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A Flat Learning Environment - Learning To Solve Ill-Structured Problems

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Abstract

Our approach is to capitalize on the research findings on linkages between higher-order thinking and peer learning to create and evaluate a flat learning environment, entitled Teaching to Learn (TeatoL). Within TeatoL students are introduced to a "flatter" instructional environment; all participants have dual roles as students and instructors who are embedded in a collaborative environment where all learn collectively from each other's experiences, even the instructor.

TeatoL blends computer and mobile smart devices for peer-to-peer interactions to enhance critical thinking and competencies essential for students to solve ill-structured problems. The main objective is to understand, develop, implement and evaluate a flat learning environment utilizing technologies. The focus is on peer learning mode, where students are instructors to share their experience and then learn from fellow student instructors. In this paper, we present our initial results and findings from implementation at the University of Oklahoma. We close the paper with observations from our initial implementations on peer-learning as a network.

Introduction

Enabled by technological advances, increased globalization[1] has put engineering education and the profession at a challenging crossroad[2,3]. On one hand, the impact of rapid technological innovations on modern societies has increased; hence, better living standards afford increasing equity in education. Despite this fact, students' graduation percentages in U.S. engineering schools have been decreasing over the years[4-5] with the exception of top academic institutions[6-10]. The competitiveness of the U.S., which is linked to our standard of living, is dependent on our ability to educate a large number of sufficiently innovative engineers[11-14].

Several high-level reports[3,7,15-20] have been published recommending learning skills and ability to formulate and solve open-ended problems as critical to prepare the next generation of engineers. U.S. needs a well-trained workforce in science, technology, engineering, and mathematics that is also equipped with these critical skills. With the research unfolded here, we *explore the effectiveness of peer learning through mobile smart devices to address the need for inculcating engineering competencies related to open-ended problem solving.* We adopt our definition for peer learning from Baud, Cohen, and Sampson[21] as "the use of teaching and learning strategies in which students learn with and from each other without the immediate intervention of a teacher" (pp. 413-414). In this paper, we present our initial implementation of a technology-based flat learning environment to enhance open-ended problem solving skill development. We also present initial observations from initial implementations. We believe that technology based learning environments can play a key role in on-line learning environments and needs to be investigated further.

Motivation and Rationale

Open-ended problems significantly differ from the well-defined text-book problems, and require critical thinking and problem solving experience. Applying engineering principles to solve open-ended problems is a very challenging task for most students. One of the reasons for this is that much of engineering education continues in a "teacher-centered" mode that emphasizes content mastery and support reliance on standard text-book problems solved in well-defined step-by-step processes. However, most common traditional teaching approaches fail to nurture the development of higher order cognitive skills needed by today's engineers. These methods often fall short to move students from acquiring to applying knowledge and creating solutions[22-23].

The medium of instruction needs to be modified to play a significant role in engaging students to learn the complex engineering concepts in a useful format. Instruction modes should allow students to grow as critical thinkers with proficiency in learning, and in creative problem solving for increasingly complex and uncertain engineering environments. Active learning strategies can promote higher order thinking[11-13], hence project-, or problem-, or case studies-based learning, have been developed and applied in engineering courses.

Observation is critical in learning; starting from childhood, humans learn via observation, especially from peers[24-26]. Learning in peer-led, problem-based learning settings[27-28] can be a highly effective means to encourage student engagement in more profound learning[29-31]. Meaningful learning emphasizes active, constructive, intentional, authentic and cooperative learning[32]. Peer learning encourages meaningful learning that involves students teaching and learning from each other as well as sharing of ideas, knowledge and experiences, and emphasizes interdependent as opposed to independent learning[33]. Peer learning is a 'two-way reciprocal learning activity' [34, pg.3] as students do not hold power over each other by virtue of their position or responsibilities; hence, it is a learning environment that is "flat".

In peer-learning environments the technology (e.g., computers, mobile phones, tables, etc.) participants possess presents a potential to facilitate learning. 63% of students own internet-capable hand-held devices[35]. 43% of all college students used mobile gear to get on the Internet every day in 2010, compared with 10% of students in 2008[36]. Hence, peer learning strategies and applications for hand-held devices can enhance the learning experience of a large number of students. A recent survey of students[37] indicates that students learn best when professors balance the use of instructional technology with human interaction.

