Collaborative Teaching in Large Classes of Computer Science Courses

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***Abstract*—Collaborative teaching was applied by eight teachers for teaching nearly 700 students in four different sections of three different computer science courses with section strength varying from 120-240. Different forms of collaborative teaching were tried. Collaborative teaching at JIIT, Noida has turned out to be successful for large classes of the strength of 100 and above.**

Keywords—collaborative teaching; active teaching; computing education; information technology education; large class; computer science education; lecture

I. INTRODUCTION

Worldwide there is a lot of emphasis on increasing the Gross Enrolment Ratio (GER) in higher education. Countries are making a lot of effort in this direction. In India, at the time of independence, the GER was only about 1%. It has increased from around 11% to approx. 20% in the last one decade. While there is a huge growth in the number of colleges and teachers, it has not kept pace with the growing number of students. The country-wide faculty-student ratio in the higher education at the time of independence was around 1:9. This has now reduced to around 1:23 [1]. Even at many IITs, this ratio varies between 1:15-1:20 and lecture class in a few courses at a few IITs can be as large as 250-400. With successive governments aiming to further increase the GER in higher education to around 50 % by 2030, the faculty-student ratio is further likely to deteriorate. While the countrywide student faculty ratio in higher education is deteriorating, the increasing emphasis on national/international university/college rankings, accreditation, and outcome based education are placing higher importance on quality and effectiveness of the educational process.

The growth of engineering education has outpaced the general growth of higher education. It has gained a lot of popularity in the last few decades [2] and evermore so in India. Many reasons like societal mindset and financial stability have contributed to this. Further, an engineering education with its problem-solving approaches is also considered as a good program that prepares students for pursuing higher studies in other disciplines as well. The number of students enrolled in engineering courses has increased many folds in the last one decade. This "massification of higher education" has occurred globally [3]. Tremendous growth of manpower requirement in IT industry has fuelled more admissions in popular branches of Computer Science, Information Technology and Electronics and Communication Engineering. This has raised the number of students being enrolled to such attractive courses leading to large class sizes. Hence, traditional models of engineering education are not sustainable anymore and innovative approaches have to be developed for all aspects of higher education. Some universities, academicians, and policy makers believe that Massive Open Online Courses (MOOCs) offer a solution to this problem. However, this paper is about an innovative approach for the conventional mode of face-to-face teaching in classroom.

In India, regulatory bodies like UGC & AICTE prescribe norms for maintenance of standards for technical institutes. AICTE [4] prescribes a maximum class size of 60 for a section. However, this is not always feasible due to faculty, administrative or resource constraints. Hence, large classes are not an uncommon sight in engineering education. No doubt, learning in small group is good; however, having large classes may not be such a bane. Large classes have their pros and cons. Though there are varied outlooks regarding large class sizes in engineering education, nonetheless, it is also true that large classes are very challenging for ensuring a good quality of teaching-learning process.

"*Learn by listening and he may retain for a day or two, learn by watching and he may remember for some more time, but learn by doing and he will have gained knowledge for a lifetime*" is a common saying. Such sentiments are now increasingly shaping education systems worldwide. The traditional way of delivering lectures is of limited educational value. Active and interactive lectures are found to be much more effective [5]. However, prodding many students into in-class learning activities is a herculean task. It is often a big challenge for many students to speak even before a class of 50 students. This wax museum-like aspect has, often, wreaked havoc even with otherwise wonderful courses.

This paper discusses an experiment in collaborative teaching in large computer science classes. The experiment was conducted for teaching nearly 700 students in four

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different sections of three different computer science courses with section strength varying from 120-240. The next section of this paper gives an overview of the problems of large classes and also discusses the approaches of collaborative teaching as reported in the literature. Collaborative teaching was applied by eight teachers for teaching nearly seven hundred students in four different sections of three different computer science courses with section strength varying from 120 to 240. Different forms of collaborative teaching were tried. This is discussed in the third section. The fourth section briefly presents the results of this experiment and the papers concludes in the fifth section.

