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Evaluating Methods for Students to Identify and Clarify Doubts in Computing Design Courses

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Abstract — This full paper evaluates the effectiveness of doubts identification and clarification methods applied in undergraduate computing design courses. Many undergraduate courses in computing require students to understand abstract design concepts. Exposed to the design concepts for the first time, students need to be able to identify and clarify their doubts about the abstract concepts in order to make the right design decisions. In this study, we seek to evaluate the effectiveness of six methods that help students to identify and clarify their doubts. These methods vary in their timing (immediate or delayed), communication style (online or face-to-face) and participation style (individual or group-based). We conduct surveys on the effectiveness of these methods in two undergraduate computing design courses, a course on design thinking and another on software architecture design. We evaluate the quantitative and qualitative responses for each method used. Students generally prefer methods with immediate feedback on face-to-face communication with specific questions that allow them to have another perspective of the content covered. Methods that ask self-reflective questions on what they learnt on their own are less preferred based on this survey. This study outcome illustrates that the students require more guidance to be self-directed and wants more immediate face-to-face guidance in clearing doubts on the concepts taught. We hope this study can help educators to compare and choose the suitable methods to draw out and clarify doubts for their students.

Keywords—*doubts identification, doubts clarification, computing, design courses*

I. INTRODUCTION

Based on Bloom's Taxonomy [1], we want our students to understand, apply, analyse and design concepts with justifications. To achieve these in courses with abstract concepts, students need to be actively involved in identifying and clarifying their doubts. Doubts are knowledge gaps that they know they do not know and requires more clarification. When students raise a doubt, this can potentially can be a statement or question to seek more clarification of a given topic so that they can learn better. A doubt can be different from a question since it may not be expressed in the form of 5W1H (who, what, where, when, which, how) or ends with a question mark. [2]. For example, "I am still confused about ..." is a doubt statement but not a question. There are two parts to address their doubts – doubts identification and doubts clarification. Doubts identification focus on students to realize what they do not know. Doubts clarification focuses on students to be able to clear their identified doubts.

Many computing courses require students to learn abstract design concepts for them to make design decisions. For undergraduates who have experienced programming giving deterministic outcomes during development, the ability to trade-off design elements to reach a justifiable design decision

can be challenging for students. For undergraduates with limited working experiences and attending computing design courses, doubts identification can be a challenge for them to identify when they do not know what they do not know. During the delivery of computing courses that involve design concepts, there is a need to elicit student's doubts and for instructors to have an effective method to clarify them.

Research suggests that questions often do not emerge spontaneously from students [3]. Students have to be encouraged, and teachers need to specifically employ strategies to elicit questions. There are many identification and clarification methods available to help students and these methods differ in their delivery modes. When we teach a student a new design concept, the student needs to understand and conceptualise the concept before being able to identify further doubts. This process requires time and different students have a different degree of learning rate. For fast learner students, they can identify doubts within a short period, while others require more time. Methods with immediate timing (e.g. posing related questions in lectures after covering the concept) works well for fast learner students. On the other hand, methods with delayed timing (e.g. giving out a take-home assignment) allow students to have more time to understand the concept and identify doubts. The timing also differs for doubts clarification. For immediate timing, instructor seeks to clarify their doubts on the spot. For delayed timing, students pose their doubts and instructor revert later.

The communication and participation styles may potentially affect the effectiveness of identifying and clarifying doubts. Online communication allows students to discuss with instructors virtually. They can pose their doubts on online forums or instant messaging and clarified online. Face-to-face communication requires students to arrange and meet with the instructors physically. Online communication allows students to discuss and resolve doubts with higher frequency and not be restricted to a synchronized period. Face-to-face meeting does help students to better explain their doubts and understand explanations. The participation style can be with an individual or group-based. Passive students may prefer to identify their doubts when discussing individually with the instructor. However, some students may identify their doubts through discussions in groups (e.g. during a discussion in assigned project team or as a class). Students can also seek to clarify their doubts either individual or as a group.

The methods to help students to identify and clarify doubts differs in the degree of their effectiveness. In this paper, we evaluate six methods that exhibit a combination of timing, communication and participation styles. Following are our research questions.

1. What are the methods that are effective for a student to identify doubts?
2. What are the methods that are effective for a student to clarify doubts?

We first describe the related works in Section II. We provide the course design in Section III and describe the doubts identification and clarification methods we applied to address the above research questions in Section IV. Section V shows our evaluation results and Section VI list possible threats to the validity of our results. We conclude our study in Section VII.