It is not always clear, however, how the principles of peer learning transfer to technology-enhanced learning environments where transfer of discussion, communication and articulation of ideas can pose a challenge. Virtual learning communities are knowledge based social entities where knowledge is the key to their success[38]. An important activity in a virtual learning community is the collaboration. Seamless linking of learning collaborators is essential to create a learning environment for mobile devices[39].

An important factor in peer learning is providing feedback to others. Bransford et al.[40] suggested that the quality of feedback can be improved by allowing students to work collaboratively, and that the feedback is particularly useful when students can use it to revise their work and thinking on a project. Reviewing is an evaluative process of detecting problems, diagnosing them, and

generating solutions to improve the problems. In review process, students may develop important strategies for problem solving and revising[41]. Peer review provides student reviewers with frequent opportunities to practice problem-solving strategies important for improvement. Peer review activities may provide the reviewer with concrete and solid experiences on how to improve problem solving by connecting diagnosed problems with solution types[42]. Participating in review encourages student reviewers to reflect upon their own skills while examining peer work[43-44].

Some of the emerging technologies are also enabling new ways of peer review. For example, online videos changed the way we create, view and share videos online today. With smartphones like the iPhone, and phones running on Android and Windows operating systems, it is effortless to create, share and evaluate videos using the basic features phones offer. Videos can be an effective media to quickly generate content and provide feedback to peers.

Overview of Teaching to Learn: The System

As part of our work, we intend to test the potential of technology-enhanced peer-learning using TeatoL. Using TeatoL students create videos and instructions, based on their experience and process for solving open-ended problems, with the mindset of teaching the process and sharing the learning experience with others. An overall flow of activities in TeatoL is shown in Figure 1.

Students are teachers uploading their approach to solving the problems to the system. The posts are viewed using their computers or mobile devices. The students then critically evaluate and critique posted approaches, submitted by other students, to improve their open-ended problem solving technique. The students have the opportunity to use comments from others to critically evaluate and modify and improve their approaches. These steps can be recursive focusing on the entire or part of the process. The final step of the process involves students writing a short report on their modified problem solving process and then applying the process to a new open-ended problem in a similar topic.

Initial Implementation for Sheet Metal Forming

In order to understand the effectiveness of technology enabled peer learning as well as the potential implementation difficulties, we have developed course materials during Fall 2012 semester for sheet metal processing. The prepared contents were then included in the Sophomore level Design and Manufacturing Processes (AME 2303) during Spring 2013. There were 45 students in the AME2303 section. The students were from Mechanical and Industrial Engineering majors. The lecture on sheet metal forming was about 35 minutes in length (Phase 0). Then, an additional 30 minutes were spent on IRB and an explanation of the other phases of the peer-learning activities.

