Flipped Biomedical Engineering Classroom using Pencasts and Muddiest Point Web-enabled Tools

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Abstract

Studies have shown that student-centered instruction can be more effective than teacher-centered. Here, we investigate student persistence and attitude regarding several student-centered strategies in a one-hour per week statistics and design of experiment course for upper-division biomedical engineering (BME) undergraduates. More specifically, we ask “What is the effect of the flipped classroom, pencasts (online lectures), cyber-based muddiest point (unclear concept) collection, and group-based activities on student attitude and persistence?”

The organization of classes is as follows: students watch pencasts outside of class, submit the muddiest and most interesting points online, engage in a review of the muddiest/most unclear points in class, and then apply the lecture material in- and out-of-class using group activities.

Two surveys were administered anonymously to discern student value and attitude regarding these strategies: 1) the validated Student Value Survey on Muddiest Points (SVM) which focuses on interest and usefulness as well as cost (emotion, time, effort) related to muddiest point collection and 2) a new survey called the BME Student-centered Strategies (BSS) Survey regarding the flipped classroom, pencasts, muddiest points, and group activities.

Survey analyses on the pilot data showed that the BSS was a valid and reliable survey. Preliminary analysis showed positive student attitude with respect to value, interest, and cost. Overall, both the persistence and survey data support this unique instructional paradigm as an effective pedagogy for teaching and learning in the flipped classroom.

Introduction

Research has shown that student-centered instruction can be more effective than teacher-centered instruction. In this study, we investigate persistence as well as student value and attitude of several strategies in a student-centered biomedical engineering statistics and design of experiments course for junior-level undergraduates. Here, we ask “What is the effect of the flipped classroom, pencasts, cyber-based muddiest point (unclear concept) collection, and group-based activities on student attitude and persistence?” The following are student engagement strategies explored in this study: the flipped classroom, web-enabled online lectures called pencasts, cyber-based muddiest point collection, and group-based activities.

In the flipped classroom, the lecture is delivered outside of the classroom, typically in the form of an online video. Many studies have investigated the effectiveness of the flipped classroom. More specifically, Mason, et al. found that the flipped classroom allowed instructors to deliver more content and showed similar or improved student achievement in comparison to the traditional engineering classroom. Further, Wilson found that the flipped classroom was effective in terms of attitude and performance in the statistics setting.

To facilitate the flipped classroom, many forms of the online lecture have been introduced including those produced with screencasting software and Photoshop posted on YouTube,
animated PowerPoint slides, and the emerging pencast. Here, we focus on the pencast. More specifically, pencasts are created using a smart pen, capturing both handwriting and voice and then distributed easily as a small, audio PDF. Pencasts in this course are typically fifteen minutes long and contain information typically written on white boards during lectures.

An additional student-centered engagement strategy is cyber-based muddiest point collection. Muddiest points are student-generated unclear concepts first introduced in 1988 by Frederick Mosteller. Mosteller asked students three questions: 1) What was the most important point in lecture? 2) What was the muddiest? and 3) What would you like to hear more about? Muddiest points have been classically solicited via paper and pencil and addressed in class using handouts or incorporating into the beginning of the next class lecture. Recently, muddiest points have been collected online using Concept Warehouse available through Oregon State University. In Concept Warehouse, students electronically submit both the muddiest and most interesting point of the lecture and the data is automatically output in tabular form, with an intensity scale of 0-5 and a word cloud with word size proportional to word frequency. This allows instructors to easily pinpoint the muddiest and most interesting concepts.

Finally, group-based activities such as in-class activities and projects have been found to be an effective student-centered engagement strategy. Here, students work with team members to complete short-term or long-term assignments or projects. In this study, we will explore both short-term assignments in the form of class problem sets involving statistical software and long-term design projects focusing on design of experiment and statistical analysis of previously untested hypotheses.

Overall the organization of classes is as follows: students watch pencasts, submit the muddiest and most interesting points online, engage in a review of the muddiest points in class, and then apply the lecture material in-class using group activities. Moreover, this study was conducted in a course comprised of roughly equal numbers of males and female at the junior level. All 91 students were biomedical engineering majors. In this study, we hypothesize that the aforementioned student-centered strategies (the flipped classroom, muddiest point exercise, pencasts, and group activities) are effective in the biomedical engineering statistics classroom.

