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Student Perceptions of Learning and Engagement Using an Educational Technology Tool

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Introduction

In this full empirical research paper, we aim to identify dimensions of student practices and perceptions using the Concept Warehouse (CW) [1] when answering concept questions within statics and dynamics classes. Instructional practices centered on active learning have been shown to positively impact student outcomes like retention, engagement, and learning gains [2] - [7]. Freeman et al. [2] call for "second-generation research," where researchers should explore the relationship between instructional practices and active learning, the intensity of active learning and learning gain, or other measures related to understanding active learning and its impacts. The use of educational technology to promote active learning has been previously evaluated; however, work still needs to be done to consider instructional practices, student perceptions, and the ecosystems in which technology is being implemented [4] - [11].

The CW is a free web-based active learning tool and content repository to help instructors implement student-centered learning [1]. The CW currently has over 1700 faculty and 40000 students using the tool, as well as over 3500 concept questions in various disciplines. Concept questions, commonly called ConcepTests [12], [13], are single-right-answer multiple-choice questions with little to no math involved that ask students about fundamental concepts they are learning. The abundance of resources and community support provides instructors with an accessible gateway to concept-based learning at any point in their instructional journey.

Here, we investigate the factors that impact students' experiences with active learning using the CW. In this study, we surveyed 448 students across a diverse set of two- and four-year institutions, asking them about their experiences using the CW in their mechanics classes. We then use exploratory factor analysis (EFA) [14] to explore dimensions of student experiences around the usage of the CW. We scaffold our study with the following three research questions:

1. What are the dimensions of student practices using an educational technology tool?
2. What are the dimensions of student perceptions regarding using an educational technology tool?
3. What correlations exist between student practices and student perceptions?

Background

Educational technology (EdTech) use has been growing, especially with the emergence of Generative AI, prompting study into the design of learning environments using EdTech, professional development for instructors, and student outcomes. In this study, we aim to understand student perceptions of an educational technology tool that serves as an audience response system (ARS) and a content repository for high-quality and content-oriented questions [1]. Students can use a personal electronic device to answer concept questions. Instructors are also able to contribute concept questions. Work detailing student practices and perceptions of ARS or "clickers" [15] in undergraduate classrooms has observed that students generally have improved attendance, motivation, engagement, and participation due to this technology [17]. ARSs also provide an opportunity for near-instantaneous feedback and the ability to check understanding. Still, students have expressed that a lack of interest from peers or uncertainty in their answer choices could be a barrier to use [16] - [22]. Student practices and perceptions around EdTech tools in engineering classrooms are an area of research that can be further investigated to design learning environments more effectively. Furthermore, Kay & LeSage [16] note the need for quantitative and mixed-method studies that explore the impact of ARSs on student experience and cognition.

Concept questions ask students about fundamental concepts that they are learning and help instructors enact cognitive, social, and epistemological learning goals related to active learning [4], [23]. For example, concept questions are commonly used within Peer Instruction (PI) [12], a teaching practice that asks students to complete a concept question, asks them to talk to their peers about the answer choices, and then asks students to redo it. PI has been shown to promote improved learning outcomes [5], [12], [13], [24] - [30], making teaching practices that utilize concept questions promising to probe into student understanding.

In this study, students were often asked to justify their answer choice in writing. Such a practice encourages writing-to-learn (WTL) through a low-stakes reasoning task. WTL in STEM classes has been shown to promote student reasoning and improve writing skills and engagement [31], [32]. Short-answer justifications for concept questions have been observed to promote conceptual understanding, improve answer choice, and prepare students for in-class discussions [33], [34]. This study aims to investigate dimensions of student practices and perceptions with their experiences of an EdTech tool that utilizes concept questions alongside self-explanation, an instructional practice shown to be generative in previous work.

