the knowledge kind "*why*". Know-*why* knowledge is characterized as contextual knowledge ([49]) and is concerned with understanding the reasons and principles underlying the performance of activities ([51]).

In this study, students of the experimental group worked together in small groups of three or four towards common goals such as the completion of group learning activities and the course project. Members within each small group were instructed to discuss the goals of the learning activities and to agree upon the strategies that would be used for the purpose of performing these activities. In order to reach a consensus about the process for successfully complementing the learning activity, students with different ideas and opinions discussed and argued about their different points of view. During these discussions students tried to identify, organize, develop, and exploit knowledge needed for the learning activity. These discussions were largely dealing with the understanding of principles and purposes underlying the performance of the activity. In this respect, students were provided with the capability for questioning and suggesting new ideas and solutions. This process allowed group members to see different points of view and solutions to a problem, to raise a more meaningful inquiry and thereby contributed to the construction of contextual knowledge. As already mentioned, know-*why* knowledge is gained from experience and understanding of the objectives and cause-effect relationships underlying the activities and procedures involved in the performance process ([49]). This interpretation may explain why students in the experimental group acquired more knowledge of the kind "*why*" than the students of the control group who had not experienced group learning activities and who also conducted their course project individually. This finding is consistent with previous research on collaborative learning activities which reports that students working towards the completion of a group project gained deeper content knowledge ([56], [57]) and become critical thinkers ([58], [59], [60], [61]), since they had to figure out what was needed to be done and to exchange arguments about the best group solution and thus, had to be actively engaged in meaningful inquiries.

Another explanation for the above finding may be that the students of the experimental group, unlike the students of the control group, participated in two levels of discussions: the small group discussion forum and the central discussion forum. Establishing a discussion forum for each small group of students and asking them to work together on the group activities helped in keeping every member involved in the discussion ([62], [63]), enabled group members to create a sense of a community of learners with shared goals, and allowed them to manage the discussion according to their needs. This way of organizing the online discussion increased group interaction and interdependence ([64]). In addition, it encouraged students and in particular those with low knowledge levels not to be shy to ask for help and clarifications when they did not understood the learning materials because they were not

exposed to all the students of the online course. Different studies have found that small group discussion forums provide a venue for productive discussions, supported student learning and the development of community, and enabled students to make connections between the course materials ([65], [66]).

On the other hand, each small group of students presented its product in the central discussion forum, where all students from all groups were participants, and then discussed the questions and comments given by the other groups on their work. This opportunity opened the gate for more meaningful discussions which were mainly focused on "*why*" questions. These discussions contributed to a deeper understanding of the learned subjects as well as of the principles underlying the performance of the activities suggested by each group since group members were requested to defend their proposed solutions in front of the other groups.

5.2 Knowledge Acquisition of the Kind *"How"*

Another important finding of the current study was concerned with the acquisition of the knowledge kind "*how*". It was found that the students of the experimental group acquired significantly more know-*how* knowledge than the students of the control group. The difference in know-*how* knowledge acquisition between both research groups was lower than the difference which was obtained between the same groups in the acquisition of the knowledge kind "*why*". Know-*how* knowledge is concerned with the acquisition of skills and the ability to perform activities ([50]) and focuses on practicing and learning-by-doing ([67], [50]). This finding is in agreement with other studies which compared the effect of structured and unstructured discussion forums on critical thinking skills. These studies ([11], [12], [13], [55]) reported that students who participated in a structured discussion forum demonstrated critical thinking skills at a higher level than the students who participated in an unstructured discussion forum.

During the online course students of the structured discussion forum were confronted with problem-based learning (PBL) activities that needed to be performed in the small group discussion forum. These activities were collaborative in nature and aimed to enhance the understanding of the learned materials and to improve problem-solving, critical thinking, and collaborative skills by the students. These kinds of activities gave small groups in the structured discussion forum the opportunity to discuss and argue about the ideas and strategies that could be adopted and implemented in order to solve given problems. These discussions incorporated explanation and analyses of the problem as well as the generation and evaluation of the possible solutions. In addition, these discussions also allowed know-*how* knowledge to be more explicit and accessible for all the members of the group and thus contributed to the improvement in know-*how* knowledge acquisition among the students of the structured discussion forum. This may be a possible explanation for the finding about the difference in know-*how* knowledge acquisition between both research groups. This interpretation is in agreement with studies that investigated the adoption of PBL in computer science online courses and have shown an improvement in critical thinking, communication, and problem solving skills ([68], [69]).

