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A novel game-based approach for teaching an engineering course: Implementation in Mechanical Vibration course

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Abstract

Profound and applicable understanding of most engineering courses has to be achieved by being exposed to different examples and solving a variety of problems. This process is inherently time consuming and difficult and can easily become boring.

The method presented in this paper offers a game-based approach to enhance students' learning. Students are divided into teams, competing with each other regularly based on an organized match-up schedule. At each match-up, points are awarded based on the performance on solving an assigned problem and explaining that to the rest of the students. A "Q and A" session follows each presentation for additional points. Certain measures are discussed to improve the process of assigning members for teams and contribution of every member to the overall results.

The rules are thoroughly explained and the motivations behind them are discussed. In addition, the faced challenges during the implementation are discussed and the adopted remedies are elaborated. The efficiency of the method has been verified by pre and post evaluations of students' learning assessment and students' feedback. The paper proposes a novel teaching method which successfully exploits the excitement and fun in playing games in order to improve the learning experience for students while improving their social skills such as teamwork and presentation skills. The method proposed is independent of the course contents and therefore can be applied to any other engineering course.

Introduction

Engaging Students in learning environment has been advocated by educators, researchers and policy makers for many years. Instructors from different disciplines practiced a variety of means to increase students' engagement in the classroom or out of the classroom. Active and cooperative learning, learning communities, service learning, problem-based learning and team projects are some instances of such efforts. In spite of all the support and emphasis on engaging students, it is not widely practiced in engineering courses. Engineering education community similar to other teaching and learning communities needs pedagogies of engagement that can help to develop a new generation of engineers who are resourceful, engaged workers and citizens that America now requires [1].

In this paper, considering the new generation of students' interests, a new engagement method for engineering courses has been suggested. This engagement pedagogy is a combination of two other engagement means: collaborative learning and game-based learning. The combination offers a new tool to achieve all benefits of collaborative and game-based learning.

The rules of the game are thoroughly explained and theoretical foundations of the proposed engagement method are discussed. The efficiency of the method is verified by implementing this method in an engineering course (Mechanical Vibration) and assessing students' performance and feedbacks. Challenges and benefits of implementing this method in classroom are discussed and the adopted remedies are elaborated.

Theoretical Foundation: Collaborative Learning

The theoretical foundation of collaborative learning stems from Vygotskian social development theory [2]. Basic themes of Vygotskian theory are:

- Social interactions play a fundamental role in the development of cognition.
- A peer could also be a more knowledgeable other – MKO (like: teacher, coach or older adult)
- Learning occurs in the zone of proximal development (the difference between what people can do alone and what they can do with assistance).

Students involved in collaborative learning with the same level of knowledge will benefit by co-constructing a new understanding of an unknown material through discussion with peers [3-5]. Students with different levels of knowledge will both benefit from collaborative learning. The more knowledgeable students get the opportunity to explain the material to the other members of the group. To do this, they need to organize their knowledge and offer that in a clear and understandable manner. Also, the help-seeker students can benefit from their peers explanation of material and discussion in group [6].

The studies mentioned above along with other researches conducted to uncover the benefits of collaborative learning [5-7] supports the old saying that "The best way to learn something is to teach it!" [8-10]

Despite all proven benefits (discussed above) and National Science Foundation (NSF) and education communities' support of collaborative learning, there is a lack of support from engineering education community for collaborative learning classrooms.

The inertia and hesitation from engineering education community toward collaborative learning could stem from a traditional engineering male-dominant environment. Research has shown that female students may have preference toward collaborative and supportive educational systems [11]. Therefore including collaborative classroom strategies not only has advantages for all engineering students but also contributes to recruit more female engineering students and faculty. The latter is of more importance when we observe statistics such as only 13.9% of the national tenured and tenure-track engineering professors are women [12] and only 23% of engineering students are female [13].

Theoretical Foundation: Game-based Learning

New generation of undergraduate students have grown up with games (mostly computer games). Computer gaming is one of the main reasons for students' poor performance in their courses and eventually leaving with no degrees from college [14]. Taking advantage of this interest of students and embodying games in engineering classrooms can provide educators with an effective teaching tool that motivates students in learning process. Game-based learning environment can draw students into virtual world that is similar to their familiar real environment. The key challenge to use games as a teaching tool is to engage students [15]. Creating the sense of challenge in players and opportunities to explore new information can play an important role in keeping them engaged and interested.

