Work-in-Progress: A Novel Approach to Collaborative Learning in the Flipped Classroom

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Abstract

The *flipped classroom* is widely regarded as an excellent approach to exploit the affordances of digital and on-line technologies to actively engage students and improve learning. The traditional lectures "covering" course content are moved to on-line videos accessible to students before the class meetings, with the class meeting times being devoted mostly to *discussion* and *application* of the new ideas, and other *active learning* tasks. The expectation has been that this will make the courses much more effective and students will be able to achieve the intended course outcomes to a much greater extent than in the traditional classroom. But the results have been disappointing. Although students find the flipped classroom engaging, student achievement of course learning outcomes, as reported by most researchers who have used the approach, has been roughly the same as in traditional classes.

How do we tailor the flipped classroom to achieve its full potential? That is the question our work-in-progress attempts to address. The thesis underlying our approach, based on classic work in the area of how people learn, is that it is not enough to have students watch the on-line videos before the class meeting. They should also engage in serious, structured discussions with other students, and thoughtfully consider ideas that may conflict with their own understanding of the topic in question both in order to help them develop a deeper understanding of the topic and in order to highlight problem areas that need further elaboration by the instructor. We discuss the theoretical basis behind the work, provide some details of the prototype implementation of an on-line tool that enables such structured discussions, and describe our plans for using it in an undergraduate course on software engineering and for assessing the approach.

1. Introduction

The most widely accepted definition of the *flipped classroom* is one where "events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa", see, e.g., Lage et al. [1]. Thus the knowledge transfer that the traditional lecture tries to achieve is instead intended to be achieved, typically, via on-line video lectures which the students are responsible for viewing before attending the in-person class meeting. The in-person meeting is devoted to answering questions (that students may have based on their viewing of the corresponding video lecture(s)), joint problem solving activities, as well as other active learning tasks that provide individual and group practice. The expectation is that, given the ability of active learning tasks to engage students in learning, the approach will help students better achieve the intended learning outcomes of the course; and, as an added bonus, students' abilities with respect to such important professional skills as *team work* and *communication* will also be improved.

A number of researchers have reported on their experiences with the approach of the flipped classroom, henceforth abbreviated *FC*. We will briefly summarize some of this work. Lage et al. [1] were among the earliest to use the approach of the flipped or *inverted* classroom. They used the approach in an introductory economics course. They argue that a main problem with traditional courses is that they do not allow the instructor to match the *teaching* style to the *learning* style of the student; and that by posting the usual lectures as on-line videos that students would be responsible for viewing before class meetings, the instructor would be able to tailor the class meetings to match the needs of particular groups of students. They report that students reported satisfaction with the course and expressed a preference for this type of course over traditional courses. The instructors were also satisfied with the inverted course. Lage *et al.* do not, however, report on how the students in their inverted classroom performed with respect to achieving the intended learning outcomes of the course compared to students in the traditional version of the course. Foertsch et al. [2], another group of early adopters of the flipped approach, report on their experiences with it in a large, previously lecture-based, computer science course for engineering majors. The lectures were converted to online videos that students were responsible for viewing before class meetings to free up class time for working on problems similar to ones that were previously assigned as homeworks. Students who took the course reported satisfaction with a number of aspects of the course including, in particular, the ability to view/review the lectures as needed and on their own schedule although a few felt that in-class lectures, being more "formal", would have encouraged them to pay fuller attention. Foerstsch *et al.*, like Lage *et al.*, do not report on how the students in their class performed in comparison to students in the traditional version of the course. Zappe et al. [3], similarly, report on student satisfaction with their FC course but do not say how the class performed in comparison to a traditional version of the course.

Thomas and Philpot [4] present a detailed description of their experience, over several years, using the FC approach in a course on the mechanics of materials. They present a detailed evaluation of what seems to work and what needs improvement in terms of assessing which concepts in the course students seem to have problems with, as well as what kinds of materials (on-line videos, worked homeworks, etc.) the students seem to prefer to learn from. More importantly, from the point of view of our work, they also present results comparing the performance of students in the FC version of the course with students in the traditional course. They report that there were "no statistically significant differences between the two groups ... based on performance on the common final exam".