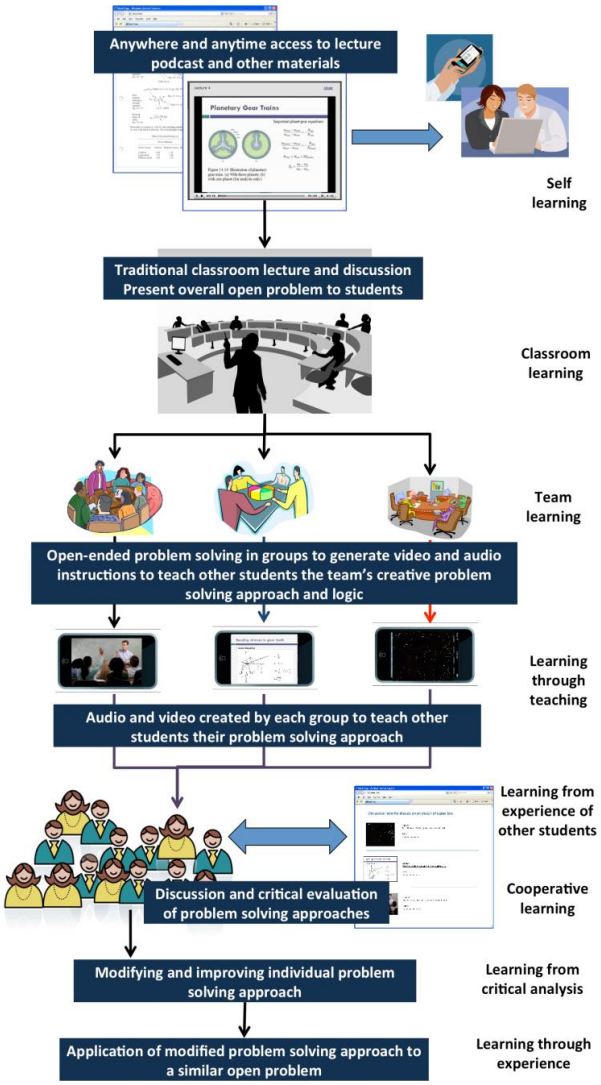

Figure 1. Steps and Activities in *TeatoL* Environment Along with Target Mode for Learning

Procedure

Phase 0: Lecture and Web-based content

Fundamental concepts are made available to students through web-based content (self-learning). The lecture and content presented in class covered content on different topics of sheet-metal forming process and equipments (Figure 2). We would like to note that during the lecture, the content made available to students did not include information on the steps that need to be taken to design a component for sheet metal forming processing. This was done intentionally to ensure that the process of designing a component for sheet metal forming is developed through peer-to-peer learning without input from the instructor. The sheet metal forming design problem given to students is shown in Figure 3.

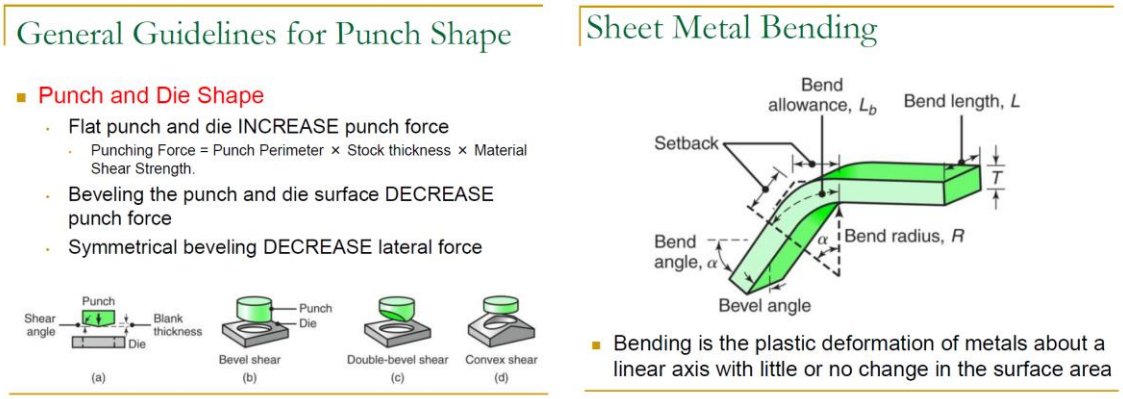

Figure 2: Sample Slides on Sheet Metal Forming

Phase I: Solving Open-Ended Sheet Metal Forming Design Problem as a Group
As a team the students were tasked to make a 2-4 minute video that highlights:

- Design steps that they have taken
- Assuming the part (Figure 3) is fabricated by a sheet metal worker rather than being completed in an automated way, what steps they would recommend to manufacture, using sheet metal forming, the above part from raw material to finished product while keeping cost and lead time as low as possible?
- Explain sheet metal forming rules/guidelines that have been used
- Discuss any significant features or concerns to the sheet metal processes that they have used
- Show calculations that they have made
- Changes that they have made to the design along with justifications
- Students were asked to prescribe a suitable intermediate annealing procedure for the material used, including the necessary details of time, temperature, cooling conditions, and so on. Would some form of protective atmosphere be required? If so, what would they recommend?
- Noting its features and that the sheet is bent in two different directions, students were asked to comment on relevant manufacturing considerations. Include factors such as anisotropy of the cold-rolled sheet, its surface texture, the bend directions, and the nature of the sheared edges.
- The sheet metal forming steps recommended by your team

When making the video, students were instructed to keep in mind that it will be used for others to understand: (i) the suggested manufacturing process by their team, and (ii) why as a team they suggested these steps. Once the team has created a video to their satisfaction, the teams uploaded the video in D2L dropbox. The teaching assistant for the class then made the video available to other teams in the class for review, comments, and discussions.