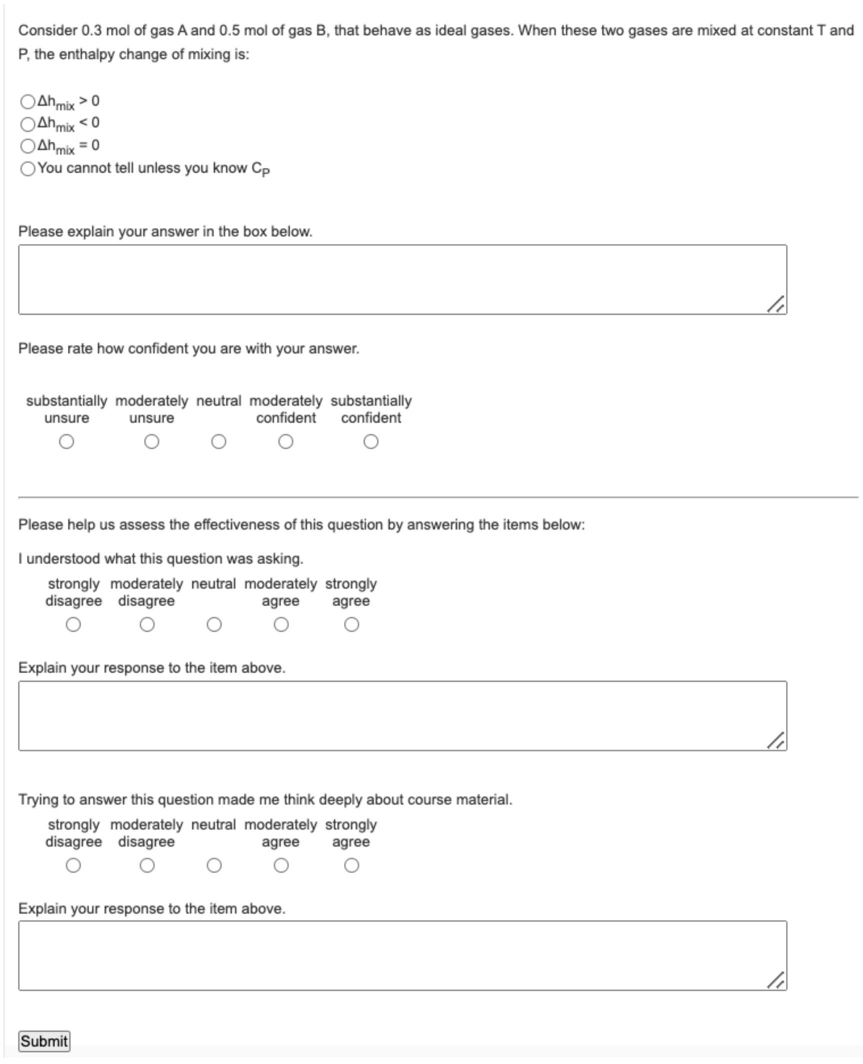
Conceptual Framework

We define active learning as any instructional method that promotes student activity and engagement in the learning process [3]. Active learning principles are guided by social constructivist principles that allow students to learn with peers and a more experienced adult (e.g., instructors, graduate teaching assistants, undergraduate instructional assistants, etc.) who can foster the development of skills and acquisition of disciplinary knowledge. The design of active learning environments involves thinking about the productive involvement of students in the learning process, as well as engagement, collaboration, agency, application, and feedback. Engagement is students' "energy and effort" in their learning communities and has cognitive, affective, and behavioral dimensions; collaboration in active learning aims to promote interpersonal interactions between students and teachers to engage in problem-solving; agency regards students' sense of ownership of learning; application is about the *practice* of concepts learned in class; and feedback in active learning focuses on how feedback to student learning happens frequently [22], [35] - [38].

Methods

Research Design

This study is part of a larger project investigating the propagation of the CW in undergraduate engineering courses at diverse two- and four-year institutions. Here, we ask instructors to implement the CW in their classes in any manner they choose (e.g., in-class clicker, homework, quiz, etc.), followed up by three short-answer follow-ups that ask students to 1) justify their answer choice, 2) Likert-scale rating of confidence, and 3) provide comments on the effectiveness of the question, as shown in Fig. 1. Student data is anonymized to protect privacy.


Consider 0.3 mol of gas A and 0.5 mol of gas B, that behave as ideal gases. When these two gases are mixed at constant T and P, the enthalpy change of mixing is:

- $\Delta h_{mix} > 0$
- $\Delta h_{mix} < 0$
- $\Delta h_{mix} = 0$
- You cannot tell unless you know C_P

Please explain your answer in the box below.

Please rate how confident you are with your answer.

substantially unsure | moderately unsure | neutral | moderately confident | substantially confident

Please help us assess the effectiveness of this question by answering the items below:

I understood what this question was asking.

strongly disagree | moderately disagree | neutral | moderately agree | strongly agree

Explain your response to the item above.

Trying to answer this question made me think deeply about course material.

strongly disagree | moderately disagree | neutral | moderately agree | strongly agree

Explain your response to the item above.

Submit

Fig. 1. Student view of concept question asked on the CW.