II. RELATED WORKS

Many existing studies focus on methods to identify doubts. Lo, Tan and Ouh in their work [2] demonstrate their effectiveness of an automated method to identify doubts from student's feedback. Burgh, Thornton and Fynes-Clinton [3] advocate the community of inquiry pedagogy with deep reflective thinking to cultivate doubt in the classroom. Chin and Osborne [4] study the effects of teaching questioning skills to students for them to identify doubts. They conclude that students' questions help them to monitor their own learning; explore and scaffold their ideas; steer thinking in certain specific directions, and advance their understanding of scientific concepts. Ge and Land in their study [5] revealed that question prompts had significantly positive effects on student problem-solving performance. Methods that involve student-generated questions and interview questions are also common to elicit their thinking and doubts. Rosenshine, Meister and Chapman [6] in teaching students to generate questions had resulted in gains in comprehension, as measured by tests given at the end of the intervention. Montfort, Brown and Findley in their work [7] revealed that by asking students open-ended conceptual questions, researchers are able to observe misconceptions in action.

There are also studies focusing on methods to clarify doubts. Kumar et al. in their study [8] show student's perceptions are in favour of problem-based learning to clarify of doubts. Loh and Teo [9] study that the role of culture on the students' learning styles to clarify their doubts. They conclude that Asian students prefer learning in small groups, and they can clarify doubts without always approaching teachers for assistance.

In this study, we seek to evaluate the effectiveness across six methods that vary in their timing, communication and participation styles. We apply these methods in both areas of identification and clarification of doubts.

III. DESIGN COURSE INFORMATION

In this paper, we evaluate our doubt identification and clarification methods for students in two computing design courses - design thinking (DT) and architecture thinking (AT). Both courses require students to understand design concepts with exercises and projects for them to apply their knowledge gained. We conduct both courses over 13 weeks with a 3-hour lesson each week that involves our methods under evaluation. We cover an overview of the course structure in this section and discuss six methods we applied in the next section.

The design thinking course focuses on the design thinking process for students to understand and practice each of the process stages. Students are required to understand abstract

concepts and apply their learnings in both discussions and project assignments.

This architecture thinking course focus on the design of software architectures with a process method for them to design a software architecture solution. Students are required to understand the abstract concepts in architecture thinking and apply the process taught to design and deliver a solution architecture.

IV. DOUBTS IDENTIFICATION AND CLARIFICATION METHODS

In this section, we describe the six doubt identification and clarification methods in general and how we apply the method in our courses.

A. In-Class Lecture

This method allows the student to understand key concepts, analyse and pose their doubts through questions to the instructor in real-time. To assist students in identifying doubts, the instructor can pose provoking questions on the slides or during delivery of the slide contents to engage the students in thinking about the topic.

For both courses in our evaluation, instructors engage students with an in-class topic for the students to discuss with their groups and present their answers. The topic related to concepts taught earlier requires them to apply the concept in a scenario-based context. They can consult the instructors on their doubts during the discussion. Other instructors and teaching assistants in the class can also guide them along. In a 3-hour lesson, student can apply two or three main concepts. This method allows students to identify doubts during lectures or discussion and seek clarifications directly with the instructors in class.

B. In-Class Quiz Reflection

This method is initiated by the instructor with a set of quiz questions. It allows each student to reflect on their understanding. The quiz is conducted either immediately after the instructor covers the contents or sometime later within the same class session. The instructor can use digital tools to allow the students to answer the questions on their digital devices or use pen and paper.

For both courses in our evaluation, we use Kahoot as a gamification tool to prepare and execute the quiz questions. We prepared these questions based on the specific course contents covered. This method has a time constraint, and students have to decide the answer individually. We conduct this quiz in an anonymous mode so that we cannot identify the student directly from the response. The entertaining elements provided by these tools, such as music and interactive comments, also helps to smooth the tense situation of taking a quiz. We use this method once a week and can be at the start of the lesson to recap previous week content or during the lesson for a summary of the contents covered. This method allows students can identify their doubts during the quiz and seek clarifications when the answers to the quiz are discussed in the same class session.

C. Out-of-Class Self-Reflection

This method allows the student to reflect on their learnings for the topics covered in that session and students usually do it after the class.

For both courses in our evaluation, we create a survey of the content covered for the students to answer and think about any doubts they may have. Due to limited class time, we remind the students on the survey in the class, and they do it after class. The survey questions are open-ended as follows.