Although leisure games have been widely developed and increased interest, the use of game to support teaching especially for college level engineering students is still in its infancy.

Bringing Fantasy games to Engineering Education: Rules and Regulations

Fantasy sport is a game where participants act as a sport team manager. Participants enter a league made up of 10 or more members. They build their team of real individual players of a professional sport by drafting players or receiving randomly assigned players. Then they compete against each other based on actual performances of their players. According to Fantasy Sport Trade Association, 32 million people participated in some type of fantasy sport in US and Canada in 2010. This is 60% increase over last 4 years. Considering the popularity of this game between the college students a similar game-based learning activity has been developed with the purpose of enhancing students' learning.

In this game students are divided into teams of 3 members. The captain of each team is selected by the instructor to ensure that each team has a member with strong background. Then the rest of the team members are drafted by the captains. Every other week teams will be given one problem by instructor from the material covered in the class. The students are given sufficient time to solve the problem in their own time and discuss it among the other teammates. They also know that they should have enough dominance over the material to be able to explain the problem for the rest of the class and answer relevant conceptual questions. At regular intervals, the so called "Match-ups" will be held where teams play against each other.

Members of each team receive points based on their performance on solving the problem and explaining that to the other students. Each team has three major responsibilities:

1. Solve the assigned problem in their group and make sure every member of team understands the concept. In this step they can get direct feedback from instructor.
2. Present that problem in class and answer other students' questions.
3. Ask 3 questions from their opponent team and answer 3 of their questions.

The result of each "Match-up" is treated as a quiz grade and the winner gets the full grade (regardless of their actual points) even if they had lost points during the game and the other team gets points based on their performance. At the end of the semester the league champion gets a prize or extra credit.

Table 1: A sample of points for a match-up

		Team 1	Team 2
Solving the problem	(out of 20)	20	18
Presenting the problem	(out of 20)	15	20
Answer other students or instructor question	(out of 15)	15	10
Question 1 from opponent team	(out of 15)	15	0
Question 2 from opponent team	(out of 15)	10	15
Question 3 from opponent team	(out of 15)	15	15
Total points	(out of 100)	80	78

Table 1 shows how points are awarded in a sample game. In a regular academic season there are 16 weeks which can provide us with sufficient time to have 8 games. However, this number can vary in case of time restrictions or instructor's decision. Table 2 shows a game schedule with 6 teams in a 5 week league. Final standings of this sample league are shown in table 3. The rules explained here are presenting an ideal game and can be modified by instructors to fit their specific course. A case study of implementing this method is presented in following sections.

Table 2: Sample weekly match ups

Match up	Game 1	Result	Game 2	Result	Game 3	Result
Week 1	T1(85)–T2(80)	T1 (w)	T3(85)–T5(75)	T3 (w)	T4(80)–T6(80)	T4 & T6
Week 2	T1(75)–T3(80)	T3 (w)	T2(85)–T6(90)	T6 (w)	T4(70)–T5(80)	T5 (w)
Week 3	T1(80)–T4(80)	T1 & T4	T2(85)–T3(85)	T3 & T2	T5(85)–T6(90)	T6 (w)
Week 4	T1(75)–T5(85)	T5 (w)	T2(90)–T4(85)	T2 (w)	T3(85) – T6(100)	T6 (w)
Week 5	T1(80)–T6(95)	T6 (w)	T2(85)–T5(90)	T5 (w)	T3(85)–T4(90)	T4 (w)

Table 3: Sample league standings

Team	W-L-T	Pts For	Pts Against
Team 6*	4-0-1	455	415
Team 2	3-1-1	425	435
Team 5	3-2-0	415	405
Team 3	2-2-1	420	425
Team 4	1-2-2	405	415
Team 1	1-3-1	395	420

*: teams can choose a specific name

Fantasy Vibration: A Case Study

Implementation

The procedure explained above was practiced at Mechanical Vibration course at ME department. There were 15 students in the class who were organized in 5 groups of 3 students. Authors particularly chose the number of teammates to be 3 as in groups with two members, the dominant student will lead the team and in groups with more than 4 students not everyone gets the chance of speaking and some members will be inactive [16].