Redekopp and Ragusa [5], while they report on student satisfaction with the FC approach in their computer organization course, also focus specifically on comparing performance, with respect to achieving intended course outcomes, of students in the FC version of the course with the performance of students in the traditional version. They divide the performance into two categories, one with respect to "higher-order outcomes" which they identify as such abilities as team work in projects, and the other with respect to "lower-order outcomes" which they identify with student performance with respect to conceptual and technical knowledge as measured by performance in course exams. They report that student performance in the course projects in the FC version of the course was better than student performance in the traditional version by an average of 12 percent.

They also report that this improvement was not seen in one section of the FC version of the course; and they attribute this to the fact that the instructor in that section "neglected to utilize modeling and demonstration techniques ...". This, of course, raises the question, which the authors do not consider, of whether the performance of the students in the projects in the traditional version of the course would have matched the performance in the other FC sections of the course if the instructors in the traditional course had used these techniques. In any case, the point remains that the performance of students in the FC courses, at least with respect to conceptual and technical knowledge, is no better than in the traditional courses.

We conclude this brief survey by considering the work of Swartz et al. [6]. They use a fairly broad conception of FC on the basis of which they consider three different approaches. What is different about their conception of FC, compared to those of some others, e.g., Bishop and Verleger [7], is that the course lectures do not necessarily have to be on-line; instead, students may be asked to do relevant focused reading and review of worked problems before class meetings. The key requirement is that the class meetings are mainly devoted, as in all models of FC, to active learning tasks rather than lectures by the instructor. In their first approach, used in a small class on the mechanics of materials, the lectures are in the form of videos; in addition, audio explanations are added to the *pdf* files of class notes. In the second approach, used in a large class on environmental engineering, the weekly lectures are in the form of 90 minute on-line videos, divided into 10 minute chunks. In the third approach, used in a medium sized class on structural design of foundations, instead of lectures, students are expected to perform focused readings as noted above. In each case, there is a "quiz" before the class meeting which allows the instructor to identify specific problems that students might have in understanding the videos/readings, that can be addressed briefly at the start of the class meeting. Much of the class meeting is devoted to working on individual or group problem solving activities. The authors report, for each of their approaches, such benefits as students being better prepared for class and faculty having time to discuss applications and develop deeper level thinking (as well as guest lectures, field trips, etc.) They do not present any information on performance of students with respect to understanding course concepts and technical knowledge.

The key question that the work of various authors summarized above and others in the literature raises is, why is it that student achievement with respect to the learning outcomes, with respect to concepts and technical knowledge, for the courses is roughly the same as (and in some cases[5] even worse than) in traditional classes? Given the increased level of active learning componenents in the FC, shouldn't the levels of achievement not just of such outcomes as team-working abilities, but also those related to understanding of the technical material in the course, be superior compared to that of students in the the regular versions of the same course? Or, to put it differently, how do we fine-tune the FC model to improve achievement of outcomes related to the technical content of the FC courses? This is the question that our work-in-progress tries to address.

In the next section, we outline the theoretical framework underlying our approach to FC to help improve student performance with respect to conceptual and technical knowledge. The key idea, as we will see, is to engage the students in on-line discussions, about the underlying technical material, with each other in a carefully orchestrated manner. Widely accepted models of learning stress the importance, to student learning, of detailed discussions with peers, especially when those peers have *conflicting* ideas about the topic in question. Our approach extends the FC model to take account of this important notion to improve the quality of learning. In Section 3, we will present details of our prototype implementation of the approach in the form of an on-line tool, *CONSIDER*, that will be available on smart phones, etc., as well as on the web. In Section 4, we briefly describe our plans for using the approach in a course on software engineering; and for assessment of the approach. Section 5 concludes the paper by summarizing why our approach has the potential to significantly enhance the effectiveness of the FC model with respect to student achievement of course outcomes related to conceptual and technical knowledge.