1. How well did you understand today's materials? (Totally got it, Pretty got it, Not very well, Not at all)
2. What are the important things you learned in class today? If you have doubts about a specific concept/topic/point for the course, please state below.

The first survey question is to have a general understanding of the student's learning for that day. The second question requires the student to reflect on the contents covered for that day and identify questions to ask. Most students choose either "Totally got it" or "Pretty got it" for the first question, and few choose to express their doubts. The instructor will review the survey results after the class and address their doubts either through emails or in subsequent class time. If a student chose "Not very well" or "Not at all", the instructor will still communicate with the student even if he did not express any doubts. In this process, students can identify their doubts during reflection and get clarifications from instructors.

D. Out-of-Class Assignment Work

This method involves the students doing project work out of class that usually takes weeks to complete. The type of assignment can be a short exercise or a longer project. The assignment may be an individual or a group-based assignment. The exercises usually are smaller in scope and performed by one or two students. The project assignment usually takes the form of a series of problem sets that requires the students to discuss as a group and prepare a set of deliverables.

For both courses in our evaluation, we assign both individual exercises as well as group projects. Students are required to work in teams of four to five members to complete the project. They are required to present their projects at the end of a milestone. To complete these assignments, they have to meet frequently within their groups to work on the assignments. This method allows students to identify doubts with their peers during group discussions and to clarify them as well.

E. Out-of-Class Online Communications

This method involves the students' communication with the instructors outside the class to identify and clarify doubts. The instructor usually has agreed communication channels with the students, and it can take the form of messaging or online forums or both.

For both courses in our evaluation, we provide communication channels over email or Telegram for the student to post their doubts when they identify them. We also use these channels to broadcast the commonly asked questions too. Many students adopt this approach as it allows them to clarify doubts whenever they need it. There is a need to moderate expectations, as there are considerable time and effort from the instructors. This method allows each student can ask questions outside the class instead of raising them the next time in the class. The instructor can also have an immediate understanding of the doubts and adjust the subsequent contents accordingly.

F. Out-of-Class Face-to-face Communication

This method involves the students arranging a face-to-face meeting with the instructor. With this method, the instructor can understand student's doubts better in a face-to-face environment. Students usually come in groups to discuss doubts with the instructor.

For both courses in our evaluation, we arrange for a consultation in specific weeks of the semesters for each group to engage the instructor. Ad-hoc consultation time is also available for individuals to request. In both cases, this method allows better timing with the students but requires more time to arrange and prepare. The consultation time is usually 30 minutes or 1 hour. This method allows students can prepare beforehand and seek clarifications on their identified doubts in the meeting. Many students manage to identify more doubts during the meeting.

In this section, we described six methods we applied for doubts identification and clarifications. For both courses, students are strongly encouraged to participate in all these methods. Up to 30% of the total grade involves out-of-class assignment work, and up to 10% of the total grade involves participation marks for the rest of the methods.

These methods differ in the timing, communication and participation style, as shown in Table I. We consider both in-class lecture and in-class quiz as immediate timing. We trigger the students to identify doubts by asking questions within a short period after the contents are covered. Clarifications are also given right after the students answer these questions. We consider the rest of the methods as delayed timing as students identify their doubts only after a significant amount of time the contents are covered. Clarifications can also be delayed. Besides the out-of-class online communication, we consider the rest of the methods to be face-to-face where students meet with the instructors or other peers physically. We consider out-of-class assignment work and out-of-class face-to-face communication as group participation and the rest to be individually carried out.

V. STUDY CONDUCT

In this section, we explain how we design a study to understand the effectiveness of the methods to identify their doubts and clarify their doubts. This study involves two computing design courses – design thinking and architecture thinking. We apply the methods as described in section IV. We conduct the study twice, once during the second semester of 2019 and once during the first semester of 2020.

The design thinking course is a core module, and we had 153 students. These students are mostly in their second or third year of studies. The architecture thinking course is an elective and 56 students took the course over two semesters. The same instructors teach both courses in the two semesters.

