Active Learning Through Discussion: ICAP Framework for Education in Health Professions

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Abstract

Background The ICAP framework based on Cognitive Science posits four modes of cognitive engagement: Interactive, Constructive, Active, and Passive. Focusing on the wider applicability of discussion as interactive engagement in medical education, we investigated the effect of discussion when self-study preceded it and further investigated the effect of generating questions before discussions.

Methods This study was conducted in the second semester of 2018, and 129 students majoring in health professions, including medicine, dentistry, veterinary medicine, and nursing, participated. The students were assigned into four different trial groups, who were asked to fill out a Subjective Mental Effort Questionnaire after completing each session. Their performance in post-test scores and their mental efforts were analyzed.

Results These results indicated that the self-study and question group had the highest performance and that the lecture and summary group had the lowest performance when comparing the total score. Using the analysis of mental effort, it was confirmed that the participants who showed higher levels of mental effort also showed higher levels of studying and discussion.

Conclusions Our findings support the ICAP framework and provide practical implications for medical education, representing the fact that students learn more when they are involved in active learning activities, such as self-study and question generation, prior to discussions.

Background

A large number of university students majoring in health professions have achieved outstanding academic performances. Nonetheless, they sometimes struggle in their major[1] because they face difficulties in integrating a vast knowledge base into novel circumstances. Earlier, it was believed that studying medicine or medicine-related fields simply involved memorizing extensive information; in this sense, students who were able to memorize well were considered excellent students. In this regard, educators paid more attention to lectures because they are the most effective ways of delivering vast amounts of knowledge to students. However, owing to the rapid development of technology, students can access information and data more easily than ever before. Thus, amassing knowledge would not be the objective of learning anymore. Instead, it has now become all the more important for students to apply what they have learned to the problems at hand. Moreover, it has been found that traditional lecture-centered education does not lead to students' effective learning.[2] Lectures fail to promote students' thinking,[3] and even extraordinary lectures by exceptional professionals cannot guarantee students' performance.[4]

Accordingly, flipped learning (FL) has emerged as an alternative to lectures. Nowadays, FL has been widely used in universities due to its potential to replace lecture-centered learning; however, it lacks a consistent effect. Therefore, as an effective alternative to a lecture, the active participation method in class has been explored multilaterally, a method commonly known as “active learning.” However, as active learning refers to all class methods excluding lectures, the scope is broad, and as a framework for its further segmentation, the Interactive-Constructive-Active-Passive (ICAP) framework was proposed.[5,6]

The ICAP framework that describes engagements in active learning suggests four modes of cognitive engagement: Interactive, Constructive, Active, and Passive. The passive mode generally refers to a situation of calmly sitting in traditional lectures, and the other three modes have segmented traditional active learning methods. In active modes, students not only gain new knowledge but also physically manipulate the information in education materials. In constructive modes, students make better efforts to gain knowledge by drawing diagrams or asking questions, rather than simply relying on the education materials. In the interactive modes, two or more colleagues cooperate and co-construct through the process of asking queries and responding to one another during their conversation. With the aforementioned classification and previous literature,[6] it is confirmed that learning achievement is lowest at P and increases in the order of A, C, and I. Given that the ICAP framework involves both interactive and active learning, its application to the education of health professions would further promote and expand learning performance with regard to acquiring knowledge when compared with FL, provided that FL simply comprises active learning.

By applying interactive learning as a discussion with the mutual exchange of students, research has revealed that discussion is more effective than lectures and verified that depending on what is learned before the discussion, the quality of the discussion may differ.[7] The quality of discussion increased when self-studying came first; thus, it was substantiated through experiment that both memorization and transfer abilities were influenced. In this study, based on the ICAP framework that more learning will be promoted if the students are active, we intend to establish an empirical learning model. Hence, this study aims to identify the effectiveness of active learning based on the ICAP frameworks and its impact on the student’s performance. By expanding on the work of previous studies, the component of this active study comprised two folds: (1) a self-study condition and (2) a question condition.

