CONSIDER: A Novel Approach to Conflict-Driven Collaborative-Learning in Engineering Courses

1 Introduction

It is well known, see, e.g., Piaget[1], that when learners engage with peers in critical discussion of ideas concerning which they have different understandings, it contributes effectively to the learner's developing deep understanding of the concepts involved. In effect, the disagreements with other learners' conception of the same idea highlights alternatives to the learner's own conception and the learner is forced to consider and evaluate these alternatives on equal terms. This difference in conception or the mental disequilibrium is called *cognitive conflict*. In this paper, we report on a novel online approach to *collaborative learning* that builds on the foundation of cognitive conflict to enable engineering students and, more generally, STEM students, to develop deep understanding of technical topics. Note that the discussion should be among *peers*; if the instructor were to participate, the students are likely to simply accept what she says without engaging in thoughtful analysis of the different conceptualizations.

Adopting such an approach to engineering education poses some challenges. First, unlike the children that Piaget's work addressed, college students, especially engineering students, may be less willing to engage in deep discussions with their peers. Second, large class sizes (with 40 or more students) and short meeting times (around 55 minutes) make it difficult to expect deep discussions in-class in small groups of students without the groups disrupting each other. Moreover, faculty tend to be concerned about the potential impact of such activities on topic coverage. Our approach addresses these and other concerns.

In Section 2, we review background theories and some related work. We describe our approach and the web app built around it in Section 3. We briefly describe our experience with using the tool in a Computer Science and Engineering course. Near the end of the course, students were asked to complete an opinion survey concerning the approach. In Section 4, we present an analysis of the survey results, and conclude in Section 5 with a summary and plans for future work.

2 Background

Collaborative-Learning is a teaching strategy in which small teams, each with students of different levels of ability, use a variety of learning activities to improve their understanding of a subject. It has been widely used in K–12 as well as college education. Some commonly used collaborative learning techniques include Jigsaw[2], Think-Pair-Share[3], and Team-based-learning[4].

The concept of cognitive conflict driven learning, discussed in the previous section, plays a central role in some other collaborative learning techniques, like peer-instruction (PI)[5]. In PI, each student individually answers a conceptual multiple choice question, submitting the answer via a *clicker*; then the students turn to their neighbors and, in groups of 3 or 4, discuss the question; after a few minutes of discussion, each student again answers the same question. During the discussion time, the instructor walks around the room, observing the discussions but not participating in them. Mazur[5] reports that the percentage of students who, following discussion with their peers, change their answer from a wrong choice to the correct one far exceeds the percentage who change from the correct choice to a wrong one. But there are a number of limitations with PI, mostly related to the fact that it is a classroom technique: (a) Since the multiple-choice question is about the topic being discussed in the lecture, students may not have had enough time to think about it deeply; (b) The groups are formed primarily based on which students happen to be seated next to which other students, rather than on the basis of ensuring cognitive conflict in each group; (c) Some students may dominate their groups irrespective of whether they have the right answers or not; (d) The amount of time spent in the discussion is limited; hence, students who need time to formulate their arguments may not contribute effectively. As we will see, our approach addresses all of these limitations.

Using computer technology, it is possible not only to record interactions in better ways, but also to create newer, better interactions. The branch of the learning sciences that studies "how people can learn together with the help of computers"[6] is called Computer-Supported Collaborative Learning (CSCL). One of the earliest CSCL systems is CSILE, now known as Knowledge Forum[7]. A group of students using CSILE focuses on a specified relatively broad problem and begin to build a database of information about the topic. Some other researchers have used *wikis* to allow users to add, modify, or delete content using a standard browser, to create a site that thoroughly explores a topic. But many of those studies have reported poorer than expected results. For example, Cole[8] conducted an experiment in an information systems course where students were supposed to discover new material and post to the class wiki. Fully one quarter of the questions on the final exam were to be from the material that students posted. Halfway through the course there had been no posts to the wiki! Judd, Kennedy, and Cropper[9], Leung and Chu[10] report similar experiences in their attempts to use wikis for collaborative learning. An important reason why it did not work in these cases could be the fact that there is little or no structure to the activities in these uses of wikis. On the other hand, in our approach, the activities have a specific structure that ensures that students will engage in effective collaborative learning.

3 Approach

Our approach, named CONSIDER (an acronym for CONflicting Student Ideas to be Discussed, Evaluated, and Resolved), works as follows. Following the standard class lectures on a given topic, the instructor will create a two-part assignment, call it A. The first part of A, call it I for *initial component*, will be a central, conceptual question that can, ideally, be presented as a multiple-choice question with distractors chosen to correspond to common misconceptions about the topic; the second part, P, is a more in-depth question, that is an extension of I, possibly including a substantial problem-solving component. The instructor posts I on the CONSIDER web app and each student in the course is required to, individually, submit his/her answer to I within 24 hours. The system, possibly with help from the instructor, then organizes the students into groups of 4–5 each with each group containing students who choose different answers for I.