Instructors also attend a bi-semesterly community of practice meeting to discuss their instructional practices around implementing the tool in their classes. The goal is to build a community where instructors new to the tool can learn from more experienced users.

Participants, Settings, and Data Collection

Only students who consented to have their responses used were included in this analysis. Survey data was collected from 2021 to 2024. Students were surveyed from statistics and dynamics classes at twelve diverse institutions, detailed in Table I. Participating instructors hold a mix of teaching- and tenure-track positions.

TABLE I
DETAILS OF PARTICIPATING INSTITUTIONS

Institution Type	**Research Activity**	**Number of Participating Institutions**
Private non-profit	Very high research activity (R1)	1
Private non-profit	N/A	1
Public 4 yr	Very high research activity (R1)	2
Public 4 yr	High research activity (R2)	2
Public 4 yr minority-serving	Larger master's program (M1)	1
Public 4 yr	N/A	2
Public 2 yr	N/A	3

Survey Design

The survey was designed as part of the larger project to support the investigation of tool propagation in diverse settings. For survey pretesting, three students were interviewed about their interpretations of the survey items. After considering the interviews, edits to the items were made, which were confirmed with the larger research team before the final version was deployed for data collection in 2021. The survey items have remained constant since then. Appendix A includes all survey items, but here, we focus on items related to student practices (Items Q5_1-Q5_6) and perceptions (Q8_1 - Q8_17), shown in Tables II and III, respectively. Both questions have students respond on a one-to-five scale.

TABLE II
PRACTICE ITEMS

Item No.	**When I am working on a CW question...**
Q5_1	I usually try to really understand the CW question.
Q5_2	I would like to know the answer so I can check my understanding
Q5_3	When doing a CW question, I really just want to know the answer
Q5_4	Chegg is a good resource to use on CW questions
Q5_5	I try to see how the CW question fits with things we are learning in the course
Q5_6	I try to see how the CW question relates to things I know from outside the course

TABLE III
PERCEPTION ITEMS

Item No.	Finally, we would like to know your opinions about using the CW in this course. How much do you agree with each statement?
Q8_1	Things make more sense after we do a CW question
Q8_2	I pay more attention to the instructor's explanation if I have done a related CW question
Q8_3	Doing CW questions is often a waste of time.
Q8_4	I'm more actively involved when we use CW in class
Q8_5	After we do a CW question, I can understand the concepts better
Q8_6	CW questions increase my stress level
Q8_7	Seeing the class responses to CW questions helps increase my confidence
Q8_8	Discussing CW questions in class helps me make sense of challenging ideas.
Q8_9	When we use CW in a class I have to think more
Q8_10	I wish more of my instructors used the CW or something similar
Q8_11	CW questions are often interesting
Q8_12	Writing explanations for CW questions helps me think more about the question and answer that I chose
Q8_13	Using the CW makes me more aware of my misunderstandings.
Q8_14	I wish my instructor would just tell us how to solve the CW questions
Q8_15	Using the CW helps me learn difficult concepts
Q8_16	Discussing CW questions in class is enjoyable
Q8_17	I remember concepts better after working on them in the CW.

Sampling and Missing Data

Instances of entirely blank rows were omitted from the analysis, and individual missing data were replaced with the average for that class. This reduced 482 responses to 448 valid responses.

Data Analysis

Exploratory factor analysis (EFA), a data reduction technique that allows for characterizing and conceptualizing interrelationships between survey items [14], [39], was conducted to understand dimensions of student practices and perceptions of using the CW. A factor is an unobservable, or *latent*, variable that describes abstract dimensions of observable, measurable items. These factors combine directly measured variables with a common variance, which can be helpful to describe meaningful phenomena in data that cannot be directly measured [14], [38]. For example, a survey can ask about income level, demographic characteristics, and other variables, but the latent concepts related to society or culture cannot be directly measured.
Several decisions need to be made regarding how researchers run EFA:

- **Suitability of Data:** Data must pass metrics (e.g., Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, Barlett's Test of Sphericity, etc.) to meet the assumptions of normality and linearity, and a sizable number of correlations must be present to do EFA. All items of interest should have the same response scale.