II. PROBLEM OF LARGE CLASS

Large classes can be seen as contrary to the objectives of university teaching "*foster the growth of individuals, and encourage them in their individuality so that they become independent, creative, self-motivated, critical thinkers and learners*" [6]. However, large classes have now gained larger acceptance to accommodate the burgeoning number of students who are able to enrol and complete their higher education. Nonetheless, class management and teaching time face significant negative impact, making it inept and dull for both the students and instructors [7]. Some problems faced in large classes, as reported in literature [7]-[10], [13], and [15] are as follows:

- Large space and theatre-like setting: to physically accommodate a huge class, lecture rooms must be large and for visibility have a theatre-like projection facility. This reduces eye-to-eye contact between teachers and students.
- "Sage on the stage" problem: Many large classes tend to follow the "sage on the stage" style of teaching which is not considered an effective teaching style.
- Maintaining instructor enthusiasm: Consistent enthusiasm for the course of such large student-teacher ratio is a tasking job.
- Class management: Administrative tasks such as taking attendance, maintaining class decorum and discipline are at times difficult.
- Maintaining students' interest: Attention spans of students are difficult to maintain in large class where there may be many distractions.
- Poor discussion: The large strength of the class deters discussion that includes everyone.
- Declination in active learning: Active learning and class-participation by students and their engagement in the learning process is very important for deeper understanding of a subject. However, maintaining active engagement of students in a large class is difficult and demanding both for the instructors as well as the students.
- Student isolation and anonymity: With so many students of different socio-economic-academic backgrounds, students may feel as if they are surrounded by strangers and many prefer anonymity instead of chipping-in the discussion, doubt-clearing or even in a general question-answer session.
- Appropriate pace and lecture content selection: In a large class, information dissemination itself may not be properly carried out; hence, engaging them in thinking becomes even more difficult.
- Manageable and reliable assessment: Assessment must be such that it arouses the students' higher-order thinking capabilities without overburdening the instructors with too much paper checking.
- Feedback coordination and management: Timely feedback can save the course from being a disaster.

These and several other issues need to be sensitively addressed to promote a rewarding and fruitful teaching-learning experience in large classes. "*The main goals for instructors teaching large classes, apart from delivering the course knowledge, are to make the class seem smaller than it is, encourage students to participate more, and make themselves accessible to the students*" [7]. Many solutions to the numerous difficulties of teaching a large class have been reported in the literature.

A. Changing Passive Learning to Active Learning

For learning, instead of the size of the class, what should count is the quality of teaching-learning. Many problems, so encountered in large classes, can be reduced to manageable limits, if not erased altogether. In order to overcome the limitations of large classes the instructors and the students both need to be simultaneously active. Active teaching in large classes has been promoted through following approaches [10]-[13]:

- Instructor competency and enthusiasm: In addition to the knowledge and experience with the subject, the instructor's enthusiasm in assisting the students and helping in their learning process is very important.
- Organizational and teaching strategies: Proper communication of the subject matter is very difficult in a class size of, say, 100 or above. Hence, now using technology within the classroom has become a norm, not only in higher education but also at school level. This helps not only in delivering lecture using visual aids, but also encompasses using audience response system and communication [14].
- Assignments: Graded and ungraded assignments may be supplemented with impromptu questions, surveys and participatory activities [12].
- Personalizing teaching-learning space: The student should not feel isolated or anonymous within such large groups and this can be done by encouraging student-faculty interaction, discussions and debates, encouraging questions, and sometimes giving personalized feedback too [28].
- Encouraging more collaborative and cooperative learning environment: These not only involve learning

in cohesive groups but also being available for group discussions and giving feedback to the groups [18].

- Collaborative Teaching: This involves having the assistance of teaching assistants and/or presenting the course through team-teaching. This will not only reduce the cognitive burden on an individual instructor but also enrich the learning in the course.

B. *Moving towards Collaborative Teaching*

As an idiom goes "Two heads are better than one", many-a-times, two or even a small group of people working together will not only have more ideas but also implement these ideas in a better manner. Collaborative teaching involves collaboration by multiple teachers playing complementary roles [16]-[18]. It can also use a rotational model where collaborating teachers keep on changing their roles [19]. Collaborative teaching provides many pedagogical advantages over traditional teaching methodology. It helps in creating a dynamic and interactive learning environment [20].