The students in each group will then engage in a series of rounds, $R1, R2, R3, \ldots$, of discussion, each round lasting 24 hours. The goal of the discussion will be to help each student arrive at an answer to the assignment. Suppose G is one of the groups and has four students, S1, S2, S3, S4. Note first that the students will not know the identities of the other students in G with the system simply referring to them as S1, S2, etc. When S1 logs in for, say, round $R3$, she will see the posts made by all four students in $R2$. In her post for $R3$, S1 will have to indicate (by clicking a *green/red/blue* button on the app) whether she *agrees with, disagrees with, or is neutral/unclear about* the posts made by each of S1,..., S4 in $R2$ along with an explanation; and also include her current approach to the problem. Note that S1 has to indicate, in $R3$, whether she agrees/disagrees with her *own* post from $R2$; the point is that, she may have found the $R2$ post from, say, S4 so convincing that she no longer agrees with what she said in $R2$! Indeed, this is *precisely* the point of peer discussion based on different conceptualizations of a problem. At the end of a round, say, $R5$ –this will be decided by the instructor and will vary with the topic– each student will be required to *individually* submit her final answer to the assignment, along with a brief summary of the discussion in her group. S1's grade for the assignment will depend *only* on the correctness of her final answer and the quality of her summary; so she will not have to worry about losing points for switching from the wrong to the correct answer.

We have implemented the approach as a scalable, platform-independent web application, using Google App Engine and Python, making it ubiquitous, accessible from any internet-connected device of choice of the user. Figure 1 shows the user interface of the discussion phase as seen on a smart-phone device. Note that the members of this group are known to each other by aliases (S1, etc.) and not by their real names or any other identifiable nickname.

We used CONSIDER in a graduate-level Programming Languages course in Computer Science and Engineering in a large public university in the mid-western United States. The main goal of the grad course, like similar courses in other universities, is to study formal ways of defining syntax and semantics of programming languages. The main topics are attribute grammars; operational, axiomatic, and denotational semantics of languages. One of the regular homework assignments was conducted as a CONSIDER discussion. 39 out of the 40 students used the tool; one student missed the deadline for answering the initial question, and hence could not be included (he was given an equivalent assignment offline). The students were divided into nine groups of 4 each, with the tenth group having 3 students.

The assignment was about how Lisp, being a *functional* language, differs from *imperative* languages, and how can the constructs of imperative languages, like an assignment statement, be implemented in a Lisp interpreter. The discussion that followed was about whether it was possible

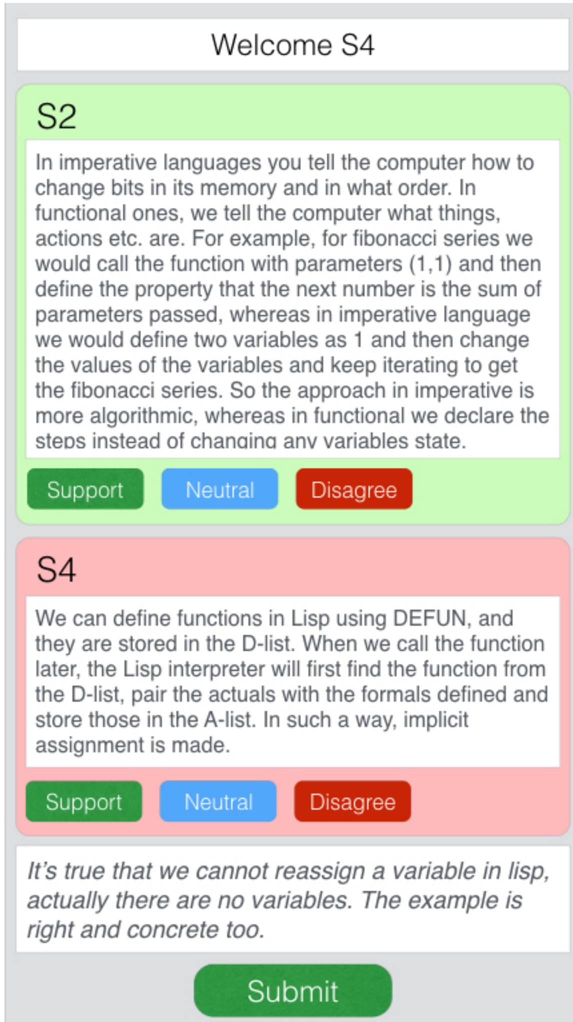

Figure 1: CONSIDER UI–Discussion in a group

to implement a construct that is equivalent to an assignment statement in Lisp –and, if so, how.