In order to make sure we have a captain in each team with strong background, students' performance in previous related courses such as Statics and Dynamics was observed in addition to their overall grade point average (GPA).

Following the organization of teams and team members, the game began based on the rules explained earlier. Because this activity was tried for the first time we could have 3 match ups. Several challenges were faced during the implementation of the proposed plans. We discuss the challenges in addition to the applied remedies to overcome them in the latter section. Subsequently, the efficiency of the method and its benefits have been investigated. Also, students' experience has been studied based on questionnaires and has been reported in the following sections.

Challenges and Remedies

One of the major challenges in implementing vibration fantasy was keeping students interested. When students are introduced to any unconventional learning method, they might show some resistance. The competitive spirit inherent in such a method can keep them motivated for the first rounds however the instructor has to be cautious that firstly the competing teams take the game seriously enough to remain motivated through the entire match-ups and secondly the noncompeting rest of the class maintains their interest and attention during others' match-ups. The important variable that affects how students perceive this learning activity is its impact on their final grade. Instructor can dedicate a reasonable percentage of the final for each competition and students' involvement in effective discussions. During the trial case discussed in this paper, the final grade was divided into 5 categories of 20% match-ups (instead of homework &quiz), 30%final exam and 25% each midterm (2 midterms in total).

In order to investigate the students' engagement in this method versus traditional homework and quiz system, the first round of homework and quiz has been given in the conventional format. When traditional method of homework was applied, only 68% of students were submitting homework assignments and the performance on a conventional quiz was below an expected average (5.1 out of 10). Same students were teamed up for the fantasy vibration following the first homework and quiz, and the match-ups were substituted for a quiz and homework grade. Interestingly, 100% of students began to turn in homework and more engagement was observed by all students. Students' attendance and performance has shown in table 4.

Table 4: Students' performance in fantasy vibration

	First Quiz	First homework	1st Match-up	2nd Match-up	3rd Match-up
Student attendance	100%	66%	100%	100%	100%
Student grade average	5.1 out of 10	56 out of 100	100 out of 100	83.3 out of 100	81 out of 100

Another issue that might concern the instructors to adopt this method is time management. In most of engineering courses, if not all, the materials need to be covered are a lot. Therefore, affording extra time to do any other activity seems very difficult or impossible. First, the nature of the proposed method is such that the number of class sessions devoted to the match ups can comply with the time the instructor has. It can vary from a single competition session to multiple league-like sessions. Also the time for each of these sessions can vary from 15 to 40 minutes for match ups and 30 to 75 minutes for discussing the problem in group.

In our case study, there were 3 competition sessions. These sessions were so organized that they played the role of a review session at the end of the main chapters of the course contents. Two midterm exams and the final exam were scheduled right after these match-ups. The first one took 75 minutes for group discussion and 40 minutes for presentation and competition. Our initial experience helped us improve our time management and for the second match-up group discussion was done by students out of official time devoted for lectures and we managed to spend 75 minutes for presentation and competition and Q and A session afterwards. Students' performance in the midterms following these two match-ups showed that they did better in the first exam than the second exam. This could be attributed to the fact that not all of the students participated in group discussion for the second time where they were asked to do it on their own. Therefore, for the third match-up we came up with a time different than our regular class time for team discussions and 100% of students attended this section and it was followed with another 75 minutes class session to complete the follow-up activities. Students' attendance and performance at each match up are presented in table 4. It is noted that as the instructor and the students gain more experience in doing the activity less time is devoted to the activity and consequently higher efficiency is achieved.

A delicate challenge in executing the suggested method is the reward system. Rewards are necessary to keep students engaged and interested. The well suited reward for this type of game activity is the grade. The proposed method is a learning-instructional activity and the assessment of students' performance in this activity is based on team performance not students' individual performance. Therefore in our case study there were 2 grade categories assigned to each group work and competition sessions. Students were asked to hand in the solution of the assigned problem individually after discussing in their team (treated as homework). The presentations and competition were assumed to be quizzes. 10% of the total grade was assigned to homework and 10% to quizzes (total of 20% to match-ups).