2. Theoretical Framework

The main thesis underlying our work is that in order to exploit the full potential of the FC model, it is not sufficient to use the class meeting times, freed up by having students access on-line videos (and other materials) of the lectures prior to the class meetings, in various active learning tasks such as problem solving and project work; the thesis is that we must also use the capabilities of on-line systems to have students engage in serious discussions with their peers about specific questions related to the technical content of the on-line videos.

Over the years, a number of researchers have investigated the importance of interactions among students in order to best enable learning. Bishop and Verleger [7] summarize results from many of these researchers' investigations. For our work, a key notion is that of *cognitive conflict*, introduced by Piaget [8]. Although Piaget was concerned mainly with the intellectual growth of children, his ideas are very relevant for adult learners as well, including undergraduate engineering students. A key point in Piaget's theory was that *peer interaction* was a potent component of a learner's grasp of new concepts; in particular, cognitive conflict, i.e., disagreements with *other* learners' conception of the same problem or topic was fundamental since it highlighted alternatives to the learner's own conception. The learner is forced to consider and evaluate these alternatives on equal terms. This is quite different from a *teacher* telling a learner that his or her conception is incorrect because then, given the authority of the teacher, the learner simply accepts this without critical evaluation. By contrast, when the (cognitive) disagreement is with *peers*, the learner is forced to evaluate the alternatives critically and pick one after careful deliberation (although, naturally, how critical this evaluation is will depend on the level of maturity of the learner). As Howe and Tolmie [9] put it, "conceptual growth depends on *equilibriation*, that is the reconciliation of conflicts between prior and newly experienced conceptions." A distinction between Piaget and the work of Vygotsky [10] is that the latter stresses the importance of a "more competent other" in the interaction. In other words, according to Vygotsky, interaction among peers is most fruitful when one of the members of the group is more competent than the others. Interestingly, while some researchers have confirmed the importance of Vygotsky's "more competent other", the results of other researchers suggest that what seems to matter most is the cognitive conflict that a student experiences because of disagreements with other students' conception of the same problem or topic. It is indeed possible that the importance of having a somewhat more competent peer in the group may depend on the level of development of the learners. Since much of the research that has been carried out thus far has focused on relatively young children, it may be useful to investigate this question carefully as it applies to groups of undergraduate engineering students. As we will see later in the paper, our system is designed to allow us to do so.

We should also mention a more general framework that concerns the importance of interaction among students to ensure effective learning. Fig. 1 depicts the *Community of Inquiry* (CoI) model created by Swan and Ice [11]. The CoI was designed for analyzing on-line educational systems.

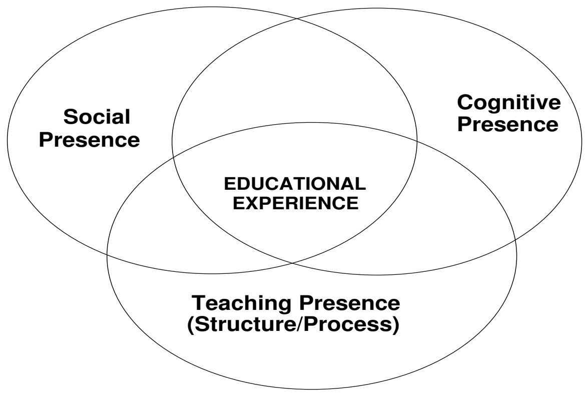


Fig. 1. Community of Inquiry

But it is also appropriate for learning environments that are partly face-to-face and partly on-line. The three principal elements of the CoI model are social presence, cognitive presence and teaching presence. Social presence may be defined as the degree to which participants in the learning environment feel affectively connected one to another; cognitive presence represents the extent to which learners are able to, via interactions with each other, construct and refine their understanding of important ideas through *reflection* and *discussion*; and teaching presence is the design of various instructional activities such as lectures *as well as* activities intended to facilitate interactions among students to help their learning. In terms of the CoI framework, the focus of our work is to effectively use on-line systems to improve the cognitive presence component in the FC approach. The social presence component, as we will see later, raises interesting question that we plan to investigate in our work.