At the last week of the course, we requested the students to take a survey for these methods. The students are briefed by the instructors on the purpose of this survey and are aware that these results are anonymous and do not affect their course grade. Survey participation is voluntary, and student can opt-out if they wish to do so. We conduct this survey using Google Forms. We design the questions based on the six doubt identification and clarification methods for them to identify and clarify doubts. The two survey questions are

1. How effective are these methods for you to identify doubts?
[Quantitative – Likert Scale]

Please explain your answers. [Qualitative – Free Text]

2. How effective are these methods for you to clarify doubts?
[Quantitative – Likert Scale]

Please explain your answers. [Qualitative – Free Text]

The first question focus on the effectiveness of the students to identify doubts. We want to find out to what degree do they realise what they do not know when they use each method. The second question focuses on the effectiveness of the students to clarify their doubts. We want to find out to what degree each of these methods enables them to clear their identified doubts. The students rate question 1 quantitatively using a Likert scale of 1 to 5 with 1 being the least effective and 5 being the most effective. They are also required to explain their given ratings qualitatively for each question.

I. STUDY EVALUATION AND ANALYSIS OF THE OUTCOMES

In this section, we process, evaluate and analyse our study findings on the method effectiveness to identify and clarify doubts. We manage to receive a total of 133 responses for the design thinking course and 31 responses for the architecture thinking course.

A. Data Processing

For the quantitative ratings, we sum their selections per each rating and each method for both courses. We then calculate the average effectiveness per course and overall for both courses. The outcomes are shown in Fig. 1 and Table II for the doubts identification and Fig. 2 and Table IV for the doubts clarifications.

Based on a within-subject design and collection of ordinal data, we perform the Wilcoxon signed-rank test to evaluate the significance of the differences between two methods. We wish to find out if the difference in effectiveness between any of the two methods is significant or not. We also perform statistical correlation analysis to evaluate the strength of relationships between the values to identify and clarify doubts for each method. We wish to find out if any of the methods is effective (or ineffective) in both identifying and clarifying doubts. We use the R programming language for the Wilcoxon test and Excel Analysis ToolPak for the correlation test.

For the qualitative questions, we first pre-process each comment and split them into separate comments if it is referring to more than one method. For example, this comment *“For the most effective, quiz helps the most as I only realised I have doubts when I could not answer the questions. As for the least effective choice, exit tickets may play a part to identify the doubts, however, will not be as effective for me personally.”* is split into two comments. We also remove irrelevant comments with no reference to any of the methods (e.g. NA). After performing these pre-processing steps, we place each of the remaining comments into one of the method baskets. We sum up the number of comments in each basket and perform sentiment analysis for each comment. We use an online tool [10] for the initial sentiment analysis to measure the polarity of each comment - positive, neutral and negative. As the outputs of the tool cannot be 100% accurate, we further perform another round to verifications manually to discover any obvious inaccuracies on the polarity of each comment. We

show these outcomes in Table III for the identification of doubts and Table V for the clarification of the doubts.

B. Evaluation and Analysis - Doubts Identification

We address our first research question in this section. Referring to Fig. 1 and Table II on the average level of effectiveness for doubt identification across both courses, students find the in-class quiz reflection method most effective to identify their doubts, followed by the in-class lecture and out-of-class assignment work. On the other hand, ratings for out-of-class self-reflection, out-of-class online and face-to-face communications methods fare the lowest. These outcomes are also consistent within each course.

Based on an alpha (α) value of 0.05 or 5%, we evaluate the significance of the difference in values between two methods to identify doubts. Based on the Wilcoxon signed-rank test, the p-value of the two-tailed test between two methods for all methods paired are significant (<0.05) except for one case - between in-class lecture and out-class assignment work (p-value is 0.606). For this case, there is no significant difference if either method is applied. For the rest of the combinations, there is a significant difference when applying one method over another to identify doubts.

One takeaway from these outcomes is that the top two methods (in-class quiz reflection, lecture) with immediate timing works well for our students. Most students prefer to identify doubts in class when the contents are covered. For the top three methods, we realize questions are prepared by the instructor to validate student's understanding of the concepts taught specifically. On the other hand, the rest of the methods comprise of indirect questions that require the students to reflect on their learnings. These outcomes potentially indicate that our students require guidance to be more self-directed to be able to derive their own questions. Another takeaway from these outcomes is that most students do not prefer online communication style done out-of-class to identify doubts. In terms of participation style, students do not show a clear indication of their preference.

We analyse the qualitative comments for more insight. For these qualitative comments, we pre-process these comments as mentioned earlier and end up with 234 comments. After using the online tool to perform sentiment analysis, we agree to adjust the polarity of some comments after manual verification. For example, the comment *“Reflection is less effective cos i don't usually know my doubts right after class.”* is rated positive but we feel that this comment should be neutral. We show the polarity of these comments for each method in terms of total count and percentage in Table III. We segregate methods with significant results in bold based on the percentage above 40%. The order of the methods in terms of positive comments is closely related to the quantitative outcomes. In-class quiz reflection, lecture top the list while out-of-class self-reflection and out-of-class online communications are at the bottom.