The four predominant forms of collaborative teachings are supportive, parallel, complementary and team teaching [21]. In *supportive* form, the co-teacher(s) taking the supportive role provide one-to-one tutorial assistance when necessary, while the main teacher continues to lead the class. In *parallel* teaching, multiple teachers work with different groups of students in different subsections. It has eight variant – split classes, station teaching (learning centers), co-teachers rotate, each co-teacher teaching a different component of the lesson, cooperative group monitoring, experiment or lab monitoring, learning style focus, and supplementary instruction. In *complementary* teaching, the co-teacher does something to enhance the instruction through paraphrasing, model note taking, pre-teaching, etc. In the most sophisticated form of collaboration, *team* teaching, multiple teachers take responsibility for all of the students in the classroom with respect to planning the lesson as well as teaching and assessing the students. Instead of team teaching, we shall use the term *synergetic* teaching for this form of intensely collaborative teaching.

There are many models to handle team taught courses which can fall in any of the four predominant forms of collaborative teaching at school as well as university level.

1) *Collaborative Teaching at School Level*

In collaborative teaching at primary and secondary schools teachers have teamed up and integrated their approaches of teaching to make the teaching process more efficient and enjoyable for the students.

Work in [22] has implemented the concept of collaborative teaching in Taiwan's primary and secondary schools for the course of Mathematics. In this model, co-teachers shared experiences and were involved in co-generative dialogue with each other. A review [23] accessed the effectiveness of interdisciplinary collaborative teaching in enhancing student achievement at Northwest Regional Educational Lab at Portland. It identified various areas which are positively affected by collaborative teaching - self-concept, happiness with school, attitude toward teachers, interest in subject matter, sense of personal freedom, sense of influence on the school environment and self-reliance. Work in [24], [25] discussed an effective collaborative teaching using a special educator and a general educator to accommodate the needs of students with and without disabilities.

2) *Collaborative Teaching at University Level*

Problems of large classes are usually handled using parallel teaching by dividing classes in several sections. Each section is handled by individual instructor. All instructors collaborate together from course design to final evaluation and grading [21]. In literature, most cases of collaborative teaching at University level have followed supportive [18], [20], [26]-[28] and synergetic forms [19], [26], [27], [29]-[33]. Complimentary teaching is evident in combination with other three forms [27], [33].

Authors in [28] experimented with supportive form of collaborative teaching model employed at a regional university of Australia for a large undergraduate marketing course. One instructor focused on lecture delivery and the other on assisting and monitoring students. Instructors swapped roles depending on the lecture activity. In another model, role of co-teacher was that of a careful observer and an exemplary student [18], [20]. As an exemplary student, co-teacher actively participated in discussions to create high level debates in class.

Work in [29] showed synergetic form of collaborative teaching approach in interdisciplinary courses. Two instructors one from the Computer Science department and another from the Writing Program in the College of Humanities collaboratively taught senior software seminar course. An integrated framework with a structural paradigm was adopted in [31] wherein collaborative teaching was introduced as a language intervention in the course. Performance of students was evaluated before and after intervention. Course topics division based on individual preferences and lecture materials, was another model adopted in [32]. In "Rotational Model" discussed in [19], one instructor is always present every time and a series of instructors keep changing depending upon course topics that fall within their specialty. In another work [30], guest lecturers were used as part of collaborative teaching model to expose students' to a variety of topics from a different backgrounds and teaching styles.

Another study was done in [26] on challenges faced in collaborative teaching activities and its effectiveness which identified six types of collaborative teaching structures like "One teach other observe, One teach other drift, parallel teaching, station teaching, alternative teaching and team teaching". Work in [27] adopted two different Mentor-mentee models. In first model, during first half, mentor taught the class and mentee observed, in the second half, mentee taught the class and mentor was observing. In second model, mentor taught the class up until the first examination with mentee observing. Subsequently, class was taught by the mentor or the mentee.

C. *Evaluation of Collaborative Teaching Models*

Collaborative teaching approaches have been evaluated both from student as well as teachers perspective.

1) In Terms of Student Perspective

Collaborative teaching creates increased dialogue and participation of students in discussion of class. It leads to two or three level fair grading system for evaluation of students. Students have better understanding of the course and their connectivity with other related courses. Instructor's debate leads to understanding of different disciplines for students [19], [20]. Results from Stanford University [19] state that collaborative teaching increases student participation and improves student learning outcome. It also encourages students to have variety of perspective on a topic to make valuable contributions in class discussions. Collaborative teaching in interdisciplinary courses even enhances students' technical writing and communication skills with improvement in programming concepts [23], [29].