Figure 1 is a snapshot of this discussion in one of the groups. S4 of this group made an initial comment: "We can define functions in Lisp using DEFUN, and they are stored in the D-list. When we call the function later, the Lisp interpreter will first find the function from the D-list, pair the actuals with the formals defined and store those in the A-list. In such a way, implicit assignment is made." S2, on the other hand, had a slightly different take on the matter. She explained that in imperative languages bits are manipulated in memory which are assigned some meaning by the programmer, whereas in functional languages, the programmer tells the computer "what things, actions etc. are". She explained this with an example of Fibonacci numbers, and concluded, "So the approach in imperative is more algorithmic, whereas in functional we declare the steps instead of changing any variables state.". These were S4 and S2's posts, respectively, from $R1$. Upon entering $R2$, S4 sees S2's above comment and *agrees* with it by clicking the green 'support' button. S4 now *disagrees* with her own previous position, and modifies it to acknowledge that a variable cannot be reassigned in lisp (shown in italics in the figure), unlike her initial claim. They continued to discuss in detail how the functionality of assignment can be implemented in Lisp. All groups had discussions with similar results, with either a student who started with a wrong approach changing it to a correct one over the course of the discussion, or one who started with the right idea refining it as they heard their peers' viewpoints.

4 Survey Data Analysis

Near the end of the course, an optional, anonymous online survey was used to get the students' feedback on the CONSIDER approach. 22 of the 39 students, all graduate students of Computer Science and Engineering, completed the survey.

Using a Likert scale, we asked the students if they thought that CONSIDER provides a better opportunity to learn compared to in-class discussions. 68% answered 'agree' or 'strongly agree' (Figure 2). Some of them explained in the comments that due to short meeting times, they are usually not able to get into the details of a topic while discussing in-class. This limitation was overcome in CONSIDER.

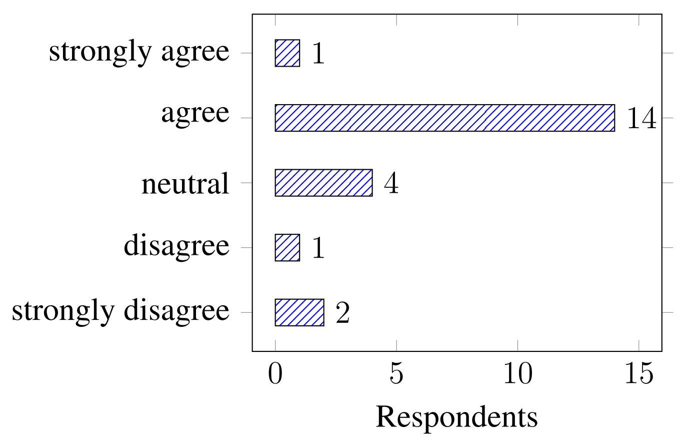

Figure 2: CONSIDER provides a better opportunity to learn compared to in-class discussions.

The survey also asked students their feedback on the duration and number of rounds used in the assignment and the features of anonymity, rounds-based structure. Figure 3 summarizes student responses to each of those. 59% and 73% students, respectively, responded that the number of rounds and the duration of each round were just about right.

73% of the respondents felt that ability to post anonymously was helpful. Their comments on why they felt it was useful are in line with the reasons why we included it in the approach in the first place: it made sure that "answers were discussed without prejudice".

Responses on the rounds-based asynchronous discussion feature were rather mixed. Only 18% students liked it the way it was, while an equal number said they would prefer a 'live' discussion.