Another possible explanation for the above finding is connected to the building of heterogeneous groups of students with mixed knowledge levels and abilities, which allowed the weaker students to learn through the assistance of other more knowledgeable group members. The process of questioning and answering helps both the weaker and the stronger students to improve their understanding of the learning materials ([62], [70]) and to appropriate different skills such as critical thinking and problem-solving ([71], [72]). In the small group discussion forums, group members with different knowledge levels discussed different types of questions and communicated experience and viewpoints with each other towards the successful implementation of the instructional group learning activities. This kind of discussion and collaboration enabled both the weaker and the stronger students to gain a deeper understanding of the materials being learned and to make relationships between the different learning subjects. This implies that grouping students with mixed background knowledge around shared goals benefited all the members of the group and resulted in a more knowledge acquisition specifically of the kinds "*how*" and "*why*", as the findings of the current study showed.

In this study, the instructor regularly posted a variety of questions and authentic problems on different types of knowledge in an attempt to make the discussion more effective and to promote a deep understanding of the subjects being learned. Studies have shown that students favored a variety of questions asked in the discussion forum ([73], [74]). "The questions asked by the instructor should not be mundane or ask for recall of memorized facts, but instead should be challenging so that they attempt to deepen enquiry and improve the opportunities to actively acquire knowledge" ([75], p. 178). During the online course, there was an activity where each question was directed to a different

student. Students were asked to answer their questions and to comment on other students' answers within a given period of time. This way of activating the discussion forum helped students to construct knowledge and to be more involved in discussing and analyzing the different perspectives used in problem solving. In this process students from all the small groups participated and were exposed to a broader range of strategies that could lead to the solution of a given problem since different solutions can exist for the problem, especially because of the nature of computer science learning. Students debated with each other about their proposed solutions and answer questions that aimed to find out why they supported a particular solution and not a different one. Discussions of this type added to the development of critical thinking and problem-solving skills and resulted in an improvement in the acquisition of know-*how* knowledge. They also contributed to the acquisition of know-*why* knowledge because they were concerned with justifying the proposed solution for the problem. Studies ([34], [35]) have shown that the use of activities based on principles of PBL in computer science courses foster problem-solving skills, critical thinking skills and self-directed learning skills.

5.3 Knowledge Acquisition of the Kind *"What"*

Another finding was that no significant difference existed between students of the experimental and the control group in the acquisition of the knowledge kind "*what*". Know-*what* knowledge, also referred to as declarative knowledge ([44], [46]), is encoded as a set of facts and definitions ([44], [47]) and it refers to what is known about a particular domain ([76]). Students in online courses can interact with declarative knowledge presented in different ways. For example, declarative knowledge can be found in the uploaded learning materials and references to the online course, in reading books, in knowledge databases, and in the discussion forum. Students can access these resources and learn from them according to their needs. According to this view, know-*what* knowledge refers to explicit knowledge which is easy to capture and transfer ([77]). Because of these features of the know-*what* knowledge, students can individually learn this kind of knowledge from the different resources by memorizing, without even being actively involved in the discussions that took place in the discussion forum. This could be a possible reason for the obtained finding about the no difference in the acquisition of the knowledge kind "*what*" between both research groups.

A second possible explanation for this finding is that the proposed structure of the discussion forum paid more attention on the acquisition and improvement of procedural knowledge and less on the acquisition of declarative knowledge. The reason for that depends on the nature of computer science education which commonly includes some form of problem or inquiry based learning. Because of this fact, most of the learning activities and discussions within the discussion forums were based on how to utilize problem-solving techniques in order to solve given problems as well as the understanding of reasons underlying the choice of a specific technique and were less based on the acquisition of know-*what* knowledge.

5.4 The Effect of Intervening Variables on Knowledge Acquisition

The findings showed that a significant effect only of the variable *prior knowledge of subject matter* on knowledge acquisition by the student was obtained. Students' *prior knowledge of subject matter* was determined with the help of a pre-test that was conducted before the start of the online course. The findings also showed that students in the experimental group in each one of the three prior knowledge levels (high-achievers, average-achievers, and low-achievers) acquired significantly more knowledge than the students in the control group. This result is in line with the findings of research on collaborative learning in online computer science courses which has shown that students who were engaged in collaborative learning activities demonstrated higher academic performance, achieved higher grades in the course and developed sound programming skills than the students who worked individually ([78], [79], [80], [81]).

6 CONCLUSION

Online discussions are an integral part of online courses so the adoption of communication technologies, particularly discussion forums, will continue to grow in educational online environments. In this study data was found to indicate the significant effect of structured discussion forums on knowledge acquisition of the kinds "*how*" and "*why*" and on the improvement of collaborative skills by students in online computer science courses. These findings are generally consistent with previous studies ([11], [12], [13]) which showed a significant effect of structured discussion forums on the development of critical thinking skills by the students.

The main contribution of the current study to the field of asynchronous online learning is in providing a structure for discussion forums that has the potential to enhance knowledge acquisition of different kinds and to improve collaborative skills by the students. As such, the proposed structure of the discussion forum can be adopted in online courses for the purpose of increasing the effectiveness of online collaborative discussions and thereby the quality of online learning.

Note: This study was a part of a Ph.D. study conducted at the university of Bar-Ilan.

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