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This paper will describe a synopsis of the development and application of a survey instrument to assess team skills and professional development outcomes of Team-Based Learning (TBL) in a human factors course. TBL is an advancing teaching pedagogy that shifts instruction from a traditional lecture-based teaching paradigm to a structured learning sequence that includes individual student preparation outside of class followed by active, in-class problem solving exercises completed by student learning teams. As an evolving teaching method, TBL appears to be producing new empirical learning outcomes in areas that have only preliminarily been explored. Traditionally, the effectiveness of TBL has been assessed through grades and numeric measures of performance; however, TBL was designed to both enhance learning as well as team collaboration and critical thinking skills. Thus there a need for a validated measurement instrument emerged to assess the development of team skills in TBL classes. The newly developed survey instrument is designed to assess three overarching factors within the TBL framework: 1) attitudes and beliefs about learning; 2) motivation to learn; and 3) professional development. A pilot survey was created and administered in the summer of 2013 to 25 undergraduate students at a large Mid-Western university and was tested for internal consistency. To further improve the quality of the survey, two focus groups were also conducted. In the fall of 2013 the revised survey was administered to 182 undergraduate students and in the spring of 2014 to 197 undergraduate students. Based on encouraging results, the survey was used to assess the learning outcome gains in a graduate level human factors course. Preliminary results for this sample showed modest gains in critical thinking and external motivation. The survey has the potential to provide instructors a mechanism to measure student learning gains in TBL educational settings.

INTRODUCTION

Education in Human Factors, as multi-disciplinary profession spans a wide range of domains, challenges educators to develop innovative classroom techniques to engage, and effectively educate a wide range of students. Beyond content learning, there is an increasing emphasis on student-centered learning, innovative pedagogy, workplace preparation, enhanced student satisfaction, student sharing of diverse ideas and perspectives, and the cultivation of lifelong learning. Team-based learning (TBL) is a teaching pedagogy on the forefront of these objectives by shifting instruction from a traditional lecture-based teaching paradigm to a structured learning sequence that includes individual student preparation outside of class followed by active, in-class problem-solving exercises completed by student-learning teams. In a TBL course, students take personal responsibility for assimilating topical information and knowledge and, in doing so, acquire lifelong learning skills which by design can be generalizable across other classroom related and/or professional activities. Studies report better or equivalent learning outcomes as compared with more traditional teaching formats and, anecdotally find improved student attitudes toward learning (Dinan, 2002; Hazel et al., 2013; Herreid, 2002; McInerney & Fink, 2003). Experientially, students have consistently reported that TBL teaching practices cultivate a more enjoyable learning environment.

TBL is an instructional strategy that emphasizes small group interactions in permanent teams (Michelson & Sweet, 2008). Other methods of student group learning have different emphasis. For instance, collaborative learning generally includes any collaborative activity within an educational context (e.g. Dillenbourg, 1999), learning communities create small cohorts of students who take courses together (e.g. Price, 2005), and project-based learning focuses on authentic problems to engage students (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). In TBL, the use of teams is coupled with a focus on guided application of course concepts. In traditional lecture-based approaches, the majority of class time is spent in content transmission; application of course content is usually done outside of class (e.g., homework, projects). With TBL, content transmission happens primarily outside of class (e.g., flipped classroom), and self-managed teams apply the concepts through in-class group assignments with support from the instructor. Students are held accountable for the quality of both their individual and group work (Michelson & Sweet, 2008), with the expectation that students develop critical thinking skills and demonstrate mastery over course concepts.

Much of students' experiences with group work in traditional classroom-based instruction is through short-term group activities and group projects. Students generally report negative attitudes and do not prefer to work in groups (Epsey, 2010). TBL is specifically designed to address these shortcomings by establishing permanent teams in order to foster the development of collaboration, group cohesion, and trust among team members (Epsey, 2010), often referred to as "team skills". In addition to the learning outcomes, TBL

requires a high level of student engagement in the course and with their teams.

The level of engagement in TBL courses cultivates the development of skills and behaviors that are valued by employers in the professional workplace. More specifically, at the national level in higher education, professional skills for engineering students have been identified in several ways in the Accreditation Board for Engineering and Technology (ABET) Engineering Criteria (ABET, 2013). For example, ABET engineering student outcomes, listed in bold font below, have been referred to as professional skills (Shuman, Besterfield, & McGourty, 2005)

(a) an ability to apply knowledge of mathematics, science, and engineering

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) **an ability to function on multidisciplinary teams**

(e) an ability to identify, formulate, and solve engineering problems

(f) **an understanding of professional and ethical responsibility**

(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(i) a recognition of the need for, and an ability to engage in lifelong learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Typically instruction in professional topics at the university level primarily occurs in first-year design and senior-year capstone courses (McHale, Lattuca, Terenzini, & Yin, 2010). TBL offers the opportunity to embed continuing instruction throughout the curriculum, leading to more consistent development of professional and team skills in the context of the core engineering courses (Lamm, Dorneich, & Rover, 2015).

