AEQ-PHYSICS: A VALID AND RELIABLE TOOL TO MEASURE EMOTIONS IN PHYSICS

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ABSTRACT

Undergraduates' emotions in physics are not well studied despite plenty of research showing that students' emotional engagement influences their academic achievement. Our research uses the Pekrun (2006) model and adapts the associated Achievement Emotions Questionnaire, AEQ. We validate using Confirmatory Factor Analysis and check for reliability with 395 surveys completed by students taking a module run in a face-to-face mode within an introductory physics course. The new survey, called AEQ-Physics, was able to adequately measure and differentiate the following emotions, enjoyment, pride, anger, anxiety, hopelessness and boredom. The AEQ was also administered to students taking the same module in a blended mode, receiving 111 responses. Furthermore, the AEQ-Physics was administered during the COVID-19 affected period; all students were forced to continue online, and 74 responses were received. In this paper, we present Pearson Correlations and descriptive statistics for all three cases. We examine trends and patterns to ascertain if the emotions behave as per the Pekrun conceptual model, affirming that the conceptual basis is suitable for physics courses. The AEQ-Physics can now be used in other contexts providing academics with measures of emotional engagement for use in courses to positively influence students' achievement.

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INTRODUCTION

Together with factors like motivation, personal interest and student-lecturer communication, students' emotional engagement has been linked to students' learning and academic achievement (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008; Pekrun, 2006; Robinson, Lloyd, & Rowe, 2008; Svanum & Bigatti, 2009; Weiner, 2010). Sinatra, Broughton and Lombardi (2014) argue that emotions are discipline specific so they must be explored and examined in each domain (Goetz, Frenzel, Pekrun, & Hall, 2006). Bhansali and Sharma (2019) have measured achievement emotions for the laboratory context in physics undergraduate courses.

According to Pekrun (2006), achievement emotions are associated with emotions during the activity as well as emotions related to achieving the outcomes. He further places them according to positive or negative emotions (valence), and whether they are activating or deactivating (activity level). This conceptual basis has been used to develop and validate the Achievement Emotions Questionnaire, AEQ (Pekrun, Goetz & Frenzel 2005). Bhansali and Sharma (2019) modified the AEQ, measuring six emotions separating them in three quadrants; positive activating emotions which are enjoyment and pride; negative activating emotions which are anger and anxiety; and negative deactivating emotions which are hopelessness and boredom. The survey, called the AEQ-PhysicsPrac, was specific to physics laboratory practicals.

The aims of this study are, firstly to extend the AEQ-PhysicsPrac to a course, and validate and test its reliability. Secondly, to examine the conceptual basis of the new tool, AEQ-Physics using three cases in the same first-year undergraduate course; face-to-face mode, blended mode, and COVID-19 affected.

This study adopts a post positivist approach where the researchers, being quantitative scientists, utilise survey methodology to measure and interpret emotions. The researchers are participant observers, using discipline specific lens to interpret interactions in undergraduate lectures. The intention is to inform and influence practices. The researchers acknowledge that qualitative data, lacking in this study, is necessary to provide rich contextual understanding of students' emotions.

METHOD

SAMPLE AND PROCEDURE

The course is calculus based with the first 5 weeks dedicated to mechanics and the second 5 weeks to thermodynamics and waves. All students do a two-hour laboratory and two-hour problem-solving workshop face-to-face each week. However, they can choose to do either face-to-face lectures, in which case they attended four one hour lectures a week, or online lectures (blended mode), in which case they participated in an interactive online module of short videos interspersed with questions and feedback. Surveys were administered via the learning management platform Moodle. Students completed them during class time in the mechanics module in term 3 of 2019 at three points, start, middle and end; and in their own time in term 1 of 2020 at two points, middle and end. Since the second half of term 1 of 2020 was affected by COVID-19, all students were forced to do the second module, thermodynamics and waves in an entirely online mode. Table 1 shows the total number of surveys after those with three or more blank responses were removed. The sampling is non-biased and non-random. The study has approval from the institutional Human Ethics Committee.