AME 2303
Sheet Metal Forming
Bracket Design Problem

As a manufacturing engineer your team has been tasked to finalize the design of the bracket. Your team has been provided with an initial design of the bracket and it has been decided that the component will be manufactured using sheet metal forming techniques. The initial design only specifies the overall dimension of the bracket shown in Figure 1 (all units are in inches). There are some minor flexibilities for the features of the can be moved around on the bracket to ensure manufacturibility of the component with high quality.

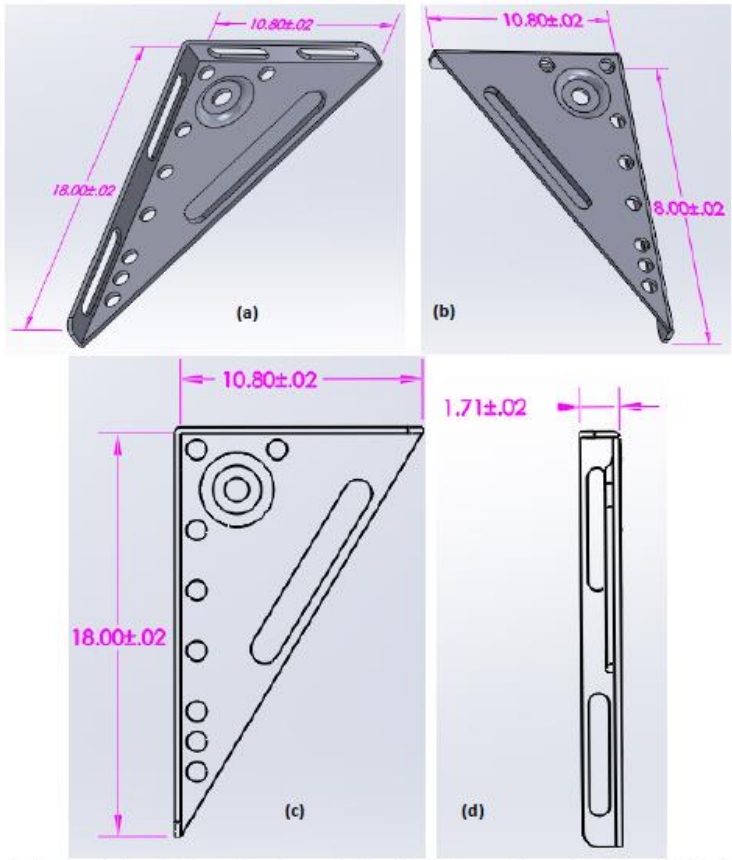

Figure 1: Isometric view of the top (a), Isometric view of the bottom (b), top view (c), and side view (d) of the bracket with dimensions (Note: All units are in inches)