Methods

Participants

We conducted a priori power analysis using G*Power software to determine whether the design in this study comprised a sufficient sample size to detect the effect of our main interest.[8] The power to detect a medium-sized effect (f = 0.25; cf. Cohen, 1977) was determined to be 0.4. Accordingly, participants were recruited at the Seoul National University’s undergraduate courses: 42 from medicine, 39 from dentistry, 36 from veterinary medicine, and 12 from nursing. Among the 129 individuals, 61 were female. However, we excluded participants who scored 5 points or more on the Likert scale for background knowledge questionnaires, indicating that these participants already possessed sufficient knowledge on the topic.

Accordingly, 21 people were excluded from the experiment, and the data for only the remaining 108 participants were analyzed. (= 19.58, = 1.04).

Experiment procedure

Participants were asked to complete a questionnaire to determine their background knowledge and interest. The participants were then instructed to study by themselves or attend a lecture. They studied a 7-page-long material that depended on their assigned groups. Participants were randomly assigned to four different study conditions: “lecture” or “self-study.” For the “self-study” group, participants were instructed to study written materials by themselves for 18 minutes. For the “lecture” group, participants were instructed to listen to a lecture while looking at written materials for 18 minutes. Subsequently, they were assigned to different question conditions: “question” or “summary.” They developed questions about the learning materials themselves or simply summarized the materials prior to the discussion. The “question” group was asked to generate three questions in 5 minutes based on what they studied. The “summary” group had to summarize materials in three sentences in 5 minutes without asking questions. They discussed the questions they generated or that were formed by their peers, and finally, they were given 20 minutes to complete a posttest questionnaire. Additionally, each participant’s mental effort was measured three times: after the study period, after the discussion, and after they completed the posttest questionnaire.

Depending on our experimental design, participants were randomly assigned to each of the four groups: two study conditions (self-study vs. lecture) and two question conditions (question vs. summary). Specifically, there were four groups: (1) the lecture and question (LQ) group, (2) the lecture and summary (LS) group, (3) the self-study and question (SQ) group, and (4) the self-study and summary (SS) group.

Questionnaires for background knowledge

We used prior knowledge check questionnaires and interest check questionnaires to minimize the effects of background knowledge. Specifically, six questions were assessed using a 7-point Likert scale: two topic-related questions and four other questions. Participants were instructed to check if they possessed sufficient knowledge of certain topics. They checked their knowledge depending on the 7-point scale ranging from “do not know about it at all (1)” to “know very well about it (7).”

Posttest questionnaire scores

Questions for the posttest questionnaire comprised rote-memory type and transfer type items. The rote-memory type items comprised 10 questions developed directly from the given materials and totaled 10 points. The transfer type items comprised four questions, indicating problems that are applied to new situations requiring total comprehension of the given materials, totaling 15 points. Thus, the posttest questionnaire was scored out of a possible 25 points.

Mental effort measurement

In addition to our main experimental design, we measured the participants' subjective mental effort for each learning session studying (self-study or attending a lecture), discussing (with generating questions or creating a summary), and testing. After further analysis, we checked whether the mental effort spent by the participants on each learning activity significantly affected the learning outcomes of the various groups. We also identified differences between the degree of mental effort spent in each condition and the participants' major, leading to general conclusions regarding the patterns and the relation between learning and mental effort.

Participants were asked to fill out a Subjective Mental Effort Questionnaire after completing each session,[7] i.e., after learning, after discussing, and after testing. The exact instructions required the participants to report the amount of cognitive pressure (effort) one felt during learning (discussing or testing) on a scale of 0–150. They were free to choose from any number on the left scale ascending in tens or from one of the expressions on the right (**Fig. 1**).

Statistical analysis

To examine the effects of study condition on learning outcome, a 3 × 4 mixed-design analysis of variance (ANOVA) was performed. In turn, the simple effect analyses using Bonferroni corrections were performed to verify the difference between the study conditions. Bivariate correlational analyses were performed to explore the relationship between study variables and individuals outcomes. Additionally, the test of a mediation effect were performed with 5,000 bootstrapped samples to test and estimate the indirect effect among the main variables.[9] All statistical analyses were performed using SPSS 23 software (SPSS, Chicago, L, USA). The statistical significance for all tests was set as $\alpha < 0.05$.