Learning and Teaching Benefits Experience in Fantasy Vibration

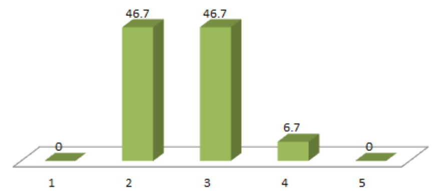
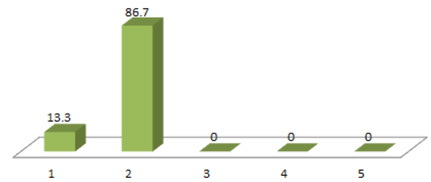
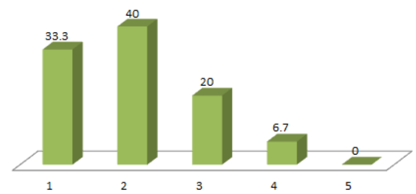
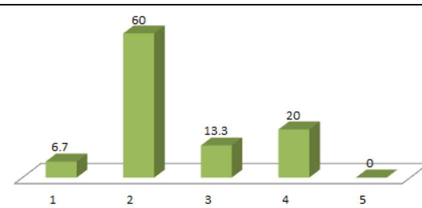
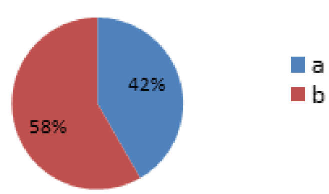
In this section we will discuss learning and teaching benefits of the proposed method from two different points of view: instructor and students. Based on the pilot program applied on a vibration course, as course instructors, we believe students enjoyed from a variety of learning benefits. These benefits are listed as follows:

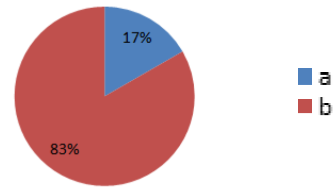
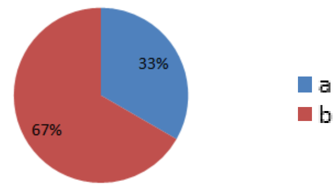
- Students' grades improved remarkably after the first game session. The first quiz average was 5.1 out of 10 while their midterm average was 91 out of 100. This improvement in grades could be a sign of students' better understanding of course material.
- Immediate feedback from instructor was provided to students when they were working on the assignment in their team. This timely feedback helped students to understand the concepts that they missed during the lecture time.
- The one on one discussion with instructor provided a friendly learning environment between students and instructor. This resulted in reducing the intrinsic tension of students not being comfortable to ask questions in class (mostly because students think the question would be senseless and that would affect instructor's judgment of their abilities and skills).
- The friendly environment was run through the students as well. Students were observed studying and preparing for competitions and exams within their team out of class time as well as helping each other to understand the concepts during the class time.
- In this activity students got the chance to practice and improve their presentation skills as well as their communication abilities.

Students' perception toward this learning activity was assessed through an anonymous questioner. This questioner designed based on Shell's SPOCK survey (Students Perception of Classroom Knowledge Building) [17]. The "collaborative learning" subscale of Shell's survey has been chosen for the assessment. A five-point Likert scale with 1 representing "Strongly Agree" and 5 representing "Strongly Disagree" were employed. Also students were asked whether they prefer the traditional approaches of individual homework and quiz or the new method presented in this paper. Details of the questions and students responses are summarized in table 5. Following are the observations from students' feedback and comments.