Most of the qualitative comments are referring to the in-class quiz reflection method (89 out of 234), followed by out-of-class self-reflection and in-class lecture. Many students respond positively to in-class quiz reflection with the highest percentage of 59.04%. Top positive comments with a high confidence score for this method include

- *“Quiz session was enjoyable in letting us know what we don't know.”*
- *“The quiz was great in helping us see the content from perspectives that we might not have thought about during the delivery of lessons.”*
- *“I feel that when I play quiz i know where my errors in understanding are.”*
- *“Quiz allows me to know what areas i am not sure about and what areas i need clarifications.”*
- *“Quiz actually allows me to know for a fact whether there are gaps in my knowledge.”*
- *“Quiz helps use to identify gaps in our knowledge”.*

Another method with a high number of positive comments (52.38%) is out-of-class face-to-face communication. Top positive comments with a high confidence score for this method include

- *“It helps me to identify which parts i am unsure of when communication is done face to face (for some concepts i can visualise better)”*
- *“I think its very important to have face to face meeting, ideas can be conveyed more easily.”*
- *“For me personally i feel that through a face to face timing is the best method to identify doubts, we are able to better and get a better understanding for the things that we do not understand.”*
- *“I feel that its easier to identify doubts in real life rather than through online medium because its harder to carry your intentions through text alone.”*

On the other hand, 46.94% of the students respond negatively to out-of-class self-reflection method. Top negative comments with a high confidence score for this method include

- *“During self-reflection we are still processing the information taught, thus hard to identify what it is we currently know/don't know. Normally i will have more doubts when it comes to revising content before exam, hope communication lines can be available then.”*
- *“As for self-reflection, i think it's not as effective as i tend to rush off other class for my other commitments”*
- *“Self-reflection like abit boring cause don't really know what I dunno, only when I do then I know”*
- *“Self-reflection if done right after, may not raise doubts but sometimes I do it on Fridays, so I realised I don't know certain things.”*
- *“Self-reflection are the least effective as I don't give as much thought in reflecting about the content learnt as compared to the other methods.”*

Another method with a high number of negative comments (43.48%) is out-of-class online communication. Top negative comments with a high confidence score for this method include

- *“Online communications such as forum are inefficient and hard to use.”*
- *“online communication- it is easier to identify doubts through consultations face to face”*
- *“Through an online communication, it is more difficult to type or phase questions”*
- *“Not so effective -> Online communication as it doesn't really trigger the content of the lectures”*

We can draw several insights by analysing these comments. The in-class quiz reflection method is effective to identify doubts when the students feel that the session is enjoyable and allow them to have another perspective of the contents taught in class. Many students feel that face-to-face meeting is still more effective and efficient to identify doubts. On the other hand, the self-reflection method is cited negatively can be due to many factors. These students tend to revise course contents to identify doubts nearer to the examination period. We should also look into adjusting and extending the time to conduct the reflection.

C. Evaluation and Analysis - Doubts Clarifications

We address our second research question in this section. Fig. 2 and Table IV show the degree of effectiveness of each doubt identification methods for the students to clarify doubts. Based on the average level of effectiveness across both courses, the top three methods to clarify doubts are in-class lecture, in-class quiz reflection, out-of-class assignment work. However, as compared to doubts identification, the top method is the in-class lecture instead of in-class quiz reflection. We attribute this outcome to the amount of time allocated for the in-class lecture, allowing better clarifications. For in-class quiz reflection, the limited time to conduct and explain each quiz question might have affected the effectiveness. The bottom three methods are out-of-class self-reflection, out-of-class online and face-to-face communications methods.

With an alpha (α) value of 0.05 or 5%, we evaluate the significance of the difference in values between two methods to clarify doubts. Based on Wilcoxon signed-rank test, the p-value of the two-tailed test between two methods for all methods paired are significant (<0.05) except for two cases – first case between in-class quiz reflection and out-class assignment work (p-value is 0.076) and second case between out-of-class face-to-face communication and out-of-class assignment work (p-value is 0.586). For these cases, there is no significant difference if either method is applied. For the rest of the combinations, there is a significant difference when applying one method over another to clarify doubts.