Results

Comparisons in learning achievement among conditions

Regardless of what group they were in, all participants studied the given materials for background knowledge. The materials used in this study were law-related and deal with the accusation, charge, and recognition of a criminal procedure code. The topic was chosen because it appeared less likely to be affected by background knowledge, and it seemed clear to set objective grading standards for posttest questions. Specifically, it was an unfamiliar topic for medicine-related students, and it had definite answers for transfer items to evaluate students' performance. There were no significant age and background differences among the four groups.

Analyses were performed to compare the effect of study condition on learning outcomes. The results revealed a significant interaction effects of the study condition and learning outcomes ($P < 0.001$, **Table 1**). To diagnosis this interaction effect at each level of sample, simple effect tests using Bonferroni comparisons were further performed. For total scores, SQ group performed better than the LQ and LS groups ($P = 0.001$; $P < 0.001$, respectively) but not the SS group ($P = 0.827$). The SS group had better performance than the LS group ($P = 0.005$). There was no significant difference between the LQ and LS groups. For rote-memory type item scores, the SQ and SS groups performed better than the LQ and LS groups ($Ps < 0.05$). However, there was no significant difference either between the SQ and SS groups or between the LQ and LS groups . Lastly, for transfer type item scores, the SQ group performed better than the LQ and LS groups ($P = 0.003$; $P < 0.001$, respectively) but not better than the SS group. However, there was no significant difference among the LQ, LS, and SS groups. The main effect of learning conditions were significant ($Ps < 0.001$), showing the same patterns of the result for transfer item scores in pairwise comparisons (SQ > LQ, LS). For item score type, the main effect was also significant, indicating the rote memory score was higher than transfer item score.

Mental effort invested in learning condition

Within the analyzed data of 108 students, we excluded 1 participant who did not complete the questionnaire. The mental effort results were coded in an increasing level of difficulty as values of 0 ("Not at all hard to do"), 10, 25, 35, 55, 70, 85, 100, and 115 ("Tremendously hard to do"). ANOVA was performed to examine the differences in the degree of mental effort between different learning conditions.

Results showed that taking the test was the most difficult part of the learning session when compared with studying and discussing (mean mental effort: 67.30, 40.50, and 49.90, respectively, $P < 0.001$). Further differences in mental effort are shown in **Table 2**, where we checked whether different learning conditions (self-study or attending a lecture and discussion with creating questions or a summary) significantly affected the degree of mental effort throughout the learning process. Although the degree of mental effort of participants of each study condition seemed to differ significantly, no significant difference was found between participants of the two question conditions. Specifically, participants who studied the learning material on their own displayed a higher mental effort during study periods (46.3 vs. 33.8, $P = 0.009$) but marginally lower degrees while taking the test (62.6 vs. 72.7, $P = 0.061$) compared with those who attended a lecture.

Impact of mental effort to learning outcome

The overall impact of mental effort on the overall learning outcome can be seen from the correlation analysis between each mental effort and test performance scores (**Table 3**). From the results, we see that only testing mental effort showed a weak negative correlation with total score ($r = -0.37$, $P < 0.001$). However, the participants who showed a higher level of testing mental effort also showed higher levels of studying and discussion mental effort ($r = 0.43$, $P < 0.001$; and $r = 0.38$, $P < 0.001$, respectively).

Simple mediation analysis

Based on the correlation results and the group differences above, a simple mediation model (**Fig. 2**) was tested to confirm our hypothesis that mental effort during task would mediate the effect of different learning conditions on learning outcomes. The simple mediation model was run separately according to each mental effort (cf. studying, discussion, and testing) and different experimental conditions during study (by oneself or watching a lecture) and discussion (with creating questions or a summary). The learning outcome for this model refers to the total score. To test for mediation effects, a bootstrapping method using 5,000 bootstrap samples and 95% bias-corrected confidence intervals (CIs) were performed, adjusting gender and age as covariates. The results were considered significant when CIs did not include 0.