- 46.7% of students agreed that the group work keeps them interested while the same amount of students were undecided in this matter. This trend shows that we still need to improve this approach and add more reasonable and exciting modules to the activity.
- All of students (13.3% strongly agree and 86.7% agree) believe that performing this activity helped them to work together and understand the material. This major achievement is in complete agreement with underlying theories of collaborative and game base learning.
- More than 70% of students agreed that performing this activity helped them to get a better grade in the course, which is again an indicator of better learning and understanding the material.
- Although more than 66% of students would like to practice this type of group study in their other courses, 13.3% are not decided and 20% don't like to repeat this activity. The fact that majority of students prefer to repeat this approach in their other class doesn't mean that we have to forget about the rest of students. Polishing this method and coming up with a method that can satisfy a larger group of students is one of the major concerns and some suggestions are presented in future work section to address this problem.
- In general students favor new style of homework and quiz versus the traditional one. 83% of students prefer the new proposed homework assignments and 63% prefer the presentation and competition versus traditional individual quiz (shown in table 5).
- Students prefer to get feedback while they are solving problems in groups from instructor (58%) versus solving sample problems in class by instructor. However this doesn't mean that the group work problem solving should replace the need for solving sample problems by instructor before getting involved in group work.
- From students' comments: "Help readily available if needed", "One of the best feature of this group study was others explaining how to solve problems", "The group work aided is not only learning the material but also better communication ", "I understood the material better by my group members helping me".

Table 5: Students' feedback

Target of study	Question	Student response*
Collaborative learning	Group work keeps me more interested	
	My classmate & I work together to help each other to understand material	
	I believe I will get better grade by participating in group work	
	I would like to practice this type of group study in my other courses	
Students overall preference	I learn more effective and understand material better by:	
	a. Instructor solving examples in class (traditional method)	
	b. Instructor giving comments and answer questions while we are solving problems in group (Group assignment done in class)	

	a.	Traditional homework assignment (solving problems on your own)	
	b.	Solving problems within your group in class	
	a.	Solving problem in class individually (Traditional quiz)	
	b.	Presenting the problem discussed previously in your group to other students and answer questions.	

*1.Strongly agree, 2. Agree, 3. Undecided, 4. Disagree & 5. Strongly disagree

Conclusion

Engineering courses have been notorious for their challenging concepts, time consuming homework and difficult exams. The traditional strategies of teaching and learning (such as, lectures, labs, homework, etc.) play a prominent role in developing such a myth. On the other hand engineers of our time need to be equipped with collaboration and communication skills and abilities to practice engineering in the 21st century. Therefore to overcome these challenges, as engineering education community, we need to offer new teaching and learning pedagogies to engage students, keep them interested while equipping them with the hard core knowledge and social skills which are engaged with engineering professions.

In this paper a new teaching and learning activity which is a combination of two major engaging strategies (collaborative learning and game-based learning) is proposed. The theoretical foundations of this method are discussed. The proposed method was implemented in a vibration course (mechanical engineering department). The challenges we encountered during the implementation period (e.g. time management, keeping students interested and rewarding system) and suggested remedies are discussed. Students' feedback is collected using a questioner designed specifically to measure students' level of engagement and interest. Based on the lessons learned from this pilot study the benefits of this method can be summarized as following:

- Improving students' problem solving skills individually and in a team;
- Providing fast feedback by instructor;
- Advancing students' active communication and discussion skills;
- Creating friendly and collaborative environment in class;
- Improving students' grades;
- Engaging students in teaching and learning process.

In future, we will include new modules to the activity to keep students engaged through the entire semester. For example, we can extend the league competition to different sections of the same course. We will also study how students' engagement is affected by students' age (freshman to senior) and gender. The other future direction of this method is to make it applicable for large classes (with more than 40 students).

Implementing this activity and studying challenges, benefits and students' feedback we believe this method can provide us with an effective and flexible tool to educate new generation of engineers.

The resources (e.g. Excel files to calculate points and keep track of league standings, sample assignments for vibration course, questioner to collect students' feedback, …) are available for instructors interested in practicing this method in their classroom.

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Appendix A: Sample Group assignment for vibration course*

a. Group 1

Calculate the natural frequency and damping ratio for the system in Figure 1. Assume that no friction acts on the rollers. Is the system overdamped, critically damped or underdamped?