In case of physically challenged students, lowering the student-teacher ratio in co-taught classrooms offers more determined and individual instruction to students [24], [25].

Differences in lecturing style, quality of lecture contents, and the perceived lack of continuity and cohesiveness in lecture topics were negative aspects reported in collaborative teaching [30]. The critical success factor behind the team taught courses is the composition of a team [21], [28], [34] for better teaching and learning experience.

2) In Terms of Faculty Perspective

Teamwork enhances the professional competence of the teachers and helps them to analyze things from different viewpoints [21]. Team teachers become expert learner and learn new approaches from their colleagues [27], [34]. Instructors develop compatible teaching style, spend more time in planning and coordinating various activities, e.g., selection of course topics, grading systems, presentation and delivery, and agreement on distribution of the course load [32]. Collaborative teaching gives instructors the opportunity "to teach in a different way, and to learn in a different way". It allows instructors to improve their academic skills and develop new topics for research [19]. The compatibility of the co-teachers and the discrepancy between their approaches to teaching, their personal characteristics and effectiveness of collaborative teaching has overall effect on the team taught courses. The effective collaborative teaching in college can enhance the learning of new faculty [27], [33].

III. COLLABORATIVE TEACHING AT JIIT

The department of CSE & IT at JIIT has been using collaborative teaching in the form of multi-section parallel teaching and topic sharing in single section for the last several years. However, in the spring semester 2015, for the first time, after two weeks of the start of the semester, multiple teachers collaborated to conduct almost all lecture class of a few selected courses. The experiment was conducted in three different courses of B.Tech programmes. We have experimented in two out of seven sections of Data structure course with class strength of approximately 120 students each in the first year, Microprocessor and microcontrollers course with class strength of 240 students in the second year and Computer Games with class strength of 211 students in the final year. Eight teachers participated in this form of collaboration to teach approx. 700 students. The different collaboration styles of Supportive, Parallel, Complimentary and Synergetic teaching were applied in this collaborative teaching experiment. Number of lectures conducted in collaborative style in each section varied from 27 to 30. For each lecture, the collaborating teachers worked together before as well as after the class. It took around an hour for collaborative planning the lecture sequence and class activities and around 15 minutes after the class for review.

A few examples of four forms of collaborative teaching in these three different computer science courses are given below:

A. Supportive

- In Data structure course, one teacher explained the concept of stacks and other one supported by providing the applications of stack in various problems. The applications included checking parenthesis matching, expression conversion like infix to postfix, infix to prefix, postfix to prefix and, postfix expression evaluation, etc.
- In Microprocessor and microcontrollers course, one teacher gave practical demonstration of MASM I/O programming with examples. Based on this topic, problems were given to students. The other teachers interacted with students off the stage clearing their doubts and helped students in problem solving.
- In Microprocessor and microcontrollers course, 8086 addressing modes were presented by the main faculty. The supporting faculty intervened with questions that helped in clarifying the topic. Further, the topic was concluded by supporting faculty with mapping of logical address to physical address.
- In Microprocessor and microcontrollers course, the concept of Programmable Peripheral Interface (PPI) device 82C55 and its mode programming was taught by the main faculty, while supporting faculty provided real-life practical applications and demonstration of PPI modules with logic controllers to students.

This model was also applied for tasks such as system set-up and support, attendance record maintenance, maintaining the general class discipline and decorum

B. Parallel

- In Data structure course, the problems related to queues such as simulation of multiple queues and priority queues was given in class. The students were divided into two subsection and two teachers in parallel guided the subsections. The students in the different groups came up with different approaches for solving the same problem. Similarly, the Backtracking problems like Rat in a Maze and Eight Queens problems were discussed in parallel style of collaborative teaching.
- In Microprocessor and microcontrollers course, delay generation using 8051 instructions for particular crystal frequency problem was given to two subsections of

students. One teacher supported each subsection. The first group to arrive at the correct solution was declared as the winner.