3. Approach and Prototype System

For the last several years, we have used a flipped approach in our undergraduate junior/senior-level course on software engineering. Our approach has some aspects in common with the approaches described in the papers we briefly considered in Section 1. Lectures are made available as on-line videos which are typically 20 minutes in length. Students are expected to watch the relevant video(s) prior to the class meeting. The class meeting *starts* with a 15 minute quiz on the topic; below, we consider a typical quiz from the course. Students may post questions about the topic on the class's electronic forum before the class meeting and the instructor or grader answers them; typically, however, no students post any questions. Following the quiz, the instructor presents a brief summary of the topic, focusing on the highlights. Then the instructor asks students what choice they made for a particular question on the quiz, picks an individual student, and asks him/her to explain the choice; other students who picked other choices are then asked to explain their choices. The intent is that the resulting discussion will help address any misconceptions that students may have about the topic. But there is no further follow-up; so it is unclear how effective this is in helping students develop a good understanding of the topic.

The main purpose of our software engineering course, like that of similar courses elsewhere, is to help students understand the importance of a systematic approach to understanding the overall domain in which the software system to be built is intended to operate, understand the problem, in the context of the domain, that the software system will help address, and the solution approach to be adopted in the software system. Quite often, however, students want to jump straight into designing and coding the software system without going through a careful analysis of the domain, the problem in the context of the domain, etc. Indeed, frequently there is confusion between the domain problem and specific algorithmic or data-structure related problems that might be encountered when developing the software system. The quiz below is intended to help identify such misunderstandings:

Quiz 6: Your team has been asked to build a campus wayfinding system to help visually impaired students at OSU. Five items identified during analysis are listed belw. Identify which category of analysis –that is, domain, problem, or solution– each element falls under.
Briefly explain why.

1. A catalog of the various types of building on a college campus;
2. The list of hard-to-find buildings on campus;
3. The range of visual and cognitive impairments that people suffer from;
4. Strategies by which people find their way in an unknown area – such as asking passers-by or by identifying major streets.

Item (3) is especially interesting. A casual reading might suggest that it should be classified under the *problem* category. But, in fact, it is part of the *domain* because it provides information about the overall range of impairments (including cognitive impairments) that people suffer from; the software system is not intended to solve the problem of visual impairments (e.g., by developing an artificial eye or something along those lines).

Different students come up with different answers to that item and with different justifications. While the class discussion helps clarify the issues for some students, many others remain unclear about the distinction between the concepts of domain, problem, and solution. How do we help the students overcome the underlying misconceptions? Based on the theoretical framework outlined in the last section, in particular on the basis of Piaget's notion of cognitive conflict, a good approach would be to divide the class into small groups of 3 or 4 students each, and have them discuss the problem and convince each other of their point of view. But such a discussion cannot take place in class. A key reason is that the students in a group need *time* to mull over the arguments of their peers, especially of those peers whose opinions they *disagree with*, in order to convince themselves of the validity/invalidity of those arguments. They need to have time present their counterarguments and the other students, in turn, need time to think about the validity of the counterarguments. Moreover, a class discussion would be ephemeral and there would be no record of it that the students in the group could refer back to at a later point to remind themselves of the arguments and counterarguments.