Table 1: Detail of the three cases in the same introductory physics course; face-to-face mode, blended mode and COVID-19 affected

Cohort and module description	Case	Number of responses
2019 term 3 Mechanics	Face-to-face	256
	Blended	82
2020 term 1 Mechanics	Face-to-face	139
	Blended	29
2020 term 1 Thermodynamics and waves	COVID-19 affected	74

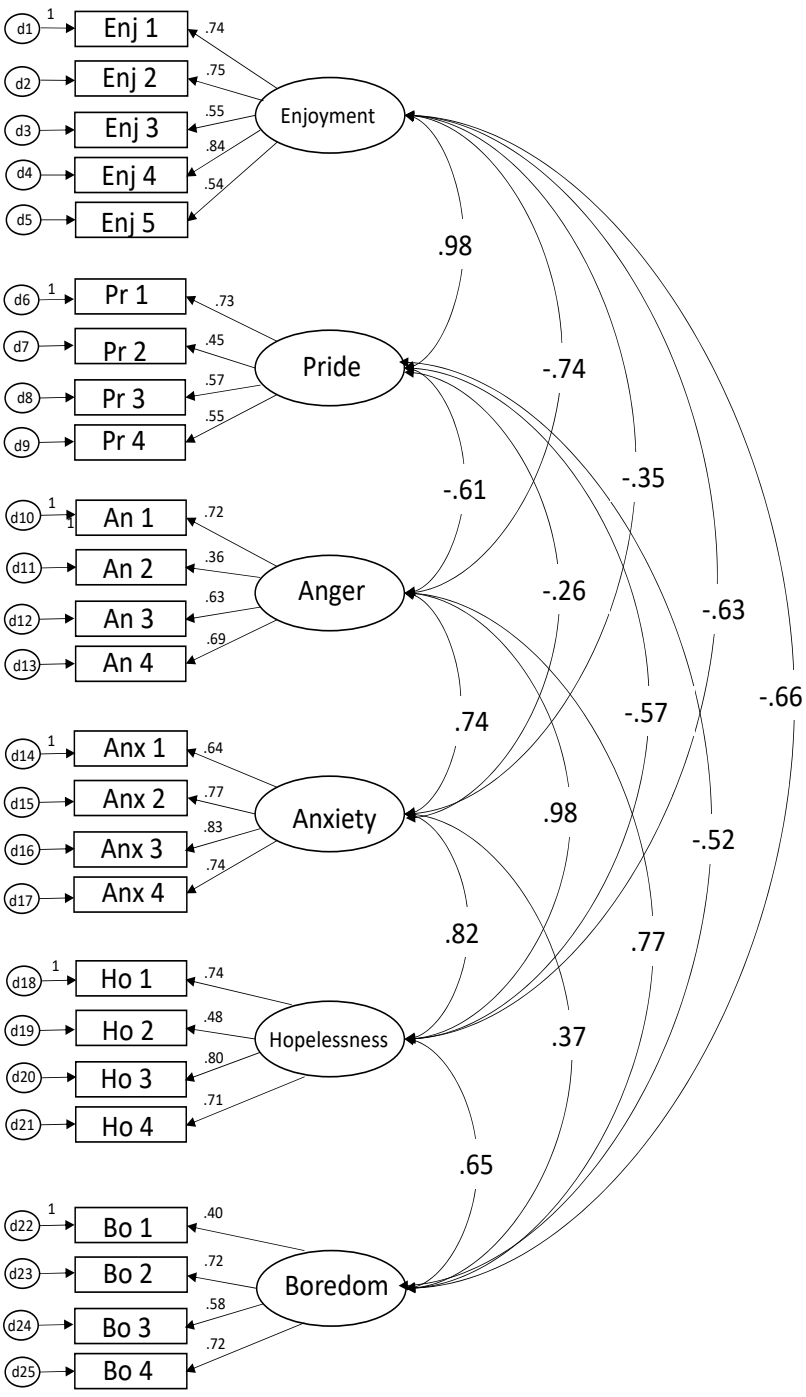
SURVEY ITEM DEVELOPMENT AND ANALYSIS

The AEQ-Physics is based on the AEQ-PhysicsPrac which has been shown to be a valid and reliable tool (Bhansali & Sharma, 2019). In particular, the same six emotions from the three quadrants of the control value theory chart (Pekrun, 2006), enjoyment, pride, anger, anxiety, hopelessness, and boredom were retained. The items were changed so that: 1) the tense was relevant, 2) the context was changed from practical work to course, and 3) new items based on the original Pekrun survey were added for negative emotions so that each emotion has at least 4 items (Field, 2000). The survey uses a Likert Scale which has been interpreted as a number, Strongly Agree=5, Agree=4, Neutral=3, Disagree=2, Strongly Disagree=1. AEQ-Physics can be found in the Appendix, new items are starred.

Data were exported into *EXCEL*, those with three or more blank responses were removed and exported into *SPSS* and *AMOS version 26* to conduct preliminary exploration of distributions and conduct suitability tests, Confirmatory Factor Analysis (CFA), Pearson correlations and to obtain descriptive statistics.