Figure 3: Bracket Design Problem

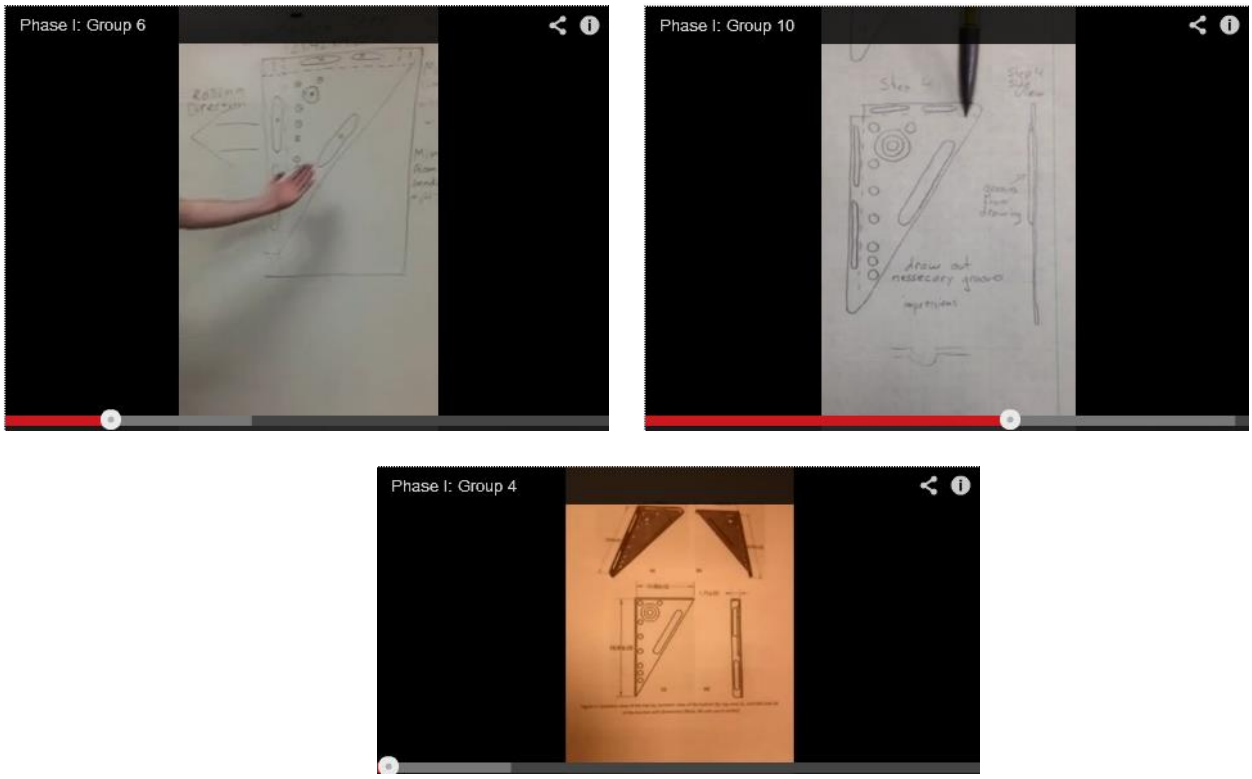

Figure 4: Sample Videos Posted by Groups

Phase II: Review, Comments, and Discussions of Solutions Proposed by Other Groups
Students were instructed to individually watch all videos created by different groups as solutions to the problem that was given to class, and then provide comments in the following manner:

1. Overall comment on the process and solution taken by the group (the video that you are watching).
   a. Comment on the steps and modifications that you think align with your team's process–were these steps justified in a similar way?
   b. Comment on the steps and modifications that you do not think align with your team's process – do you agree with their justifications?
2. Suggest changes for the solution that students are watching.

Phase III: Revisiting Solution and Sheet Metal Forming Design Process
Students were instructed to turn in an individual report with the following:

1. Student's proposed final design - with sketches (students can use the provided drawing and mark the changes on it or provide hand sketches.)
2. The step by step process to manufacture the bracket, along with justifications for the steps.