- In Microprocessor and microcontrollers course, a simple problem of checking odd or even was given for different subsections with different logic like using LSB check, using shift or rotate instruction and division to check a remainder. One teacher supported each subsection. At the end of problem solving, it was shown that using division method to check odd or even is a bad approach, as it consumes many registers and complexity of problem also increases. Whereas using LSB check is a simpler approach as assembly language is well equipped for bit manipulations. This kind of comparative study helped the students to better understand and compare the programming concepts.
- In Computer games, the topic of testing and debugging required five lectures. For each of these lectures, mostly parallel and sometimes complementary and supportive teaching styles were adopted. While teaching in parallel mode, the class was divided into two subsections. Latter, multiple groups were formed for discussions which were assisted by both the instructors. At the start of the topic, testing and debugging methods were shown to the students. While one faculty demonstrated using the computer, the other faculty (on stage) explained the manner in which testing and debugging was needed to be implemented. After demonstration, both the instructors adopted complementary teaching style for enhancing the learning by encouraging more discussions amongst students.
- The topic of game optimization was discussed for over 3 classes and the content included theoretical concepts as well as the practical example of the memory and CPU usage while running the game. For this topic, parallel and synergetic lecturing styles were interleaved. While one instructor explained the generalized best practices for optimizations, the other was involved in showing how these may be implemented in the game modules to small groups of students. The students also pointed out the required optimization in the games that they usually play and also critiqued other students' games. Further, the CPU and memory-usage snapshots of some popular as well as student-developed games were shown and profiled in Unity game engine. The students could appreciate and pin-point their modules wherein major optimization was required. In total 5 games were profiled and optimized.
- The topic of game design pattern was conducted mostly as a hands-on experience in the class for making new game plays. For this, parallel teaching style was used as the class was divided into two sub-sections which were further divided to two groups. After explaining the design patterns in the class, the students were asked to modify the patterns to create new game plays. Each subsection was given a theme within which the two groups were to follow two different game design patterns and both the instructors moved in the class to see how students are making new game plays. Hence, many spin off game plays were developed in the class itself.

C. *Complementary*

- In Data structure course, one teacher explained the concept of Graphs and its representation. To enhance this explanation, the other faculty explained the same concept in a different perspective. Both instructors supported their discussion in terms of different practical application such as representing friend's network as graph, transport system as graph etc. This gave more insight to the students.
- In Microprocessor and microcontrollers course, first attempt to make students understand the operation of XLAT instruction is generally difficult. 8086 XLAT instruction was taught by one instructor. This was followed by a comparison with 8051 MOVC instruction (taught in an earlier class) by another faculty. This helped in developing a deeper and quicker understanding of it as they were already familiar with 8051.
- In Computer games, the topics like game development life cycles and game play design were taught in the complementary style as one instructor explained storyboarding while the other stressed on game play.
- In Computer games, 3D character animation was discussed for over 3 lectures, the complementary style of teaching was followed. The theoretical aspects including the 3D designing, transformations, inter-relationship with 2D and rendering pipeline were introduced by one instructor, and subtopics such as kinematics and inverse kinematics and their implementation including animation designing were explained by the other instructor. While one instructor was teaching or demonstrating, the other was involved in minor problem solving with small groups of students.

D. *Synergetic*

- In Computer games the topic of game development was discussed following the synergetic model. The discussions included Unity3D game engine and various best practices for the development after the designing stage. These lectures were delivered in synergetic mode as both the instructors took the stage, and explained and demonstrated the game in a step-by-step manner. Both instructors also explained different aspects of the development tools.
- Often, instead of "teaching" a topic, such as critiquing a game, and finding flaws within them, the instructors adopted a debate-rebuttal style which followed the synergetic format of teaching.

IV. RESULTS

The impact of this experiment in collaborative teaching has been analyzed through reflections by 8 participating teachers as well as feedback by students through informal discussions and a structured survey at the end of the semester.

A. *Student's Perspective*

Initial reaction from the students was that of bewilderment as they had never experienced such form of teaching before. Having two or more teachers teaching them simultaneously was not only exciting but also confusing at times. This required explanation on the part of instructors. As the semester progressed, the students also accepted this form of teaching to a large extent, if not whole heartedly. Discussions with students revealed that they felt benefited from the multiple perspectives of more than one teacher on the same topic. Discussions between the teachers and amongst the students themselves enriched the learning to a greater extent. It also improved the faculty accessibility, resulting in enhanced doubt clearing.