**Methods**

**Surveys**

Two surveys were administered anonymously to discern student value and attitude regarding engagement strategies midway through the semester and at the end of the semester: 1) the validated Student Value Survey on Muddiest Points (SVM) created by Carberry, et al. which focuses on interest and utility value as well as cost related to muddiest point collection (4-point scale) and 2) a new survey called the BME Student-centered Strategies (BSS) Survey regarding the flipped classroom, pencasts, cyber-enabled muddiest points, and group activities (5-point scale with 3-neutral). Please see Supplement A for the BSS.

Both surveys were assessed for reliability and validity using pilot study data. Here, reliability is defined as the degree to which an assessment tool produces consistent results and validity is
defined as how well a test measures what it is intended to measure. Reliability is assessed using the Cronbach’s alpha and validity is assessed using factor analyses to ensure questions measuring the same latent (hidden) variable group together.

**Statistical Analysis for Student Value Survey on Muddiest Points**

Mann-Whitney tests for non-parametric data were used to investigate differences in rating means at the midway point and end of the semester using the entire data sets ($n_{mid}=52$ and $n_{final}=47$). Wilcoxon tests for non-parametric data were used to investigate differences in rating means at the midway point and end of the semester using paired data (i.e., data from students that participated in both the mid and final surveys, matched by anonymous identifier; $n_{paired}=23$). P-values less than 0.05 were considered significant.

**Statistical Analysis for BME Student-centered Strategies (BSS) Survey**

Mann-Whitney tests for non-parametric data were used to investigate differences in rating means at the midway point and end of the semester using the entire data sets ($n_{mid}=39$ and $n_{final}=36$). Wilcoxon tests for non-parametric data were used to investigate differences in rating means at the midway point and end of the semester using paired data (i.e., data from students that participated in both the mid and final surveys, matched by anonymous identifier; $n_{paired}=18$). P-values less than 0.05 were considered significant.

It is important to note that because student attitude, persistence, and achievement were not monitored when this course was taught in a traditional manner by other instructors, we are unable to make retrospective comparisons between student-centered and teacher-centered instruction in this biomedical engineering statistics course.

**Persistence Analysis**

To complement the student attitude data, persistence in this flipped, student-centered statistics course was determined by comparing the number of students enrolled in the course on the 21st day, a university standard, to the number of students taking the final exam.

**Results**

**Survey Design**

Both the SVM and BSS survey yielded reliable and valid instruments according to a pilot study. Briefly, the SVM was piloted in three different material sciences courses using muddiest points. Results of this pilot study have been reported by Carberry, et al.\(^{10}\) To assess reliability and validity of the BSS Survey, the data from the first administration (mid-semester data) were used as pilot data. The Cronbach’s alpha for the BSS survey was 0.964 indicating excellent internal consistency. A confirmatory factor analysis yielded coefficients greater than 0.7 indicating that questions intended to address the same latent variable (flipped classroom, muddiest points, design project, class activities, and pencasts) did so. Coefficients from the factor analysis using pilot data may be found in Supplement B.
Investigation of reliability and validity using post-semester data yielded a Cronbach’s alpha of 0.797 indicating good internal consistency in the post-semester survey. Factor analysis using the post-semester data showed appropriate grouping of the muddiest point and flip classroom questions. Modification of question wording will be explored to ensure mid-way and post-semester administrations have analogous validity in terms of other question groupings.

**Student Value Survey on Muddiest Points Analysis**

Although, students did not feel strongly that the muddiest point exercise motivated them to do well in the course (50% at midway point - M, and 58% at the end of the semester-E), SVM results indicate that students felt the muddiest point exercise effectively increased engagement (62% M, 69% E), helped them better understand their own learning (63% M, 73% E), and increased responsibility for their learning (62% M, 69% E). Also, students felt the muddiest point exercise did not take too much effort (85% M, 79% E), make them feel anxious or frustrated (88% M, 87% E), and did not require too much time (92% M, 87% E). Lastly, students felt that the material learned in the course will be of value after graduation (96% M, 96% E), will be useful in their careers (94% M, 94% E), and helped them see real-world relevance of the material (94% M, 96% E). These results are summarized below in Table 1.