As an emerging teaching method, TBL appears to be producing new "soft skills" learning outcomes in areas that have only preliminarily been explored (Parmelee, DeStephen, & Borges, 2009). Traditionally the effectiveness of TBL has been assessed through grades and numeric measures of performance (Eppler & Harju, 1997); however, TBL was designed to both enhance learning as well as team skills. Thus as part of an ongoing project (Bickelhaupt, Dorius, Bender, Bestler, Caisse, Dorneich, et. al.), a survey instrument has been developed to assess three overarching factors within the TBL framework: 1) attitudes and beliefs about learning; 2) motivation to learn; and 3) professional development (Bickelhaupt, Preast, Artz, Bender, Jacobs, Lamm, Orgler, & Smiley-Oyen, Working Paper).

The developed survey instrument to quantitatively measure student team skill development has multiple potential benefits (Bickelhaupt, Preast, Artz, Bender, Jacobs, Lamm, et al., Working Paper).

1. Provide a valid and reliable measure upon which to make data-driven decision regarding TBL course improvement,
2. Provide a mechanism to assess students development of team skills, which historically has not been included in student grades or assessments,
3. The ability to collect longitudinal data on beliefs, motivation, and professional development of student learning, and
4. Provide a mechanism to assess, and ultimately improve, student professional development before they enter the professional workforce.

Three iterations of the TBL survey were tested in 19 TBL classrooms from Fall 2012 to Spring 2014 (Bickelhaupt, Preast, Artz, Bender, Jacobs, Lamm, et al., Working Paper). The data were initially tested for internal consistency of the questions in order to develop the most parsimonious, reliable, and valid survey instrument possible (Bickelhaupt, Preast, Artz, Bender, Jacobs, Lamm, Orgler, & Smiley-Oyen, A., Working Paper). Encouraged by preliminary results, Exploratory and Confirmatory Factor Analysis later followed which demonstrated robust results ($\alpha = 0.82 – 0.90$) fitting the data exceptionally well (R^2 range from 0.84 to 0.95 across the five measures (Bickelhaupt & Dorius, working paper).

In this paper, the classroom that will be focused on was a graduate level class entitled *Human Factors in Product Development*. It was completely redeveloped in the TBL format and so provided an opportunity to test the survey instrument. A pre- and post-class survey was conducted to allow assessment of any learning gains in team and professional development skills.

The next section briefly describes the TBL implementation of *Human Factors in Product Development.* The subsequent section will summarize the survey instrument development process. Full publication of the survey development can be found in Bickelhaupt, Preast, Artz, Bender, Jacobs, Lamm, et al. (Working Paper). Results include analysis of the of the survey, as well as the preliminary results from the human factors course.

IMPLEMENTATION OF TEAM-BASED LEARNING IN A HUMAN FACTORS COURSE

Human Factors in Product Design (IE 576) is a course offered to graduate students and undergraduate senior who are in excellent academic standing. It was re-developed in the TBL format for the Spring 2014 semester.

On the first day of class 14 students were assigned to one of three teams each with four to five students. Team were arranged in order to maximize diversity. Students were assigned to teams by the instructors based on factors including

level of education (undergraduate/graduate), background (engineering/design/ human-computer interaction) and previous recommended courses (having taken them or not). At least one student in each category was assigned to each team. Team assignments were permanent for the duration of the course, in order to allow for the development of team cohesion. The students in the course were expected to perform weekly assigned readings (usually 3 to 5 selected research articles) and to be prepared to discuss these articles. The class met for one 3-hour session per week. At the beginning of every week's class the students were given individual quizzes on the previous weeks reading assignments. Students were given as long as needed (typically 10 minutes) to complete the quiz. Following this the students would assemble into their teams and be given the same quiz and answer/discuss questions as a team. The team would be given approximately 10 minutes to do this before the class would open up to general discussion. At this time the instructors (Dr. Dorneich and Dr. Stone) would review the quiz with the class and discuss the papers in general.