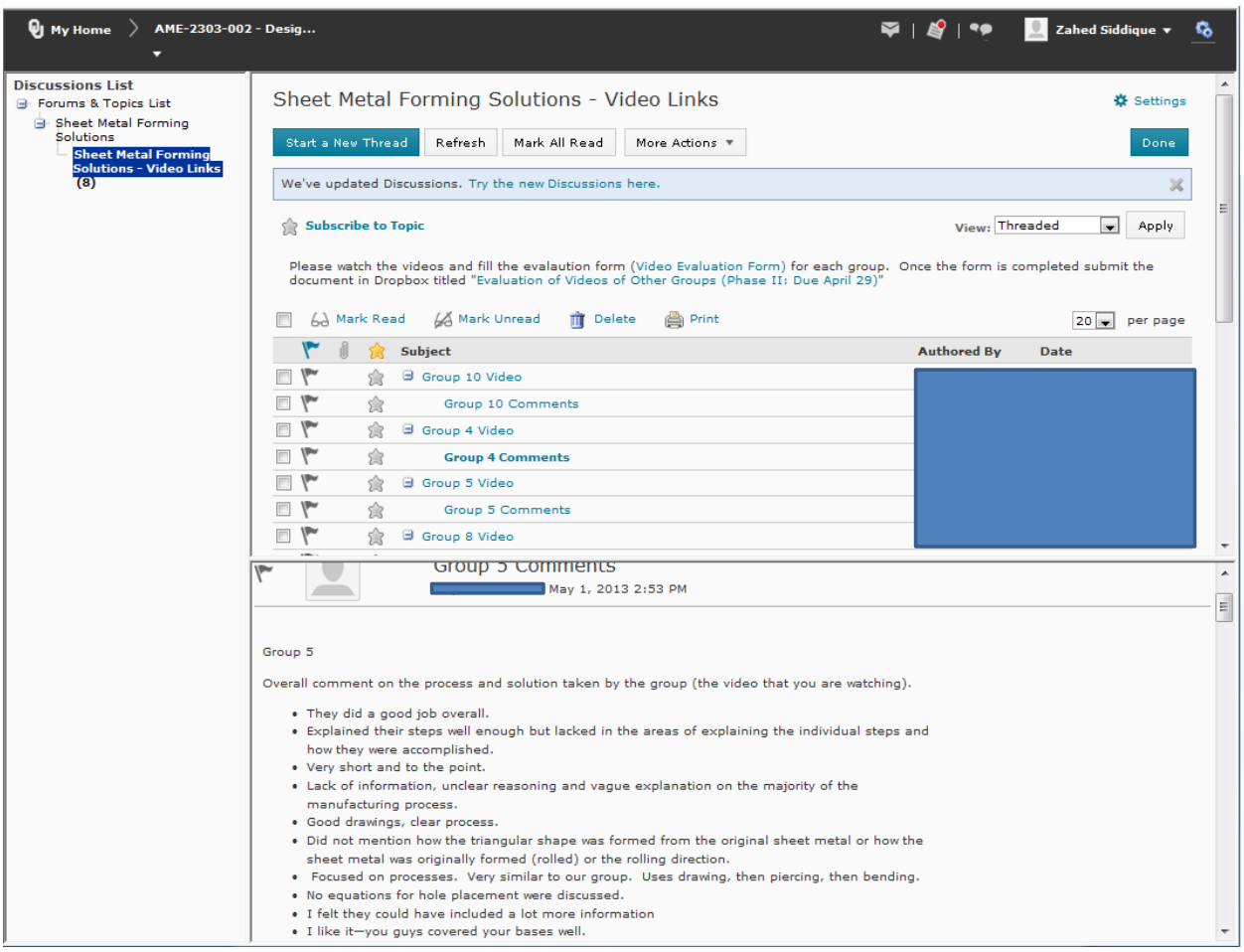

Figure 5: Student Comments and Evaluation of Solutions Proposed by Other Groups

Knowledge Gains Assessment

Fairly early on during our assessment plan and instrument preparation process, we have noticed that isolating the impact of technology enabled peer-learning across teams from individual learning and peer-learning within the team would be difficult. In an effort to isolate knowledge gains from these different modes of learning, we have designed a two-tier assessment plan. First (Phase I), we assess the individual learning from the eLecture materials as applied to solve the assigned open-ended problem, and assess the team performance after student videos (Phase II), talking about their solution, were uploaded. Finally (Phase III), we reassess the gains of individual students from their submission. In order to determine the connectivity and interactions among the students in the flat learning environment, we also categorized the comments provided by the students during Phase II. These comments were categorized into two: (1) being in-depth comments in terms of content, and (2) superficial (example: "Good approach").

The evaluation in all three phases was divided into several categories related to topics in sheet metal forming. These topics were: Dies, Punch, Blanking, Errors, Annealing, Piercing, Anisotropy, Hole Size, Hole Position, Material, Logical Flow, Long Slots, Bending and Drawing. During Phase II, an overall assessment on comments was also assigned. An

evaluation scale from 1-6 (with 0 assigned when the teams did not mention the topic) was used based on Bloom's Revised Taxonomy[46] (1-Remember; 2-Understand; 3-Apply; 4-Analyze; 5-Evaluate; 6-Create) to evaluate Phase I and Phase III. To get an overall grade, the grades from each category were aggregated.

Data Analysis

During the three phases of the experiment not all students participated. To get a better understanding of learning gains from the flat learning environment, we decided to compare score of students who participated in all three phases of the experiments. There were 29 students who participated in all phases.