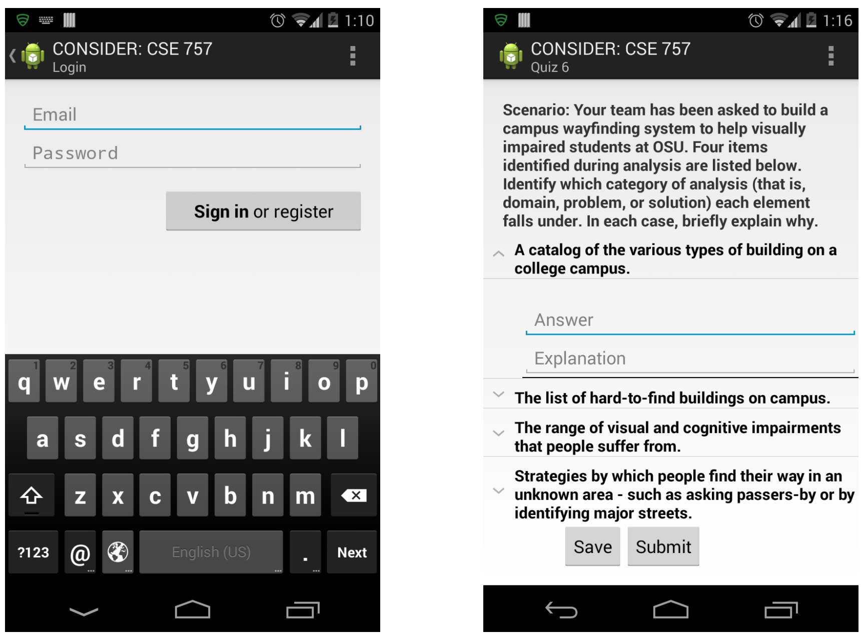
The goal of our work thus is to implement a system that will enable engineering students in a flipped classroom to engage in deep discussions with their peers, especially peers who have conflicting ideas with their own, about concepts and technical details that are the subject of a a given video lecture. In more detail, in preparing for a class meeting, each student in the class is required to individually watch the corresponding video lecture(s). The student is then required to electronically submit answers to a quiz that will be posted to the course's website. The quizzes will be analogous to the example quiz considered above. In other words, it will require the student, in answering a question on the quiz, to make a specific choice (such as "domain" or "problem" or "solution") but, in addition, will require the student to include a *justification* of his or her choice. Once the students have submitted their answers by a specified time, the system will automatically form *heterogeneous* groups of 4 or 5 students each with each group containing students who chose different answers[1].

Each student in a group will receive an e-mail indicating that he/she has been assigned to a group and should start engaging in an electronic discussion on the topic with the group; the e-mail will provide a link to the particular group's forum for this discussion. In order to encourage free-flowing discussion, the students in a group will not know who the other students in the group are. Instead, students in the group will simply be identified as S1, S2, etc. Let us assume that a given group has four students, S1 through S4. At the start of the discussion, the *initial posts* in the forum will be the answers submitted by each of S1 through S4 in response to the question in the quiz. As the discussion proceeds, each student will be expected to argue in favor of or against the ideas in the posts that have been made thus far. A student will have three distinct ways to react to a given post. The student could *respond* by creating a completely new post; the student could indicate that he/she *supports* the position expressed in the given post and provide an explanation why; or the student could indicate a *conflict* with the position in the given post and provide an explanation as to why.

The students in the class will be required to submit their original answers to the quiz approximately 4 days before the class meeting where the topic will be discussed. Within 24 hours of that submission, each student in a given group will receive the emails from the system indicating their group assignments, with links to the location of the discussion forum for that particular group. During

[1] It is possible that, for a particular quiz, most students choose the same set of answers. In that case, the system will not be able to form such heterogeneous groups automatically. The instructor or the grader will then have to intervene to form suitable groups on the basis of differences in the students' *explanations* for their answers. If there are no substantial differences in the explanations as well, then that may be an indication, if most students pick the right answer and give the right explanations, that the topic is simple and the instructor can simply move on to the next topic; or if most students get the answers or the explanations wrong, the topic may be too difficult and it may be an indication that additional video lectures and other resources might be called for.