<table>
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<th><strong>INTEREST/ATTAINMENT VALUE</strong></th>
<th><strong>Agree</strong></th>
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<tr>
<td>motivated me to do well in the course</td>
<td>50% (M), 58% (E)</td>
</tr>
<tr>
<td>was an effective way to increase engagement</td>
<td>62% (M), 69% (E)</td>
</tr>
<tr>
<td>helped me better understand my own learning</td>
<td>63% (M), 73% (E)</td>
</tr>
<tr>
<td>increased my level of responsibility</td>
<td>62% (M), 69% (E)</td>
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<table>
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<th><strong>UTILITY VALUE</strong></th>
<th><strong>Agree</strong></th>
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<tbody>
<tr>
<td>will be of value after graduation</td>
<td>96% (M), 96% (E)</td>
</tr>
<tr>
<td>was useful in career and/or graduate school goals</td>
<td>94% (M), 94% (E)</td>
</tr>
<tr>
<td>helped me see relevance of stats to the real world</td>
<td>94% (M), 96% (E)</td>
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</table>

<table>
<thead>
<tr>
<th><strong>COST</strong></th>
<th><strong>Disagree</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>required too much effort</td>
<td>85% (M), 79% (E)</td>
</tr>
<tr>
<td>made me frustrated and anxious</td>
<td>88% (M), 87% (E)</td>
</tr>
<tr>
<td>required too much time</td>
<td>92% (M), 87% (E)</td>
</tr>
</tbody>
</table>

**Table 1: Summary of Mid-semester and End-of-semester Results from the Student Value Survey on Muddiest Points.** In general, students felt that the muddiest point exercise was interesting, valuable, and did not cost too much in terms of effort, emotion, and time. (M = mid-semester survey results and E = end-of-semester survey results)

To investigate changes in student attitude with regards to interest, value, and cost over the semester, the mean ratings were compared between the mid-semester data and the final data using all the data given during both administrations (n_{mid}=52 and n_{final}=47) as well as focusing on paired data (only those results coming from students answering during both administrations;
paired = 23). Both analyses yielded the same results. The only significant change between the mid-semester and end-of-semester results was in the following question “helped me see relevance of statistics to the real world” where there was a modest increase in agreement that muddiest points helped the student understand the relevance of statistics to the real world (p-value for unpaired/all data = 0.02 and p-value for only paired data = 0.002).

**BME Student-centered Strategies (BSS) Survey Analysis**

Results from the BSS survey showed favorable responses with regards to all interventions at both the mid-semester and end-of-semester administrations. The following analysis will be centered on all data collected at both administrations (n_{mid} = 39 and n_{final} = 36) due to low endpoint number in the paired analysis; however, paired results are graphically displayed in Figures 1B, 2B, 3B, 4B, and 5B (n_{paired} = 18). Further, the scale for all responses is 1-disagree to 5-agree, with 3 signifying a neutral opinion. The most favorable response was about pencasts (4.61 at the mid-semester point-M and 4.60 at the end-of-the-semester-E), followed by muddiest points (4.14-M and 4.16-E), class activities (3.96-M and 3.99-E), the design project (3.77-M and 3.82-E), and the flipped classroom (3.36-M and 3.41-E).

As shown below in Figure 1A, students did not exhibit a strong preference for either the flipped or traditional classroom setting (3.08-M, 3.28-E). Further, students appeared relatively neutral with respect to the flipped classroom as an effective learning environment (3.33-M, 3.22-E). Students were in modest agreement with the statement that the flipped classroom helped facilitate question generation (3.67-M, 3.72-E). There was no statistical change between the mid-semester and end-of-semester assessments looking at all submissions. On a side note, if only analyzing paired data (meaning data from students that took the survey at both the mid-way and end-of-semester points), there is a slight decline in opinion that the flipped classroom is an effective learning environment as shown in Figure 1B (3.5-M and 3.01-E; p-value = 0.035).

**Figure 1A: Summary of Flipped Classroom Questions:** At both the mid-semester and end-of-semester administrations, students found that the flipped class facilitated question preparation; however, students appeared to be relatively neutral with respect to preference of the flipped classroom over traditional classrooms and their assessment of the flipped paradigm as an effective learning environment (n_{mid} = 39 and n_{final} = 36).
Figure 1B: Summary of the Flipped Classroom Questions (Paired Data): At both the mid- and end-of-semester administrations, students found that the flipped class facilitated question preparation; however, students appeared to be relatively neutral with respect to preference of the flipped classroom over traditional classrooms and their assessment of the flipped paradigm as an effective learning environment (n_{paired} = 18). There was a statistically significant decrease in student attitude with respect to flipped classrooms as an effective learning environment.