For the qualitative comments after pre-processing, we end up with 204 comments. We use the online tool to perform initial sentiment analysis and adjust the polarity of some comments after manual verification. For example, the comment *“Quiz actually clarify to my doubts as I rarely can think of the questions can be like.”* is rated negative, but we feel that this comment should be neutral. We show the polarity of these comments for each method in terms of total count and percentage in Table V. We segregate methods with significant results in bold based on the percentage above 40%.

Table I. Doubts Identification and Clarification Methods

Method / Style	Timing Style	Communication Style	Participation Style
In-Class Lecture	Immediate (Identification and Clarification)	Face-to-face	Individual
In-Class Quiz Reflection	Immediate (Identification and Clarification)	Face-to-face	Individual
Out-of-Class Self-Reflection	Delayed (Identification and Clarification)	Face-to-face	Individual
Out-of-Class Assignment Work	Delayed (Identification and Clarification)	Face-to-face	Group
Out-of-Class Online Communications	Delayed (Identification and Clarification)	Online	Individual
Out-of-Class Face-to-face Communication	Delayed (Identification and Clarification)	Face-to-face	Group

Table II. Effectiveness of Method to Identify Doubts

	In-Class Lecture		In-Class Quiz Reflection		Out-of-Class Self-Reflection		Out-of-Class Assignment Work		Out-of-Class Online Communications		Out-of-Class Face-to-face Communication	
Effectiveness / Course	DT	AT	DT	AT	DT	AT	DT	AT	DT	AT	DT	AT
1 - Least Effective	2	0	1	0	23	11	1	2	18	4	8	3
2	6	3	2	1	34	5	2	1	25	7	11	1
3	31	4	11	2	48	6	27	4	50	10	37	10
4	27	13	44	12	19	5	61	12	29	7	49	13
5 - Most Effective	61	11	75	16	9	4	42	12	11	3	28	4
Avg. Effectiveness per Course	4.14	4.03	4.43	4.39	2.68	2.55	4.06	4.00	2.92	2.94	3.59	3.45
Overall Avg. Effectiveness	4.12		4.42		2.65		4.05		2.93		3.56	

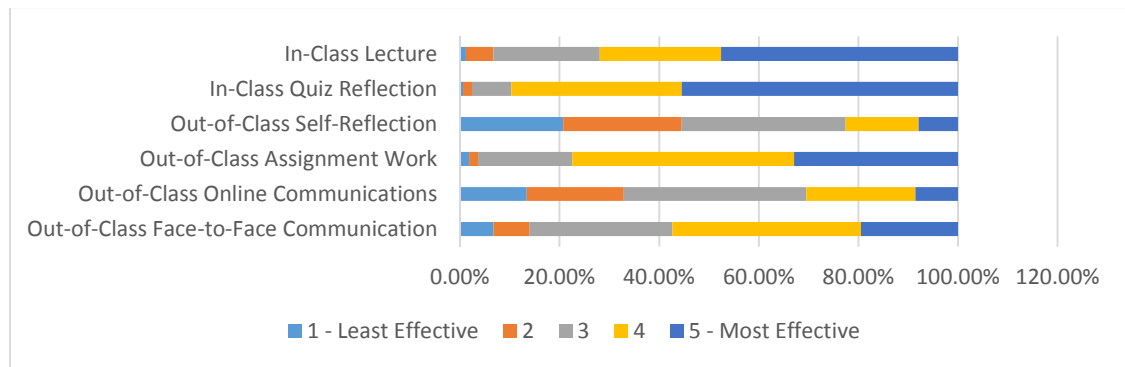


Fig. 1. Effectiveness of methods to identify doubts

Table III. Sentiment Analysis of Comments to Identify Doubts

Method / Sentiment Analysis	Positive	Neutral	Negative	Total
In-Class Lecture	21 (55.26%)	9 (23.68%)	8 (21.05%)	38
In-Class Quiz Reflection	49 (59.04%)	18 (21.69%)	16 (7.23%)	83
Out-of-Class Self Reflection	10 (20.41%)	16 (32.65%)	23 (46.94%)	49
Out-of-Class Assignment Work	10 (50.00%)	7 (35.00%)	3 (15.00%)	20
Out-Of-Class Online Communications	5 (21.74%)	8 (34.78%)	10 (43.48%)	23
Out-Of-Class Face-to-face Communications	11 (52.38%)	4 (19.05%)	6 (28.57%)	21