Further, at the end of the semester, a questionnaire was administered to get student's reaction to the collaborative teaching. The questionnaire asked them to compare the co-teaching class to typical non-co-taught class of approximately same student strength with respective to various parameters such as - their subject-specific and generic learning, problem-solving ability, soft skills, level of in-class and out-of-class learning, participation in collaborative activities and interaction with faculty. These questions were answered using 5 options. A large percentage of students reported a very positive feedback to the collaborative teaching style on various parameters. The results are shown in Table I.

From Table I, it can be inferred that, there was a greater appreciation of collaborative teaching in Computer games and Data structures. 92% of the students in Computer games and 71% in Data structure course felt an increase in the learning from the collaborative teaching. In all the three courses only a small fraction of students, 5%, 20% and 0% in Data structures, and Microprocessor and microcontroller, and Computer Games respectively felt that collaborative teaching had a negative impact on learning. The students found the integration of diverse learning from two different teachers useful. The benefits reported by students are as follows:

- More opportunities for clarification of doubts,
- Enhanced learning and understanding due to different approaches used for problem solving.
- If any part of the topic-content was not highlighted by one instructor, the other helped in identification of such minor lapses and rectified it.
- Classes were conducted even if a particular faculty was absent or busy as the others could easily take-over for that particular duration.
- Decreased monotony of classes as students interacted from two or more different instructors simultaneously.

However, the overall feedback showed an increase in active participation and enriched learning experience. The students also showed enthusiasm towards having more such collaborative teaching classes in future.

TABLE I. STUDENT FEEDBACK ON COLLABORATIVE TEACHING ON VARIOUS PARAMETERS (IN %)

Parameters	**Students (%) who selected the options in:** 1. Data Structures 2. [Microcontroller & Microprocessor] 3. (Computer Games)		
	Definitely Increased/ Increased	*Almost same*	*Definitely Decreased/ Decreased*
Subject specific technical learning	52 [31] (88)	45 [35] (14)	3 [35] (0)
Generic technical learning	45 [22] (74)	48 [58] (23)	7 [20] (3)
Generic Problem Solving learning	60 [11] (78)	33 [62] (19)	7 [27] (3)
Generic soft skills learning	48 [27] (72)	45 [47] (22)	5 [25] (6)
Level of student participation in class	52 [11] (73)	38 [53] (22)	10 [36] (5)
In-class student collaborative activities	50 [27] (72)	40 [40] (23)	10 [33] (5)
Students faculty interaction in & out of class	62 [36] (76)	32 [44] (20)	6 [20] (4)
Overall assessment of the co-teaching experience	**71 [31] (92)**	24 [49] (8)	**5 [20] (0)**

B. *Faculty Reaction*

Initially the collaborative teachers themselves were little uncomfortable, which might have contributed to the confusion with students. However, not only this gave an opportunity to build a rapport among them but also helped them in understanding a different point-of-view for a particular topic and gain more insight into it. Also, there was an increase in the learning activity experienced by the co-teachers that helped them to grow, reflect and deepen content understanding and improve its subsequent delivery, while also providing students with a variety of effective instructional methods.

The collaborative teaching model though has several advantages over single teacher taught courses, it also has many challenges and pitfalls that need to be taken care of during the design of the course and lecture session. In large classes, the form of interactivity has to be planned before, so that students are not distracted. Even the supporting teacher has to correlate to topic being taught and the terminology being used by the other faculty, so that the students are not confused with the use of dual terminology. The students sometimes faced problem in terms of switching of teacher. This may result in break of flow of delivering lecture by the instructors. Thus certain challenges that need more attention include pre-synchronization of the content delivery and smooth transition between instructors and topics.

Since the experiment was being performed for the first time, it was a great learning experience in terms of subject learning as well interpersonal understanding. Though, sometimes smooth and well-coordinated transition during lecture delivery was not always without initial discontinuities, the collaborative teachers could mutually assist, harmonize and enrich their teaching and learning.

V. CONCULSIONS AND FUTURE WORK

Despite of some initial hesitation shown by the collaborative teachers and the students, this experiment has turned out to be successful for large classes of the strength of 100 and above. From the survey it is inferred that students have felt greatly benefited from this collaborative teaching activity and want it to be repeated in other courses as well. As a future work, the department has planned to repeat this experiment in 7 different courses undergraduate as well as graduate level courses involving more than 25 faculty members and over 1,500 students in the coming fall semester.

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