Among the mental effort variables, only the test mental effort (M3) showed a significant negative indirect effect and this effect was significantly different from zero ($b = -0.41$; standard error [SE] = 0.24; 95% bootstrap CI = −0.9599 to −0.0018). The direct effect of study condition on post-test score was also significant ($b = -3.30$; SE = 0.66; 95% bootstrap CI = −4.6076 to −1.9948). These results indicated that the relationship between different study conditions and post-test performance was mediated by mental effort during test.

Discussion

Traditionally, medical education has been focused on how to teach facts and knowledge for students to learn; therefore, one-way, lecturer-centered education was considered the best way to learn. However, over past decades, there have been many changes in medical education, and various methods of education have been tried, focusing on what educational experiences and interactions among students can achieve for their learning outcomes.[10] This educational trend has also emerged in the medicine-related fields, resulting in strategies for active learning, such as Problem-Based Learning (PBL).[11] Active learning is learner-centered, where the individual's needs are considered more essential than those of the group.[12] In that regard, a learner needs to not only do something about given tasks but also reflect on what they are studying. Active learning supposes that all knowledge can be obtained individually by a learner, whereas passive learning assumes that knowledge can be transferred from one person (lecturer) to another one (learner).[13] As an example of active learning, PBL reflects that knowledge is constructed rather than received, for it is based on the assumption that knowledge arises from work with an authentic problem.

The adaptation of PBL has been very successful in the landscape of education for health professions; however, PBL has not been dominant as the collaborative learning method across or within institutions due to several limitations.[14]

As an alternative to PBL, Team-based learning (TBL) has gained recent popularity in medical education for health professions.[15] In contrast to PBL, TBL does not require several tutors but maintains the advantages of small group teaching and learning. This advantage of TBL allows education related to health professions to provide learners with effective resources and a reliable environment for teams to solve clinical problems in the real world.[16] In line with that reason, a previous study showed that students preferred TBL over PBL as the optimal teaching strategy in medical education.[17] However, as with other teaching methods, TBL also has some limitations: initial time commitment from lecturers (e.g., readiness assurance tests and application exercises), strong willingness to try a new teaching method to replace current strategies, and ample physical classroom space compared with traditional education. Thus, the demand for a novel paradigm beyond PBL and TBL applied to education for health professions has arisen.

To overcome constraints in the PBL and the TBL, health professions education may benefit from applying the ICAP. According to our results, participants performed better in the self-study condition than lecture condition and conditions across the following types of items (**Table 1**): total, rote-memory, and transfer. The results suggest that rather than making learners passively listen to lectures, it can be more effective to ask them to engage with learning materials by themselves in education programs for health professions. The implication of our result is consistent with a recently emerging educational concept, FL. In comparison with conventional learning, FL has distinctive features in a pedagogical approach that moves information-transmission teaching out of the classroom and uses class time for learning activities. As information technology advances, educational materials have become easily accessible and not just limited to classrooms (e.g., massive open online courses, MOOCs). Students can be actively involved in constructing knowledge in their own way, unbound to physical classrooms. In this regard, the role of classrooms and lecturers, which were the primary source of information, should be modified. Accordingly, students could gain a deep understanding of knowledge through activities such as concept exploration, meaning-making, experiential engagement, and demonstration/application during class time. In terms of FL, our experimental results based on the ICAP framework may present practical implications and theoretical support for new pedagogical approaches in education for health professions.

According to many studies, including the ICAP framework, the learning effect is larger when students participate in learning more actively. However, studies on how to maximize interaction are difficult to find. In this study, prior to discussion, lectures, and self-study were compared, and furthermore, the activities of simply receiving a given question and generating a question were considered. As a result, the SQ group had the highest performance, and the LS group had the lowest performance when comparing the total score of the posttest questionnaires. For rote-memory type item scores, the SQ and SS groups had higher performance ratings than the lecture groups (LQ and LS). Finally, in the transfer type item scores, the SQ group had the highest performance. Therefore, it can be considered that students who study by themselves and complete question-generated activities showed better performance compared to other students, suggesting that students who participate in more active activities rather than simply listening to lectures and receiving given questions experienced increased learning outcomes.