Table IV. Effectiveness of Methods to Clarify Doubts

Effectiveness / Course	In-Class Lecture		In-Class Quiz Reflection		Out-of-Class Self-Reflection		Out-of-Class Assignment Work		Out-of-Class Online Communications		Out-of-Class Face-to-face Communication	
	DT	AT	DT	AT	DT	AT	DT	AT	DT	AT	DT	AT
1 - Least Effective	1	1	4	0	26	7	1	1	10	3	2	3
2	4	3	13	1	15	6	13	1	16	4	19	2
3	26	7	30	5	44	3	41	9	44	5	29	9
4	40	7	46	13	31	8	55	10	42	7	56	9
5 - Most Effective	62	13	40	12	17	7	23	10	21	12	27	8
Avg. Effectiveness per Course	4.19	3.90	3.79	4.16	2.98	3.06	3.65	3.87	3.36	3.68	3.65	3.55
Overall Avg. Effectiveness	4.13		3.86		3.00		3.69		3.42		3.63	

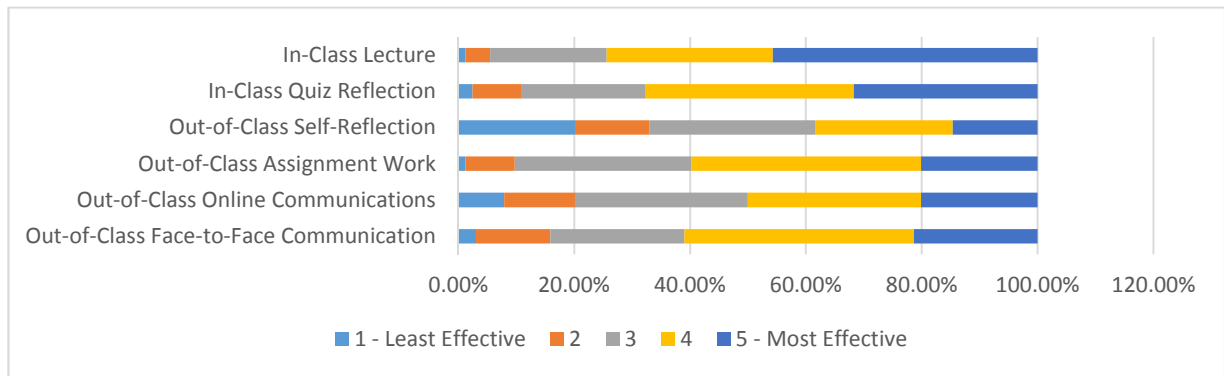


Fig. 2. Effectiveness of Methods to Clarify Doubts

Table V. Sentiment Analysis of Comments to Clarify Doubts

Method / Sentiment Analysis Polarity	Positive	Neutral	Negative	Total
In-Class Lecture	24 (52.17%)	10 (21.74%)	13 (26.09%)	46
In-Class Quiz Reflection	21 (53.85%)	12 (30.77%)	6 (15.38%)	39
Out-of-Class Self Reflection	12 (32.43%)	7 (18.92%)	18 (48.65%)	37
Out-of-Class Face-to-face Assignment Work	8 (41.18%)	3 (17.65%)	6 (35.29%)	17
Out-Of-Class Online Communications	8 (28.57%)	7 (25.00%)	13 (46.43%)	28
Out-Of-Class Face-to-face Communications	19 (51.35%)	8 (21.62%)	10 (27.03%)	37

Many of the comments are concerning the in-class lecture method. There are 46 such comments and 52.17% (second highest) of them are positive. Top positive comments with a high confidence score for this method include

- “Very effective for real time, on the spot clarification.”
- “The most effective for me would be clarifying in in-class lectures as it would be the most clear and when the problem or example still exists in my head.”
- “The instructor is very knowledgeable. His explanations in lectures and discussion help to clarify my doubts.”

The method with the highest positive comments is the in-class quiz reflection with 21 out of 39 positive comments and accounts for 53.85% of comments. Some of the positive comments with a high confidence score for this method include

- “Prof will provide an explanation of each question after the Kahoot questions which boosts our understanding as clarification is given immediately.”
- “For the quiz, it lets me know if something I believed was actually right or wrong so it helps.”
- “Kahoot is very effective and return the instant result.”