Following this the instructors would give a short related lecture having to do with specific techniques and strategies related to product design. These lectures were then immediately followed by application exercises that would be performed by the teams. During these exercises the instructors would move from group to group giving both advice and feedback as needed/requested. The design of the in-class application exercises followed the TBL "four S" rules (Michaelson & Sweet, 2008) to ensure individual student accountability and discussion within teams and between teams. These rules are:

1. *Significant problem*: teams should work on a problem that illustrates the usefulness of the course concepts in the discipline. These problems are often called application exercises by TBL instructors.
2. *Same problem*: teams should work on the same problem or question.
3. *Specific choice*: teams should be required to make a specific choice and defend that choice using course concepts.
4. *Simultaneous repor*t: teams should be required to report their answers simultaneously. This forces teams to commit to an answer and motivates them to be accountable for their decision since they will have to publicly defend it in class.

In addition to these weekly activities the teams were given three distinctive out of class projects. These projects centered around (1) product evaluation, (2) product redesign and (3) new product conceptualization and redesign. These projects were conducted over 5 week periods each and required the groups to work together and to meet externally with the course instructors. The students groups relied heavily on their various individual skills and ultimately began to cross train one another. At the end of each project the instructors would hold a session in which teams would present their project outcomes. These sessions involved not only the instructor's evaluation but that of their team through peer evaluations. In this way the students continued learn as a team and from the perspective of the designer, the client, and the team.

SURVEY INSTRUMENT

Areas of assessment

The survey development is summarized here. See Bickelhaupt, Preast, Artz, Bender, Jacobs, Lamm, et al., (Working Paper) for a complete description of the development of the survey. For a comprehensive account of the measure development for the survey, see Bickelhaupt & Dorius (working paper).

The survey items were developed over three iterations. The pilot survey contained 44 quantitative items and 2 open-ended questions across the six constructs. Many of the survey questions were based on publically available survey questions that supported the goals of this TBL survey. The second iteration of the survey (the one used in *Human Factors in Product Design*) had 41 questions and two open-ended questions. Table 1 describes the basis for the six subscale constructs within the three factors. Participants rating were assessed via a 5-point Likert Scale (ref). The scale for Group/Peer Learning, Individual Learning, Self-Efficacy and Internal Motivation ranged from (1 Not at All True of Me) to (5 Very True of Me). Questions assessing External Motivation and Critical Thinking Skills scale ranged from (1 Strongly Disagree) to (5 Strongly Agree); (Bickelhaupt, Preast, Artz, Bender, Jacobs, Lamm, et al., Working Paper).

Table 1. Basis for the survey factor constructs (Bickelhaupt, Preast, Artz, Bender, Jacobs, Lamm, et al., Working Paper).

Factor	Construct	Basis
Attitudes and Beliefs about Learning	Group/ Peer Learning	Help-seeking behavior (Pintrich, 1991) Team impact on quality of learning (Parmelee et al., 2009) Distractors, value of group work, and working with peers (Levine et al., 2004)
	Individual Learning,	Control beliefs about learning, metacognitive self-regulation (Pintrich, 1991)
	Self-efficacy	Self-efficacy for learning and performance (Pintrich, 1991) Self-confidence (Keller, 1987)
Motivation to Learn	Internal Motivation	Time and study environment (Pintrich, 1991)
	External Motivation	Satisfaction with peer evaluation (Parmelee et al., 2009) Group interaction (Watson, Michaelsen, & Sharp, 1991)
Professional Development	Critical Thinking Skills	Critical thinking and metacognitive self-regulation (Pintrich, 1991) Team impact on clinical reasoning ability (Parmelee et al., 2009) Working with peers (Levine et al., 2004).

METHOD

Objective

This survey was tested over the course of two semesters as part of the university faculty learning community TBL

project. In the current study, the objective was to assess learning gains in team skills and attitudes in a TBL human factors course. The human factors students were given both a pre-survey at the beginning of the semester, and a post-survey at the end of the semester. The surveys were delivered electronically. For further survey validation, only the post-test surveys were used.

This section will summarize the survey validation study conducted during Fall 2013. The section will also present the evaluation of TBL in the Human Factors in Product Development class in Spring 2014.

Participants

For the present study the survey was administered to 25 undergraduate students in an Industrial Engineering course at a large Midwestern land-grant university in the Spring of 2014. The survey was electronically administered at the beginning and end of the Fall 2013 semester. Nine participants (5 female, 4 male) completed the pre-survey at the beginning of the semester, and eight students (4 female, 4 male) partook in the post-survey. All but one student were graduate students.