- **Number of Factors:** The number of factors impacts the interpretability of the data structure.
- **Factor Extraction:** There are many factor extraction methods, but the two most common are the Principal Axis Factor method, which successively extracts factors until a large amount of variance is accounted for, and the Principal Components method, which extracts components based on the maximum variance of the data set to reduce the items into a smaller number of components. The Principal Axis Factor method is preferred as it measures the uniqueness of items in factors and better supports theory-building.
- **Rotation Method:** The axes of EFA can be rotated to make them more meaningful and better represent the factors. Orthogonal rotations (axes remain 90 degrees) assume that factors are not correlated, while oblique rotations (axes rotate about the origin) do not make the same assumptions [14], [39]. For most EFA, oblique rotations better represent the connections between items and factors [14].

All analyses were done using RStudio accessed through posit Cloud [40] using the psych library [41]. Our data was suitable for EFA as it meets the general recommendation for sample size (n > 300 participants), as EFA generally works better for larger sample sizes [39]. The KMO measure of sampling adequacy for student practice items was 0.75, noting that this data is adequate for factor analysis. The KMO score for student perception items was 0.93, noting that the data is excellent for factor analysis. Bartlett's Test of Sphericity for student practices ($\chi^2 = 734.88, df = 15, p < 0.001$) and perceptions ($\chi^2 = 5542.62, df = 136, p < 0.001$) was statistically significant, noting that the items are sufficiently correlated for factor analysis. All survey items are included in Appendix A. The number of factors was determined using a Scree plot with parallel analysis, shown in Appendix B. We are interested in conceptualizing latent factors, so common factor analysis and an oblique rotation method were used. Further results of the EFA are presented in the Findings section, and reliability was determined using Cronbach's alpha, a measure of internal consistency.

For Research Question 3, a Spearman correlation [42] was done between pairs of factor loadings to gain insight into the relationship between practices and perceptions. Spearman correlations measure the association between two factors ranging from -1 to 1. A value closer to -1 or 1 represents a strong correlation, and the sign dictates the monotonic relationship between factors.

Findings

The EFA of student surveys was conducted using a Principal Axis Factor extraction method, with an oblique rotation method (oblimin).

Research Question 1

Research Question 1 pertained to dimensions of student practice. Initial two-factor solutions showed that the communalities, or the proportion of common variance of an item relative to the factor [43], for items Q5_3 and Q5_4 were below the acceptable level of 0.4. Thus, we removed those items from the original EFA and reran a two-factor EFA, which yielded the statistically significant results below. Communalities for the final two-factor model are provided in Table IV.

TABLE IV
COMMUNALITIES FOR EXPLORATORY FACTOR ANALYSIS OF STUDENT PRACTICES

Item No.	**When I am working on a CW question...**	**Communality (h^2)**
Q5_1	I usually try to really understand the CW question.	0.57^
Q5_2	I would like to know the answer so I can check my understanding	0.40^
Q5_3	When doing a CW question, I really just want to know the answer	N/A
Q5_4	Chegg is a good resource to use on CW questions	N/A
Q5_5	I try to see how the CW question fits with things we are learning in the course	0.73*
Q5_6	I try to see how the CW question relates to things I know from outside the course	0.60^

*Considered ideal ($h^2 > 0.7$)
^Considered acceptable ($0.4 < h^2 \leq 0.7$)

All communalities for the final EFA were considered acceptable ($0.4 < h^2 \leq 0.7$) or ideal ($h^2 > 0.7$), noting that our factors explain moderate to large amounts of the variance for each item. Two factors were identified, detailed below, using a scree plot with parallel analysis (Appendix B), which explains 57% of the variance. Table V displays the factor loadings.

TABLE V
FACTOR LOADINGS FOR EXPLORATORY FACTOR ANALYSIS OF STUDENT PRACTICES

Item Number	**Factor**	
	1	**2**
Q5_1	0.18	**0.61**
Q5_2	-0.06	**0.68**
Q5_5	**0.73**	0.15
Q5_6	**0.83**	-0.07

Bolded items denote the relevant item for that factor.

Factor 1 contained two items (Q5_5 and Q5_6) about student practices that bridge the concept question to other concepts within and outside the course. We label this factor “Framing” to represent students bridging concepts. Cronbach’s alpha was 0.79, indicating acceptable internal consistency.

Factor 2 contained two items (Q5_1 and Q5_2) that pertain to the effort involved in understanding concepts, so we label this factor “Effort to Understand.” Cronbach’s alpha was 0.70, indicating acceptable internal consistency.

Table VI displays the factor correlations, which note a moderate correlation between Factors 1 and 2. Items in these factors are expected to be related as practices involving effort for understanding can be related to how students frame their thinking around concepts [15]. Figure 2 shows the final EFA diagram.