RESULTS

The first purpose of this paper is to validate and check the reliability of the AEQ-Physics. The number of surveys collected in the face-to-face case satisfies the sample size requirement. Preliminary data exploration showed that the data set was adequate for CFA; for example, the distributions for each item, emotion and entire data set were appropriate. Figure 1 shows the result of the confirmatory factor analysis and its interpretation, while Table 2 shows that the model fit parameters meet specified criteria (Hair, Black, Babin & Anderson, 2010; Malhotra & Dash, 2011). The composite reliability (CR) scores are >0.7 which indicates the reliability of the model. The CR for individual emotions are also above 0.6, one at 0.55. The acceptable scores validate the multi-dimensional hierarchical structure of the AEQ-Physics survey.



The set of items representing each emotion emerge grouped together. This means that each set of items are interpreted by respondents as aligning with the same construct, that particular emotion.

The set of items for each emotion are separate to those for the other emotions. This means that the sets of items are interpreted by respondents as being different constructs.

These results illustrate that the emotions are discrete and distinguishable. The items for each emotion do NOT overlap and intertwine with the items for the other emotions.

The numbers next to the rectangular boxes are loadings. Factor leadings are mostly reasonable, loading onto the intended latent factors which are the emotions.

The numbers on the arches are coefficients which indicate the latent factor 'correlations' and their directions. They behave as per Pekrun et al. (2011).

Finally, the six emotions are interrelated factors in a multi-dimensional hierarchical structure (Peixoto et al., 2015).

The conceptual model is sound.

Figure 1: Six-factor CFA model for the face-to-face physics course; Enj is enjoyment, Pr is Pride, An is anger, Anx is anxiety, Ho is hopelessness and Bo is boredom. Each box represents a separate item which load onto distinct and discrete latent factors that are interrelated.

Table 2: Validity and reliability measures of the model and measured emotions

Measures	Criteria	Face-to-Face Score
Comparative Fit Index (CFI)	Permissible > .80	Permissible at .80
Root Mean Square Error of Approximation (RMSEA)	Moderate .05-.10	Moderate fit at .098
Relative $\chi 2$ ($\chi 2$/df)	Permissible < 5	Permissible at 4.8
Composite Reliability (CR)	Threshold > 0.70	Acceptable at 0.95
Composite Reliability (CR) for individual emotions:	Enj 0.67; Pr 0.82; Ang 0.70; Anx 0.84; Ho 0.55; Bo 0.70	

The second aim is to examine the conceptual basis of the new tool, AEQ-Physics, using the three cases; face-to-face mode, blended mode, and COVID-19 affected. We start off with the bivariate Pearson Correlations. Neglecting anxiety, we found positive correlations between positive emotions, positive correlations between negative emotions, and negative correlations between positive and negative emotions; all statistically significant at p<0.01. This means that the polarity of the correlations for each of the cases are as per the Pekrun conceptual model. Anxiety is anomalous in that it has different patterns for the different cases (Pekrun,2006; Bhansali & Sharma, 2019). For all cases anxiety is positively correlated with negative emotions. However, its correlations vary for positive emotions, see Figure 2. In terms of the conceptual model in the three teaching and learning contexts within the same course, the correlations show that the emotions are interrelated and distinct, and that the polarity of the correlations are as expected.

Table 2: Pearson Correlation coefficients between the emotions for the three cases: face-to-face, blended and COVID affected

	Face-to-face mode					Blended mode					COVID-19 affected				
	Pr	An	Anx	Ho	Bo	Pr	An	Anx	Ho	Bo	Pr	An	Anx	Ho	Bo
Enj	.72**	-.51**	-.25**	-.51**	-.45**	.75**	-.46**	-.21**	-.45**	-.54**	.76**	-.53**		-.58**	-.60**
Pr	-	-.31**		-.36**	-.30**	-	-.37**	-.25**	-.44**	-.46**	-	-.41**		-.46**	-.33**
An		-	.57**	.75**	.63**		-	.49**	.73**	.62**		-	.54**	.78**	.64**
Anx			-	.63**	.41**			-	.68**	.42**			-	.59**	.38**
Ho				-	.62**				-	.68**				-	.66**