Another method with a high number of positive comments (51.35%) is the out-of-class face-to-face communications. Many students indicate the effectiveness of this method to clarify doubts due to direct communications with the instructors. Some of the positive comments with a high confidence score for this method include

- *"It's always best to clear doubts via direct communications"*
- *"I would like to add on and mention that our weekly consultation really helped clarify our doubts."*
- *"Face to face timing will still live long lasting impression"*

On the other hand, the in-class reflections, out-of-class online communications are two of the highest percentage in terms of negative comments. The out-of-class self-reflection method garners high negative comments of 48.65%. Some of the negative comments with a high confidence score for this method include

- *"Reflections do not really allow for a lot of questions because some doubts are easier to verbalise in person."*
- *"Reflections would only help if i had questions to ask, but since i don't, i won't know what i don't know."*

Many students also find out-of-class online communication less effective due to the challenge of expressing online. Some of the negative comments with a high confidence score for this method include

- *"Through online communication, it is rather hard to clarify our doubts as there may be delays in replies."*
- *"It is easier to clarify doubts when I can ask someone directly."*
- *"I can better clarify my doubts face to face as compared to doing it online as when there are more questions i want to ask i might be hesitant to do so and i have difficulties phrasing it over telegram or email."*

We can draw several insights by analysing these comments. The in-class lecture, in-class quiz reflection and out-of-class face-to-face communication methods are effective to clarify doubts, as the students prefer a direct and immediate response from the instructor. Although a student can clarify doubts anytime using online communication, the delay in response and the difficulty to express thoughts online reduce the effectiveness of using this method.

Each of these methods has a certain degree of effectiveness to identify and clarify doubts. The correlation values between identification and clarification of doubt for each method range from 0.25 (in-class quiz reflection) to 0.54 (out-of-class face-to-face meeting). These results show that there is no high correlation between identification and clarification of doubts for any one of the methods. The instructor has to select a mix of methods to achieve high effectiveness in both identifying and clarifying doubts. Although there are no high correlations between methods for identification and clarification of doubts, the in-class quiz reflection and in-class lecture have shown their high effectiveness on average in doubts identification and clarifications when compared to the other method used. Students significantly prefer a direct and immediate (in-class) method with prepared and specific questions to identify and clarify doubts. A possible reason is that these students with

limited working experiences are exposed to new concepts for the first time, and they need more guidance to identify doubts. With direct face-to-face clarifications, the students can better understand the clarifications and pose more questions if any. On the other hand, out-of-class self-reflection and out-of-class online communications need to be reviewed to improve on their effectiveness. One review area is to evaluate if the self-reflection questions can be more specific to the contents covered so that students can reflect based on those specific and direct questions.

VI. THREATS TO VALIDITY

In this study, we conduct the doubts identified and clarification methods consistently across the two courses over two semesters by the same instructor. The study results are dependent on the conduct of these methods by the instructor and may not be generalizable if the conduct varies.

We carry out this study for two computing design courses – design thinking and architecture thinking. There are other design courses (e.g. software design) in computing. Although we design these methods independently to the exact design course, the outcomes might still differ when we apply these methods in other computing design courses.

The participants for these design courses are undergraduates in their year 2, 3 or 4 of study with limited working experiences. The outcomes of this study are likely different when we conduct these courses for participants of different profiles. For example, participants with working experiences might be able to identify doubts better on their own, and the outcomes of these methods will differ.

VII. CONCLUSION

Instructors need to apply methods that allow students to identify their doubts and clarify them. This is especially true for courses with students of limited working experiences and requires them to understand abstract concepts such as computing design courses in undergraduate studies. In this paper, we evaluate the effectiveness of our six methods to identify and clarify doubts for our students. These methods vary in their timing (immediate or delayed), communication style (online or face-to-face) and participation style (individual or group-based). Our study involves implementing and conducting these methods to students in two undergraduate computing design courses over two semesters, one on design thinking and another on architecture thinking.

We survey to collect both quantitative and qualitative data at the end of the semester for each course. Our results show that in-class methods with immediate timing (in-class lecture and in-class quiz reflection) are more effective for the students to identify and clarify doubts. The students feel that the prepared and specific questions in these methods allow them to identify more doubts better. However, this outcome also indicates that these students require more guidance to be self-directed in their learning. For the communication style, students generally prefer face-to-face communication with the instructors. Students feel that it can be challenging to communicate online, and there is a delay in the replies if the instructor is not available. There is no clear indication that individual or group participation has in terms of effectiveness for them to identify and clarify doubts. Our statistical analysis shows that there are significant differences in effectiveness between most methods, and the instructor has to select a mix

of methods to achieve high effectiveness in both identifying and clarifying doubts.

We hope these findings can help other educators to implement effective methods to help their students to identify and clarify doubts. For future work, we can expand the study conduct to participants with different profiles or evaluate other methods for doubts identification and clarification.

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