Procedure

The survey was announced in class, where students were informed that participation was completely voluntary. An email went out to all students with an electronic link to the survey. Electronic consent was required to participate. Students were at least 18 years of age. All identifying information was removed following the creation of an anonymous ID to link the pre and post-tests.. The survey was administered in the Spring of 2014 in the Human Factors course. No compensation or extra credit was given for participation.

Measures and Data Analysis

The instrument consisted of 40 items (36 quantitative and 2 open-ended questions). The survey produced strong internal consistency in all five measures aggregated across all university participants (N = 197). The following Cronbach Alphas (Cronbach, 1951) demonstrate this reliability:1) Beliefs about Group and Peer Learning ($\alpha = 0.84$); 2) Beliefs about Individual Learning ($\alpha = 0.82$); 3) Beliefs about Self-Efficacy ($\alpha = 0.85$); 4) External Motivation to Learning ($\alpha = 0.90$); and 5) Critical Thinking Skills ($\alpha = 0.85$). The measures were based on a 5 point Likert scale with 5 being the best (Bickelhaupt & Dorius, working paper).

In relation to the Human Factors Course study, dataata from the questions in each construct were also aggregated to create a single score for that construct. Comparisons of means between the pre- and post-tests were conducted.

RESULTS

Figure 1 depicts the means and standard error of the survey results before (pre-survey) and after (post-survey) in the TBL Human Factors course study. The data was analyzed in aggregate, because the anonymous collected of data did not allow us to link each student's pre- and post-survey. None of the differences between pre- and post-survey averages for each constructs showed statistical significance, given the small sample size for this study. However, some notable trends did emerge. There was in increase in external motivation and critical thinking, two of the emphasis of the course. Group / peer learning remained constant, while individual leaning decreased. Self-efficacy stayed constant.

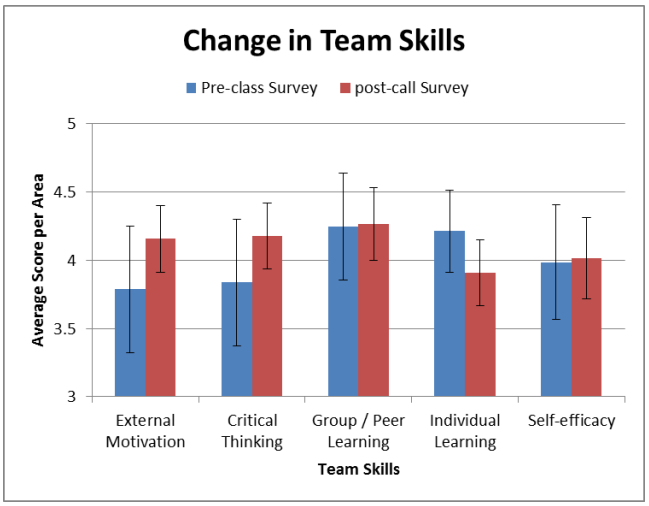

Figure 1. Comparison of TBL skills before and after the Human factors course.

Anecdotally students provided comments related to the TBL approach and their learning. Regarding individual learning, one student commented *"There's a lot of material covered, but the goal is to learn and use what you can to make your projects better. Referencing the lectures within projects has [sic] really seemed to work better for my overall retention of course material.* With respect to group learning, one student commented, *"Team-based study is a good way to enhance the team performance and improve ourselves. I like that way very much"*. Finally, students reflected on team skills such as being open to other perspectives; for instance, "*Do not judge your teammates' idea [sic] immediately, whether it works or not can be identified in the next step of project.*"

DISCUSSION AND CONCLUSION

Results from the validation TBL Human Factors course study provided empirical confirmation that the survey can assess the team and professional development aspects of TBL. Assessment and validation work on the survey development continues. With larger sample sizes to date (N = 1100), further statistical analyses are being conducted (i.e., factor analyses) to further develop a scientifically robust and valid survey instrument.

Once the survey is publically released (July 2015 anticipated), it will provide instructors a mechanism to measure the less tangible student learning gains that have only previously been anecdotally observed in team-based learning (TBL) settings. Instructors will be able to use the survey to develop a deeper understanding of how engage students fully in the TBL experience. Beyond the content learning,

instructors will be able to measure learning gains and growth in areas such as motivation for lifelong learning, professional and workplace preparation, critical thinking and problem-solving ability, and motivation to prepare for class.

As an example, the survey was used in a graduate level human factors course. Modest gains were observed, despite the low number of students in the sample, and the graduate student participants who had extensive experience working in teams. Gains could be expected to be greater in the undergraduate population, where team skills and professional development skills are less developed. Future work could use this survey across different years of undergraduate education to understand at what point in the undergraduate curriculum TBL will have the most impact.

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