the next 48 hours, the group will be expected to engage in their discussion. At the end of that period, the discussion forum will no longer accept new posts but the students in the group will be able to read all the posts. At that point, each student will be required to individually submit a three part report consisting of: a summary of the starting positions of each student in the group; a summary of the discussion/debate in the group and any conclusions that were reached; the particular student's final answer (which may or may not be the same as the group's conclusion). The quality of this report, including especially the summary of the discussion, will contribute toward the student's grade for the quiz. This report will not be made available to the other students in the group until after all students in the group have submitted their reports[2]. These reports which the instructor will have available about 24 hours prior to the class meeting will give the instructor detailed information about common misconceptions, how the students tried to resolve them, and what issues remained after the discussions. The timeline for the activity is tentative and will be adjusted as we gain experience with the system.



(a) `Login` (b) `Quiz`

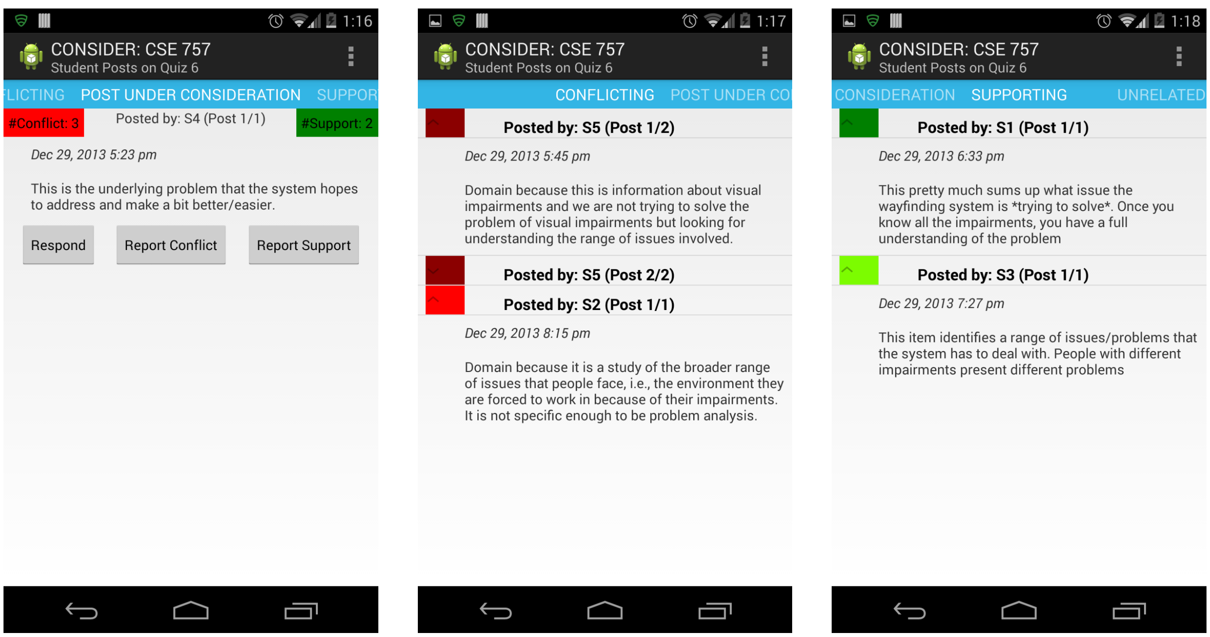
Figure 1: Initial Screens

Since many students use smartphones regularly, we are implementing our system to be accessible both on smartphones as well as via the desktop. Figure 1 displays the initial screens as seen on an Android device. The login screen is standard and authenticates the user. Once the student has logged in, he/she will see the current quiz, as in Fig. 1(b). The student will then be able to submit

[2]It is not clear that it should be available even *after* all students in the group have submitted their reports. The question is, what effect does having or not having access to the other students' reports have on the learning of an individual student. This is a question we plan to explore.

the answer along with an explanation for each part of the quiz. The system is named *CONSIDER*, as an acronym for CONflicting Student IDeas Explored and Resolved.