As shown in Figure 2A below, students found that the design project showed real-world applications (4.03-M, 4.03-E), helped synthesize class content (3.51-M, 3.83-E), and that group work used in the completing the design project facilitated understanding of statistics (3.77-M, 3.61-E). There is a significant improvement from the mid-semester and end-of-semester assessment of the design project’s facilitation of class content synthesis (p=0.045). Analysis of the paired data shown in Figure 2B shows a positive trend for improvement of class synthesis due to the design project (p=0.07) and a negative trend for group work facilitating understanding of statistics (p=0.1).

Figure 2A: Summary of Design Project Questions: At both the mid-semester and end-of-semester administrations, students found that the design project showed real-world applications, helped synthesize class content, and that group work used in the completing the design project facilitated understanding of statistics (n_{mid}=39 and n_{final} =36).
Figure 2B: Summary of the Design Project Questions (Paired Data): At both the mid-semester and end-of-semester administrations, students found that the design project showed real-world applications, helped synthesize class content, and that group work used in completing the design project facilitated understanding of statistics ($n_{paired} = 18$). There was a trend showing improvement in student attitude with respect to the design project synthesizing class content ($p=0.07$); however, there was also a trend showing a decrease in student attitude with respect to group work employed in the design project assisting in understanding statistics.

As shown in Figure 3A, students rated the following aspects of the class activities to show slight agreement: class activities are engaging (3.54-M and 3.47-E) and class activities involving statistical software will be of use to me in the future (3.56-M and 3.72-E). Students more strongly agreed that the class activities are facilitated by group interaction (4.03-M and 3.69-E), show application to the real world (4.33-M and 4.5-E) and apply homework principles (4.33-M and 4.56-E). Through analysis of the entire data set, there was no statistically significant change in student attitude with respect to class activities at the mid-semester and post-semester time points; however, there was a statistically significant improvement in opinion that the class activities with statistical software will be of use in the future when looking at the selected, paired data ($p=0.026$) as shown in Figure 3B.
Figure 3A: Summary of Class Activities Questions: At both the mid-semester and end-of-semester administrations, students found that the class activities showed application to the real-world, were engaging, facilitated group interaction, applied homework principles, and will be useful in their career (n_{mid}=39 and n_{final}=36).

Figure 3B: Summary of the Class Activities Questions (Paired Data): At both the mid-semester and end-of-semester administrations, students found that the class activities showed application to the real-world, were engaging, facilitated group interaction, applied homework principles, and will be useful in their career (n_{paired}=18). There was a statistically significant improvement in student attitude with regards to the statistical software used in class activities being useful in the future (p-value = 0.026).

As shown in Figure 4A, students strongly agreed that the muddiest point exercise helped address their questions (3.85-M and 3.69-E), was clear (4.33-M and 4.42-E), and that the muddiest points
were easy to submit (4.23-M and 4.36-E). By investigating the entire data set (Figure 4A) and the paired data set (Figure 4B), there was no statistically significant difference between mid-semester and end-of-semester assessments.

**Figure 4A: Summary of Muddiest Points Questions:** At both the mid-semester and end-of-semester administrations, students found that the muddiest points exercise addressed their questions, was clear, and was easy to submit (n_{mid}=39 and n_{final}=36).

**Figure 4B: Summary of the Muddiest Points Questions (Paired Data):** At both the mid-semester and end-of-semester administrations, students found that the muddiest points exercise addressed their questions, was clear, and was easy to submit (n_{paired}=18).

Lastly, as shown in Figures 5A and 5B, the students were in strongest agreement that the pencasts were informative (4.67-M and 4.67-E). Further, the students strongly agreed that the pencasts helped prepare them for class (4.46-M and 4.44-E), and that the pencasts helped prepare them for homework (4.69-M and 4.69-E).
Figure 5A: Summary of Pencast Questions: At both the mid-semester and end-of-semester administrations, students found that the pencasts were informative and prepare them for class activities and homework ($n_{mid}=39$ and $n_{final}=36$).