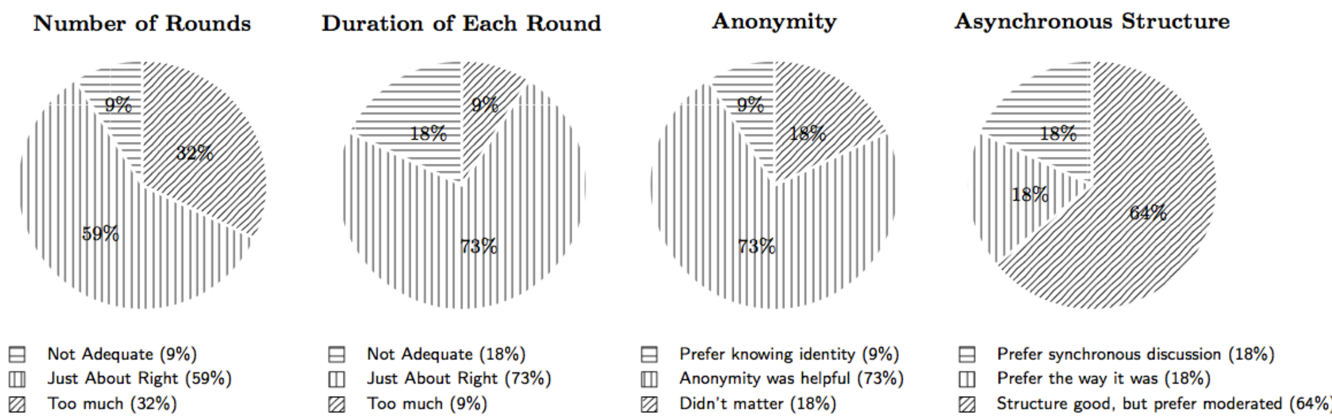

Figure 3: Survey responses on features of CONSIDER

Remaining 64% were ok with the structure, but preferred having the instructor intervene at some point of time. Some of them were okay with knowing the teacher's opinion *eventually*, which, in the form of an in-class session to clarify any remaining confusion on the topic after the exercise is over, is a practice we would recommend. But some other students felt the need of getting the instructor's feedback on *each* round. This would be essentially equivalent to grading 40-odd assignments *every day* for the duration of the activity, which is not practical. Let's also look at another comment in this context that advocates allowing members of a group to decide if majority of them disagree over a point, and ask for an instructor intervention "instead of arguing among themselves and wasting time." We believe that this comes from a deeper problem seen in STEM education – what Rick and Guzdial [11] call a "lack of collaborative culture" in STEM education. These comments seem to reflect the widespread notion that discussing and arguing with peers about their conception of a technical topic does not (usually) contribute to learning. But this is contrary to our understanding of how learning happens, particularly in the case of collaborative learning [12]. In their analysis of why their wiki-based collaborative learning environment was successful in English literature and architecture classes, but not in STEM courses, Rick and Guzdial [11] identified one of the reasons to be "competitive nature of the courses and single answer questions". The same is reflected here with the student trying to get to the (presumably one, correct) solution of the problem via the instructor, instead of trying to discuss with peers other possible approaches to the solution, an exercise he considers a 'waste of time'. Consciously employing collaborative learning techniques in all levels of STEM education might eventually mitigate such issues, and would help see learners as well as educators the value of collaborative learning.

Nevertheless, there were students who appreciated the importance of collaborative learning driven by cognitive conflict, and of the emphasis on discussing the topics with peers. We conclude the discussion on survey data by presenting a comment that reflects this understanding: "Since nobody is really expert like instructor, we have to provide strong evidence to convince others (as well as ourselves)." It is important to note here that, unlike the students who asked for the instructor to intervene in order to make sure they learn, this student indicates that they learn better *because* the instructor is *not* present, resulting in them being more vigilant about the arguments they produce. This is *precisely* the point of collaborative learning driven by cognitive conflict.

5 Conclusion and Future Work

We have developed a novel, online approach, called CONSIDER, that combines the strengths of conflict-driven collaborative learning and Computer-Supported Collaborative Learning. Its unique features and their benefits are summarized below.

- Small group formation based on cognitive conflict ensures that the discussion in each group is driven by the conceptual disagreement among its members, which enhances learning.
- Ability to post anonymously in the groups allows students to participate more freely, without compromising the effectiveness of the discussion by any gender/ethnic/other preconceptions some students may have.
- Asynchronous, rounds-based structure of the discussions ensures that each student, whether quick on her feet, or prefers to think through subtle ramifications before posting, or anything in-between, participates equally effectively.
- Since all the interactions in the discussion are recorded, students can come back and refer to their discussions logs later and can continue to learn from the experience. Instructors can also look at the interactions and decide if further explanation is required for the topic.

We have implemented CONSIDER as a scalable, platform-independent web application using Google App Engine and Python. We used it in a graduate-level programming languages course in Computer Science and Engineering. Discussion activity in the form of a homework assignment, about implementing assignment-statement like capabilities to the functional language Lisp, was conducted through the app. 39 students participated. Preliminary analysis of the discussion data suggests that the approach was very helpful in improving the participants' learning about the concept. In almost all the groups, students changed or refined their solutions, based on comments of their peers, during the course of the discussion. In some groups, it was observed that, as a student critiqued another student's solution, he realized some caveats in his own solution and refined it.

22 students completed the follow up survey for reflections on whether the approach helped their understanding of the concept. The participants' feedback highlighted the importance of the unique features of CONSIDER. In particular, students considered the feature of anonymously posting comments extremely helpful in participating freely and posting without prejudices. While 18% of the students were supportive of the asynchronous, rounds-based structure of discussions, about 64% of them said they would prefer an intervention from the instructor, instead of discussing only with the peers. This opinion likely results from a lack of collaborative culture in STEM education, in which the value of collaborative learning, through discussing with peers, is not readily appreciated.

We plan to further evaluate the efficacy of the features of CONSIDER by designing careful experiments in coming semesters and using the tool in different courses. Our tool is available as an open source software, which other educators can download and configure to use in their courses. It is highly customizable in terms of features such as number of rounds, duration of rounds, group size, etc., to suit their specific needs.

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