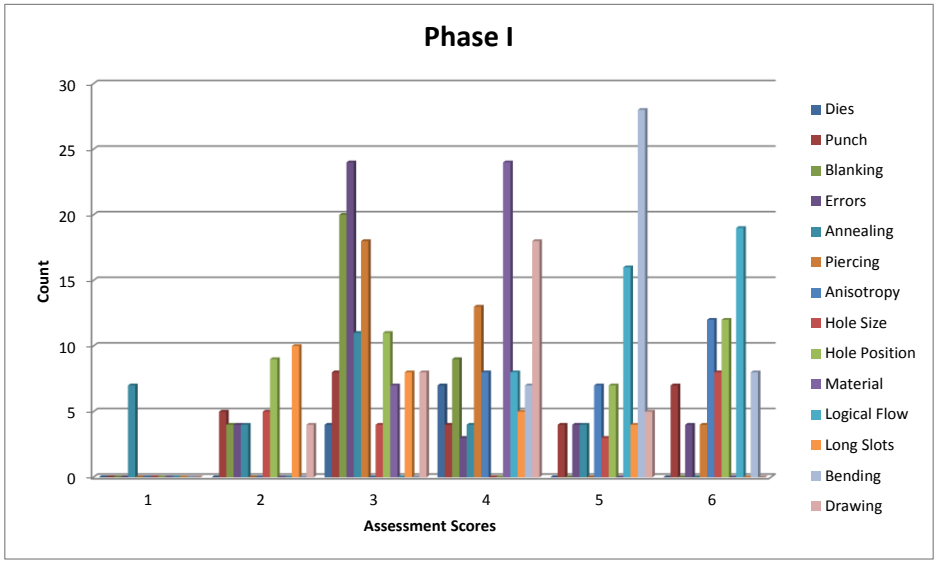

Figure 6: Phase I distribution of Student Learning

Distribution of grades on these students during Phase I (group video) are shown in Figure 6, which shows that in most sheet metal forming topics that student comprehension (assessment scores are based on 1-6) were evenly distributed. Distribution of the grades during Phase III (Individual) is shown in Figure 7. It can be seen that more students have shifted to a higher level of comprehension at this phase. A comparison of means for the overall scores, using t-test, indicates that there is a significant difference in means at the 95% confidence interval.

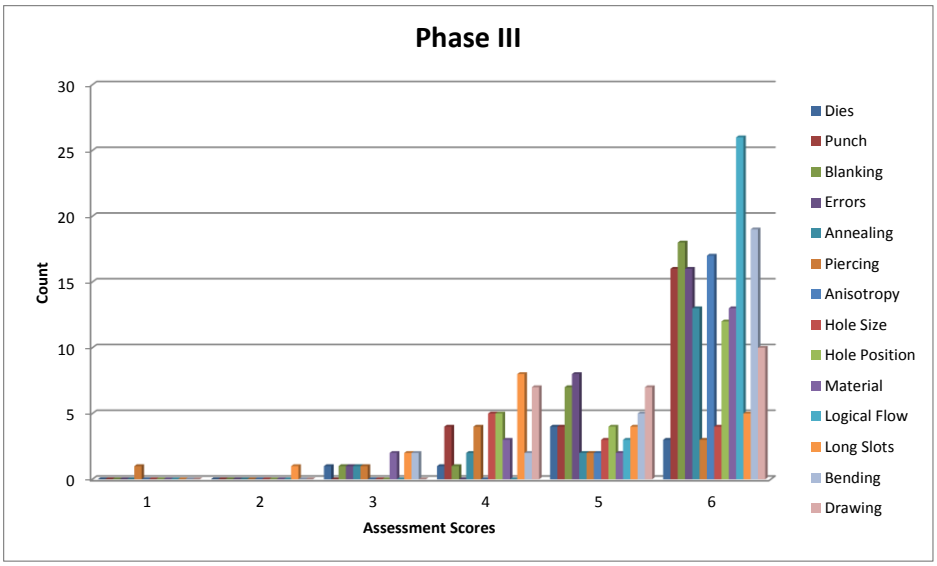

Figure 7: Phase III distribution of Student Learning

Table 1: t-Test: Paired Two Sample for Means

	Phase I	*Phase II*
Mean	41.79	53.07
Variance	116.24	202.35
Observations	29	29
Pearson Correlation	-0.075	
df	28	
t Stat	-3.29	
P(T<=t) one-tail	0.0014	
t Critical one-tail	1.70	
P(T<=t) two-tail	0.0027	
t Critical two-tail	2.048	