Figure 5B: Summary of the Pencasts Questions (Paired Data): At both the mid-semester and end-of-semester administrations, students found that the pencasts were informative and prepare them for class activities and homework ($n_{paired}=18$). There was a trend showing improved student attitude with regards to pencasts helping prepare them for the homework assignments ($p$-value $=0.083$).

In summary, the most favorable response was about pencasts, followed by muddiest points, class activities, the design project, and the flipped classroom.
**Student Persistence**

To ascertain student persistence, enrollment on the 21st day of class was compared to the number of students who took the final exam. 90 out of 91 (99%) enrolled on the 21st day of class took the final exam. Further, 91% of all students received a grade of C or better.

**Discussion and Conclusion**

This work employs the use of two validated and reliable surveys to evaluate student attitude about several student engagement strategies including cyber-based muddiest points, pencasts, the flipped classroom, and team-based classroom activities and design project. As mentioned above, the SVM has been assessed for reliability and validity by Carberry, et al. Here, we report findings from a new survey, the BME Student-centered Strategies (BSS) Survey, to assess student attitude about additional engagement strategies. Briefly, we found that this survey was reliable and valid using Cronbach’s alpha and a confirmatory factor analysis on pilot, mid-semester data. We also investigated reliability and validity using the end-of-semester data. While the post-semester data of the BSS Survey showed analogous reliability results to the mid-semester data, only the flipped classroom and muddiest point questions grouped as anticipated in the validity testing using the post-semester data. Ideally, the mid-semester/pilot validity analysis should mirror the end-of-semester validity analysis. Modification of questions in the other groups will be completed and factor analyses will be repeated; however, it is important to note that overall attitude regarding particular questions remained consistent between the mid-semester and post-semester survey administrations. The only significant difference in the BSS survey was a modest but significant improvement in class content synthesis due to the design project.

All of the student engagement strategies assessed (flipped classroom, muddiest points, pencasts, the design project, and classroom activities) garnered above neutral/positive results. Similar to our work, another study by Garmendia, et al. showed positive trends for efficacy and attitude as a result of team-work in a design project setting; however, because of the different content area and assessment of the design project’s effect, it is difficult to make a direct comparison. Additionally, one study completed by Bingham showed a similar improvement in student attitude regarding a real-world project in an introductory statistics course.

By comparison, the flipped classroom and design project ranked lowest in positive student attitude in our study. With respect to the flipped classroom, many students believed that the flipped setting was appropriate in this one-hour per week statistics and design of experiment course; however, they would not recommend the flipped classroom in other more time intensive classrooms. Mixed feelings about the flipped classroom have been observed by other researchers in the statistics setting. In our study, some students were interested in having both in-class and abbreviated online lectures as reflected in this student quote “I feel that this is the only one that would work in this way. The pencast lectures could be helpful in other classes in addition to normal lectures.” Also, because the flipped classroom is a new concept, many students may not be familiar with the format or benefits of this paradigm; however, Mason, et al. showed that over time students adapted to the format and found the flipped classroom to be effective and satisfactory.
In order to more fully evaluate the flipped classroom, persistence was also investigated. 99% of the students present on the 21st day of the semester, a university standard, were present to take the final exam. Further, 91% of the students received a grade of C or better. Future work will focus on comparing final grades to previous offering of the statistics course by other instructors using traditional lecturing. (Previous semester data is available through the university and will offer a baseline or control group.)

Other metrics such as student achievement will be included to further evaluate this flipped classroom using web-enabled tools. To assess student achievement, pre- and post-concept tests will be created and correlated to the student attitudinal data using anonymous identifier. Because student attitude, persistence, and achievement were not monitored when this course was taught in a traditional manner by other instructors, we are unable to make retrospective comparisons; however, attitude, persistence, and achievement will be tracked in future semesters to evaluate long-term effectiveness of this pedagogy. Inclusion of persistence and achievement data will ensure trends seen in attitudinal data are not due to self-reporting bias. It is important to note that aspects of this classroom, namely the design and problem solving aspect present in both the design project and classroom activities, have been shown to be effective in biomedical engineering settings in terms of achievement. However, as far as the authors are aware, this is the first time this combination of strategies has been evaluated in a biomedical engineering setting.