In addition to self-study, questions generation can be a useful strategy in actively constructing knowledge for learners. The SS group showed higher performance in the rote-memory item than the LQ/LS group, but there was no significant difference in the transfer type items (**Table 1**). Only the SS group showed higher scores in comparison to the LQ/LS group in the transfer type items. These results suggest that not only summarizing what they have studied but also generating questions regarding the content can be effective in applying existing knowledge to other contexts. The students writing the questions for discussion themselves is more effective for learning than merely responding to given discussion questions.[18] To build questions for the discussion, learners require an understanding of the given materials and then a process for "generating" new concepts based on prior knowledge. Therefore, learners need a higher level of thought than the activity of merely using given questions by others. Specifically, a discussion beginning with questions constructed by the learners can be more productive,[19] improving the quality of the class by creating a high-level discussion. During the discussion, learners may experience the knowledge-change process from interactive activity, which is promoted by transfer learning through sufficient understanding regarding contents.

Among the two experimental treatments during study and discussion, only different study conditions showed significant results in the analysis of mental effort (**Table 2**). Based on the results of the analysis of mental effort, we found that the degree of testing mental effort significantly correlates with students' learning outcomes (**Table 3**), i.e., the significant negative correlation between testing mental effort and posttest performance, and results from the mediation analysis (**Fig. 2**) support the previous study.[20] Overall, only the difference in mental effort patterns between two studying conditions and the simple mediation analysis combined suggest how students' study affects the degree of mental effort during studying and testing, eventually influencing their learning performance.[21] Thus, the negative correlation can be interpreted as students spending unproductive efforts during testing compared with when they study or discuss the materials. In other words, unlike efforts spent in studying and discussing, the efforts spent at the end of the test is too late to contribute to an increase in performance. It is consistent with previous findings that support the elaborative retrieval theory, which suggests why learner must invest substantial mental effort.[20, 21] It is possible that students who participated in active learning and question generation put in extra effort into their education than those who only listened to a lecture or received question, leading to deeper understanding of the materials.

Although, discussions themselves were not the focus of the current study, the results represented the conclusion that self-study, a more active form of learning, was associated with the level of engagement during discussion. The mental effort in the study session (M2) positively correlated with the mental effort in the discussion session (M3), suggesting that learners who actively engage in self-study would also actively engage in the course of the discussion (**Table 3**). These results suggest that not only self-study before the class but also mental effort during self-study in terms of the ICAP framework or FL is an important element, which should be accompanied by active learning.

This study has some potential limitations. First, the video lecture used in the study, like traditional lecture forms, showed one professor passively conveying knowledge. Moreover, most recent online lectures were conducted with the professor alone.[22, 23] However, in future research, the video might show a conversation and not the professor alone. In this study, we measured mental effort after studying, discussion, and test-taking. Mental effort measured after discussion or taking the test could have been affected by prior learning activities. Thus, mental effort scores may not represent the cognitive load that is spent during a discussion or taking the test. Nevertheless, our study's purpose was to identify the effects of different prior learning activities on final academic performance. Following how learning performance, the study's main dependent variable, is an accumulation of previous events, mental effort was intended to be studied in the same nature. For future research, to address the limitations of measuring mental effort, coding and further analysis of discussion dialogs could reveal how prior learning activities affect the quality of discussion and the amount of mental effort required accordingly. Lastly, in this experiment, the discussion was among students with no interference from professors. However, past studies investigated that the enthusiasm of the instructor or professor may affect the students' performance.[24] Therefore, in the future, the method of activating discussion among students by minimizing the professor's interference must also be actively reviewed.

Conclusion

Combined together, our findings demonstrate that it is better for learners to discuss what they learn after the lecture than to review the lecture. Moreover, even during a discussion, self-study of the content and the development of questions regarding what they learned must precede a discussion to maximize effectiveness of this learning modality. In addition to strategies, encouraging learners to participate actively in learning activities is also important and can lead to an increase in the transfer learning ability. Applying these findings to the curriculum will help prepare for a better future for education in health professions. The ICAP framework or FL design with the ICAP framework is expected to be useful in developing health professionals so they can grow on their own, rather than those who accumulate expertise through traditional education methods that have only emphasized memorizing information.