In Fig. 2, we present the screens seen during the discussion. Figure 2(a) shows a post made by student S4. The red block indicates that there are 3 posts that *conflict* with this post; i.e., since the time that S4 made this post, other students in the group have made three posts that conflict with the position of this post; the green block on the right similarly indicates that there are two posts that *support* this post. Clicking on the "SUPPORTING POSTS" tab on the top right (partially obscured) will bring up the supporting posts, seen in Fig. 2(c); clicking on the "CONFLICTING POSTS" tab on the top left (partially obscured) will bring up the conflicting posts, seen in Fig. 2(b). A student in the group can read any of these posts any time. And can *respond* by creating a new post (which will bring up a screen that will allow the student to specify whether the new post is supporting or conflicting), or *report conflict* with another *existing* post, or *report support* with an existing post.



(a) `Initial post`   (b) `Conflicting posts`   (c) `Supporting posts`

Figure 2: Post, Conflicting and Supporting Posts

As indicated earlier, the final report that each student will be required to submit individually (we have not shown the screen for those), will be available to the instructor about 24 hours prior to the class meeting will give the instructor detailed information about common misconceptions, how the students tried to resolve them, and what issues remained after the discussions. The timeline for the activity is tentative and will be adjusted as we gain experience with the system.

4. Assessment

We will briefly summarize our plans for using the CONSIDER system and assessing the approach. Several sections of the software engineering course are typically offered each semester. The FC approach is used in all the sections of the course. In order to evaluate the system to improve it and in order to assess the effectiveness of the approach, we will compare performance of students in two sections of the course, one that uses the CONSIDER system and one that does not. We expect that the students in the section using the system will indeed perform better than the control group in terms of the grades they receive in final examination questions related to topics discussed in the quizzes in both sections of the course. But there are additional questions that we need to consider. As we noted earlier, the Community of Inquiry framework suggests that *social presence* is an important component of learning in student groups. We intend to explore this by comparing student performance in quizzes in which students in each group in the CONSIDER system know each others' identities and are encouraged to interact socially either on-line or in person with their performance in quizzes in which students in each group in the CONSIDER system are anonymous and know each other as "S1" or "S2", etc. This part of our work will allow us to assess exactly how important the social presence component of the CoI framework is.

There are still more issues to be explored. As noted earlier, Vygotsky's theory of learning suggests that discussions in a group of students is most effective when there is a "more competent other" in the group. And, indeed, the students in the group, according to this theory, should know who the competent other *is*. On the other hand, Piaget's theory suggests that students in a group of peers learn as long as they experience cognitive conflicts because of differing ideas from their peers about the concept being learned; and it is not necessary that any member of the group be more competent than the others. Our work will enable us to investigate this question carefully. We will *seed* some groups with contributions from the course grader who is the "competent other"; and will compare the performance of students in such groups with students in other groups that do not have such members. Our system and approach will, in fact, allow us to research a number of other similar questions. And since all the posts made by students in the various groups, along with the order in which they were made, will be available, we expect to have a rich source of data to answer these questions.

5. Conclusion

McClelland [12] presents the experience of using the FC approach in a large enrollment fluid mechanics course. Interestingly, students in this course did *worse* than students in a traditional version of the course! The author also reports that the students did not watch the assigned videos, etc.

We believe that the FC approach has a lot of potential to improve student learning, not just by freeing up class time to spend on activities that contribute to their *soft skills* such as teamwork, but also improve the extent to which individual students attain the course outcomes related to the technical contents of the course. But in order to reach this potential, it is important to go beyond what has been done so far in most FC classrooms. In particular, it is necessary to engage small groups of students in deep discussions about the technical material; and to organize these groups on the basis of well understood theoretical principles. Our approach, and the *CONSIDER* system are designed to do that. We plan to use our approach initially in our software engineering course; and, over time, in other courses in our curriculum.

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