With respect to the design project, many of the students had not begun work on the project at the mid-way point of the semester and therefore could not fully evaluate the design project at that time. Students also expressed frustration over working with teams. In the future, alternate methods of team selection and management will be explored, including more frequent team evaluation with heavier grading emphasis. Additionally, student achievement and persistence data will be included each semester to more completely evaluate the team work aspect of the intervention.

Future emphasis will also be made to encourage students to complete both the mid-semester and post-semester surveys. For both the SVM and BSS Survey, less than 50% of students completed the surveys at both time points therefore paired analysis did not accurately reflect the majority of the responses. Also, gender information will be collected and used to assess persistence, achievement, and attitude differences between males and females. Further, effect sizes will be investigated using Cohen’s D.

This study shows that the muddiest point exercise, team-based classroom activities, and pencasts are effective strategies in the flipped classroom. More specifically, these strategies received very favorable reviews at both the mid-semester and post-semester assessment points in the BSS Survey. Further, according to the Student Value Survey on Muddiest Points (SVM), students felt that the muddiest point exercise was of interest, value, and did not cost too much in terms of time, emotion, or effort at both the mid-semester and end-of-semester assessments. Further, there was a modest but significant increase in utility value as students were able to better see the real-world application of statistics as the semester progressed.
In summary, this work describes a unique pedagogy highlighting web-enabled pencasts and muddiest points as well as group activities in a biomedical engineering statistics and design of experiments course for upper-division undergraduates and serves as a mechanism for just-in-time teaching. Moreover, preliminary analysis of student attitude and persistence data both support that this instructional paradigm is an effective pedagogy for teaching and learning in the flipped classroom.

Acknowledgements

The authors acknowledge the support of this work from NSF Grant #1226325.
Works Cited


Supplement A: BME Student-centered Strategies (BSS) Survey

Select a value from a range of 1-Disagree to 5-Agree.

1. I prefer the flipped* class to the traditional class setting. *Flipped meaning review material at home and work on activities in class.
2. Reviewing the "Muddiest Points" does NOT help answer my questions.
3. The design project does NOT show the application of statistics in a real-world setting.
4. Class activities do NOT demonstrate the importance of statistics in the biomedical field.
5. I feel engaged during class activities.
6. The pencast lectures are NOT informative.
7. Watching pencast lectures helps me complete the in-class activities.
8. Most popular Muddiest Points are NOT answered in class with clarity.
9. The pencast lectures do NOT prepare me to complete the homework.
10. Group discussion is beneficial for completing class activities.
11. Online submission of the Muddiest/Most Interesting Points is difficult.
12. The flipped class allows me to prepare my questions before coming to class.
13. The flipped classroom is more effective than the traditional class setting.
14. The homeworks assigned are NOT helpful when completing the in-class assignments.
15. The design project helps me apply the material covered in the pencast lectures and in-class activities.
16. I think learning statistical software (SPSS) during class activities will assist in my career/future educational plans.
17. Working in groups for the design project does NOT facilitate my understanding of statistics.

Please comment below on the usefulness of this class. Would you recommend a flip class for other BME classes? Would you recommend any of the aspects of the flip class (Muddiest Point, Pencast Lecture, In-class Activities, Design Project, etc) for other classes?
Supplement B: BSS Questions and Factor Analysis Coefficients

Supplemental Table 1: Coefficients from Factor Analysis: All survey questions group appropriately by latent variable (flipped classroom, muddiest points, design project, class activities, and pencasts) as demonstrated by coefficients greater than 0.7.

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<th>Coefficient</th>
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<td>Preference (Q1)</td>
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<td>Facilitation of Questions (Q12)</td>
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<td>Effective learning environment (Q13)</td>
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<td>Easy Submission (Q11)</td>
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<td>Group Facilitation (Q17)</td>
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<td>Are engaging (Q5)</td>
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<td>Are facilitated by group interaction (Q10)</td>
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<td>Apply homework principles (Q14)</td>
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<td>Will be useful (esp. software) in career/future (Q16)</td>
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<td>Are informative (Q6)</td>
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<td>Prepare for class activities (Q7)</td>
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<tr>
<td>Prepare for homework (Q9)</td>
<td>0.996</td>
</tr>
</tbody>
</table>