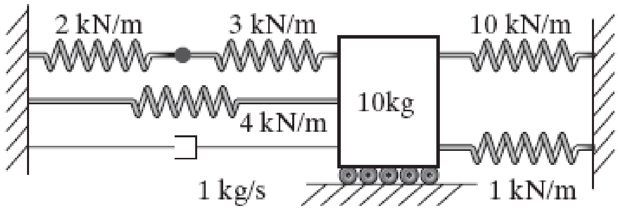

Figure 1

b. Group 2

A 2-kg mass connected to a spring of stiffness 10^3 N/m has a dry sliding friction force (*Fc*) of 3 N. As the mass oscillates, its amplitude decreases 20 cm. How long does this take? Hint: Use the graph in figure 2.

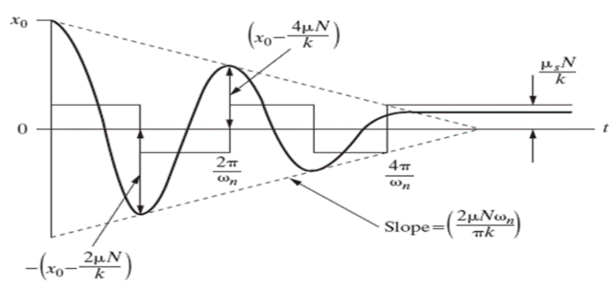

Figure 2

c. Group 3

A spring-mass system is driven from rest harmonically such that the displacement response exhibits a beat of period of 0.2 π s. The period of oscillation is measured to be 0.02π s. Calculate the natural frequency and the driving frequency of the system.

d. Group 4

Consider the system of figure 4 with m = 5 kg and k = 9 × 103 N/m with a friction force of magnitude 6 N. If the initial amplitude is 4 cm, determine the amplitude one cycle later as well as the damped frequency. (25 Points)

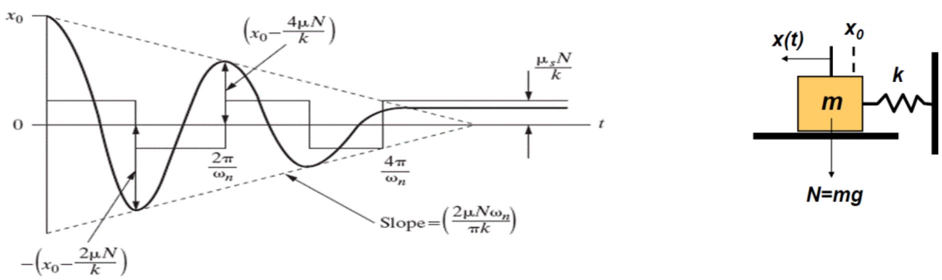

Figure 2

e. Group 5

Consider the system in Figure 3, write the equation of motion and calculate the response assuming a) that the system is initially at rest, and b) that the system has an initial displacement of 0.05 m.

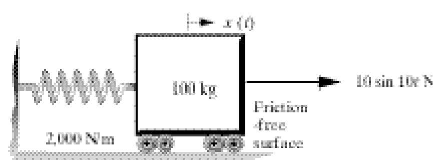

Figure 3

*: Sample problems are adopted from "Engineering vibration", 3rd edition, Daniel J. Inman, Prentice Hall.

Appendix B: Group Study Survey

1. I learn more effective and understand material better by:
    a. Instructor solving examples in class (traditional method)
    b. Instructor giving comments and answer questions while we are solving problems in group (Group assignment done in class)

    a. Traditional homework assignment (solving problems on your own)
    b. Solving problems within your group in class.

    a. Solving problem in class individually (Traditional quiz)
    b. Presenting the problem discussed previously in your group to other students and answer questions.

2. Group work keeps me more interested.

    1. Strongly agree 2. Agree 3. Undecided 4. Disagree 5. Strongly disagree

3. My classmate & I work together to help each other to understand material.

    1. Strongly agree 2. Agree 3. Undecided 4. Disagree 5. Strongly disagree

4. I believe I will get better grade by participating in group work.

    1. Strongly agree 2. Agree 3. Undecided 4. Disagree 5. Strongly disagree

5. I would like to practice this type of group study in my other courses.

    1. Strongly agree 2. Agree 3. Undecided 4. Disagree 5. Strongly disagree

6. What were the best features of this group study?

7. What were the least successful features of this group study?

8. Further comments that might be helpful.