** is statistically significant at p<0.01 (2-tailed)

To further examine the conceptual basis of the AEQ-Physics, we consider the descriptive statistics for the three cases. Table 3 shows that the AEQ-Physics is able to discriminate and measure differences between the three cases for the six emotions. In our preliminary analysis we compare the means using standard error of the mean, SEM. When comparing face-to-face with COVID-19 affected, on average, there is overlap, no difference, for all emotions. We find a difference, no overlap, favouring face-to-face over blended for all the emotions, that is, higher means for positive emotions and lower means for negative emotions for face-to-face. Blended, once again, does poorly when compared with COVID-19 affected. In short, our preliminary perusal of the data suggests that students' emotional engagement with the blended mechanics module is the poorest, COVID-19 thermodynamics and waves module is next, and face-to-face mechanics is the best. With more time, we anticipate further data analysis, quantitative triangulating with qualitative to probe the extent of this observation and to propose explanations for this observation.

Table 3: Descriptive Statistics, Mean, Standard Deviation (SD), Standard Error of the Mean (SEM) for the three cases

Emotion	Range	Face-to-face mode (n=395)	Blended mode (n=111)	COVID-19 affected (n=74)
		Mean (SD; SEM)	Mean (SD; SEM)	Mean (SD; SEM)
Enjoyment	5-25	14.2 (2.6; 0.13)	13.3 (2.7; 0.26)	13.8 (2.8; 0.33)
Pride	4-20	18.6 (3.3; 0.17)	17.2 (3.5; 0.33)	18.0 (3.6; 0.42)
Anger	4-20	11.5 (3.0; 0.15)	12.6 (2.8; 0.27)	11.1 (3.1; 0.36)
Anxiety	4-20	13.1 (3.6; 0.18)	14.1 (3.5; 0.33)	12.5 (3.9; 0.45)
Hopelessness	4-20	10.2 (3.2; 0.16)	11.9 (3.0; 0.28)	10.0 (3.3; 0.38)
Boredom	4-20	10.3 (2.9; 0.15)	11.3 (3.0; 0.28)	9.9 (2.9; 0.34)

DISCUSSION

The results indicate that the AEQ-Physics is a valid and reliable tool that can measure students' emotions in physics courses and that it is conceptually sound aligning with the Pekrun model (Pekrun 2006; Peixoto et al., 2015). While examining the conceptual basis of the AEQ-Physics, we compared three cases; face-to-face, blended and COVID-19 affected. The survey was able to discriminate between the three cases. Interestingly, our preliminary analysis comparing the means shows that face-to-face is the most emotionally engaging, COVID-19 is next and blended does the worst. Such detail and information can prove to be useful as studies show that students' emotional engagement influences their academic achievement (Pekrun, 2006; Svanum & Bigatti, 2009; Weiner, 2010).

Finally, the survey tool also helps academics reflect on students' emotional engagement with different modes of delivery which can help assess if the mode of delivery or other elements of the course are working well for students' emotions and if not, can be improved. Further studies should include the use of the survey with different cohorts and to extend to different year cohorts and possibly adapted to different science disciplines. For future studies, the tool could also be used to distil the engagement levels for gender, different mode of teaching, and different kinds of modules in lectures.

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APPENDIX

The AEQ-Physics, items which are starred are new when compared to the AEQ-PhysicsPrac

Pride items	***Item name***
During this Physics course, I was satisfied with my work.	Pr1
I felt elated by my accomplishments during this Physics course.	Pr2
I took pride in being able to keep up with the tasks in this Physics course.	Pr3
I made important contributions during this Physics course.	Pr4
Enjoyment items	
For me this Physics course was a challenge that was enjoyable.	En1
I felt this Physics course was exciting.	En2
I was glad that my efforts during this Physics course paid off.	En3
I enjoyed this Physics course.	En4
I am happy that I could cope with this Physics course.	En5
Anger items	
I felt annoyed by this Physics course.	An1
It was irritating that my efforts were not useful during this Physics course.	An2
I resented doing this Physics course.	An3
I felt frustrated during this Physics course.*	An4
Anxiety items	
I got scared that I might do something wrong while doing this Physics course.	Anx1
I felt nervous during this Physics course.	Anx2
I felt panicky during this Physics course.	Anx3
I felt uneasy during this Physics course.*	Anx4
Hopelessness items	
During this Physics course I felt like giving up.	Ho1
During this Physics course, I was so resigned that I felt that I had no energy.	Ho2
During this Physics course, I felt hopeless.*	Ho3
I found this Physics course pointless.*	Ho4
Boredom items	
I found this Physics course dull.	Bo1
I was bored during this Physics course.	Bo2
I got restless during this Physics course.*	Bo3
I got tempted to walk out of this Physics course.*	Bo4