Abbreviations

Interactive-Constructive-Active-Passive (ICAP); Flipped Learning (FL); TBL (Team-Based Learning); PBL (Problem-Based learning); Lecture and Question (LQ) group; Lecture and Summary (LS) group; Self-study and Question (SQ) group; Self-study and Summary (SS) group.

Declarations

Ethics Approval and Consent to Participate

The study was approved by the Institutional Review Board (IRB) of Seoul National University School of Dentistry (IRB No. S-D20180034). All participants were aware that they were taking part in this research and gave informed consent in addition to confirming that they would allow us to use their collected data anonymously for publication. All the data were anonymously collected and analyzed.

Consent for publication

Not Applicable.

Competing interests

The authors declare that they have no competing interests. The first two authors contributed equally to this work and share first authorship and the last two authors worked as co-correspondents.

Authors' contributions

All authors have read and approved the manuscript. Conceptualization: Lim JS; Methodology: Lim JS, Park JY; Formal analysis: Lim JS; Data curation: Yang JW, Kim SE; Investigation: Lim JS, Ko HW, Yang JW, Kim SE; Writing - original draft preparation: Lim JS, Ko HW; Writing - review and editing: Lee SH, Chun MS, Park JY, Ihm JJ

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Tables

Table 1. Learning Performance according to type of items and study conditions

Type of items	LQ (n = 21)	SQ (n = 32)	LS (n = 29)	SS (n = 26)
Total score (25 points)	13.14 (3.61)	17.19 (3.75)	12.52 (2.79)	15.82(3.56)
Rote memory (10 points)	7.33 (1.53)	8.47 (1.52)	7.38 (1.50)	8.70 (1.26)
Transfer (15 points)	5.81 (2.66)	8.72 (3.11)	5.14 (1.98)	7.12 (2.96)
ANOVA results	*F*	*P-value*	η^2_p	
Types of items (A)	10.471	< 0.001	0.112	
Study condition (B)	11.168	< 0.001	0.247	
Interaction term (A×B)	7.022	< 0.001	0.171	

Data are shown as mean (standard deviation). LQ = lecture and question, SQ = self-study and question, LS = lecture and Summary, and SS = self-study and summary. For each LQ, SQ, LS, and SS group, total scores, rote-memory type item scores, and transfer type item scores are given. Gender and age were adjusted.

Table 2. Differences in mental effort by learning conditions

Variables	Study conditions (n = 108)				
	Lecture (n = 50)	Self-study (n = 58)	F	η^2_p	*P-value*
M1	33.80 (24.19)	46.32 (25.21)	6.984	0.063	0.009
M2	46.20 (31.01)	53.16 (29.89)	1.505	0.014	0.223
M3	72.70 (23.11)	62.63 (28.40)	3.594	0.034	0.061
Variables	Question conditions (n = 108)				
	Summary (n = 55)	Question (n = 53)	F	η^2_p	*P-value*
M1	43.49 (24.82)	37.50 (25.84)	1.212	0.274	0.274
M2	47.55 (28.53)	52.22 (32.37)	0.428	0.515	0.515
M3	69.53 (25.33)	65.19 (27.52)	0.673	0.414	0.414

Data are shown as mean (standard deviation). M1 = Study mental effort, M2 = Discussion mental effort, M3 = Test mental effort. Gender and age were adjusted.

Table 3. Correlations between study variables

Variables	Total score	Scores of transfer type items	Scores of rote-memory type items	M1	M2	M3
Total score	1.00					
Scores of transfer type items	0.93^{***}	1.00				
Scores of rote-memory type items	0.70^{***}	0.39^{***}	1.00			
M1	.00	−0.10	0.05	1.00		
M2	−0.40	0.03	−0.06	0.43^{***}	1.00	
M3	-0.37^{***}	-0.36^{***}	-0.29^{**}	0.35^{**}	0.38^{***}	1.00

M1 = Study mental effort, M2 = Discussion mental effort, M3 = Test mental effort. $^{**}P < 0.01$, $^{***}P < 0.001$