Discussion

There were no-interactions with students and the instructor during the completion of Phase I to Phase III; hence, the learning gains were a result from sharing of the: (i) problem solving approach of peers, and (ii) evaluating and providing comments to others based on their presented approaches. During Phase II the students formed a community to exchange information on sheet metal forming. Analyzing the social network provides important information regarding the student network that was formed using technology. In this paper, we have looked at the comments from an overall perspective, rather than individual topics on sheet metal forming. We also used directed edges to designate the flow of information in the flat environment; accordingly, the flat learning environment is a network of directed graphs. Degree centrality for a network has one of two forms[45]. High in-degree centrality indicates that students (nodes) who received a great deal of information from other students; we characterized such students as

prominent students. High out-degree centrality indicates students, who have provided more information to other (students) in the network. So actors with high out-degree centrality can be characterized as "influential teachers" in the network. The in- and out-degree centrality for the students in AME 2303 are shown in Figure 8. The sizes of the nodes indicate higher degree of centrality, the network graphs also indicate that students overall exchanged a substantial amount of comments and information among themselves.

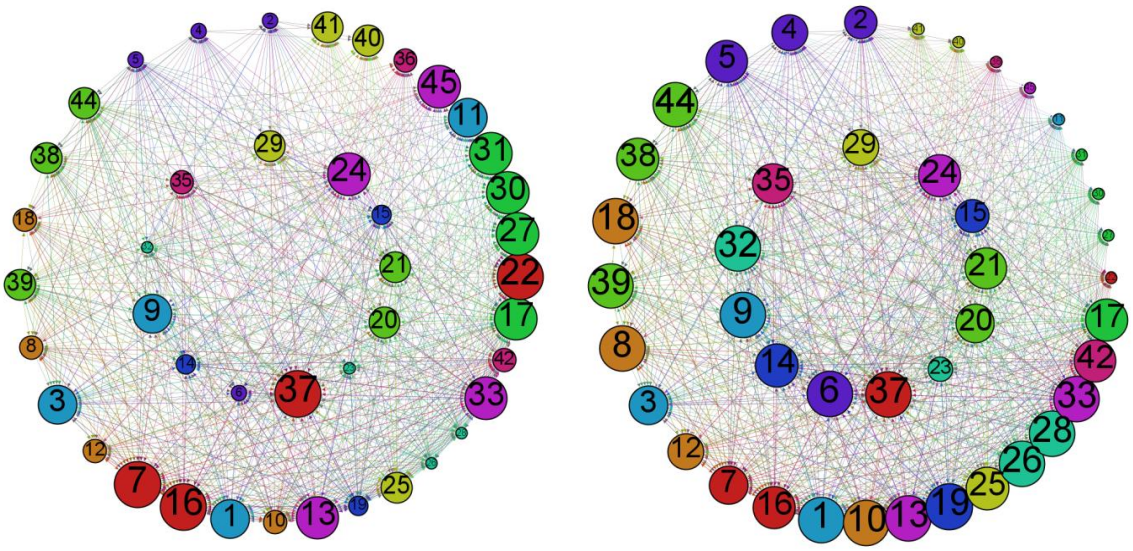

Figure 8: (a) In-degree (b) Out-degree Centrality in AME 2303 TeatoL

In this paper, we presented our initial findings for TeatoL to provide a flat learning environment to improve competencies to solve open-ended problems of our students. The main objective is to understand, develop, implement and evaluate a peer learning environment utilizing technologies and devices. The focus of TeatoL is on peer learning mode, where students are instructors to share their experience and then learn from fellow student instructors. Besides eMaterials (eBooks and eLectures), TeaTol incorporates collaborative tools, which would allow students to create and share content and feedback anytime anywhere. Students are introduced to a "flatter" instructional environment where they will learn from the experiences of other students to enhance their own learning and to enhance their problem solving competency and critical thinking. In this environment, all participants have dual roles as students and instructors who are embedded in a collaborative environment where all learn collectively from each other's experiences, even the instructor. Our initial findings indicate that flat learning environments can help students in learning to solve ill-structured problems.

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