TABLE VI
FACTOR CORRELATIONS

Factor	**1**	**2**
1	1	0.78
2	0.78	1

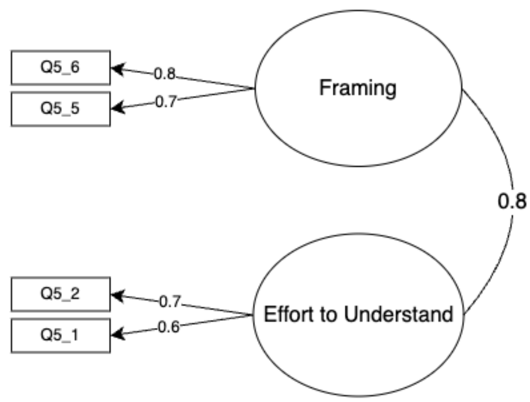


Fig. 2. EFA diagram for Research Question 1

Research Question 2
EFA of items was done on items related to student perceptions. All communalities were considered ideal or acceptable, as shown in Table VII.

TABLE VII
COMMUNALITIES FOR EXPLORATORY FACTOR ANALYSIS OF STUDENT PERCEPTIONS

Item No.	**Finally, we would like to know your opinions about using the CW in this course. How much do you agree with each statement?**	**Communality (h^2)**
Q8_1	Things make more sense after we do a CW question	0.73*
Q8_2	I pay more attention to the instructor's explanation if I have done a related CW question	0.64^
Q8_3	Doing CW questions is often a waste of time.	0.52^
Q8_4	I'm more actively involved when we use CW in class	0.62^
Q8_5	After we do a CW question, I can understand the concepts better	0.73*
Q8_6	CW questions increase my stress level	0.58^
Q8_7	Seeing the class responses to CW questions helps increase my confidence	0.54^
Q8_8	Discussing CW questions in class helps me make sense of challenging ideas.	0.84*
Q8_9	When we use CW in a class I have to think more	0.57^
Q8_10	I wish more of my instructors used the CW or something similar	0.66^
Q8_11	CW questions are often interesting	0.72*
Q8_12	Writing explanations for CW questions helps me think more about the question and answer that I chose	0.41^
Q8_13	Using the CW makes me more aware of my misunderstandings.	0.62^
Q8_14	I wish my instructor would just tell us how to solve the CW questions	0.63^
Q8_15	Using the CW helps me learn difficult concepts	0.92*
Q8_16	Discussing CW questions in class is enjoyable	0.72*
Q8_17	I remember concepts better after working on them in the CW.	0.85*

*Considered ideal ($h^2 > 0.7$)
^Considered acceptable ($0.4 < h^2 \leq 0.7$)

Four factors were identified, detailed below, using a scree plot with parallel analysis (Appendix B), which explains 66% of the variance. Table VIII displays the factor loadings.

TABLE VIII
FACTOR LOADINGS FOR EXPLORATORY FACTOR ANALYSIS OF STUDENT PERCEPTIONS

Item Number	Factor			
	1	**2**	**3**	**4**
Q8_1	0.02	0.03	**0.83**	-0.06
Q8_2	0.01	-0.04	**0.80**	0.05
Q8_3	-0.06	-0.09	-0.11	**0.73**
Q8_4	0.19	0.08	**0.55**	0.10
Q8_5	0.29	0.09	**0.55**	-0.04
Q8_6	-0.12	0.10	0.27	**0.67**
Q8_7	**0.37**	0.11	0.29	0.15
Q8_8	0.01	**0.91**	0.00	0.01
Q8_9	**0.37**	0.20	0.22	0.16
Q8_10	**0.73**	0.02	0.07	0.04
Q8_11	**0.80**	0.00	0.06	-0.01
Q8_12	**0.69**	-0.13	0.00	0.08
Q8_13	**0.80**	0.08	-0.06	-0.04
Q8_14	0.15	0.02	0.77	**0.77**
Q8_15	-0.02	**0.98**	0.00	0.00
Q8_16	**0.67**	0.10	0.14	-0.04
Q8_17	0.02	**0.92**	-0.02	0.00

Bolded items denote the relevant factors for that factor (i.e., Factor Loading > 0.3).

Factor 1 contained seven items (Q8_7, Q8_9, Q8_10, Q_11, Q_12, Q_13, Q_16) that pertained to how the use of the technology tool promoted positive emotions like confidence, which promoted productive learning behaviors associated with engagement. Thus, we label this factor "Positive Affect and Engagement." Cronbach's alpha was 0.90, noting excellent internal consistency.

Factor 2 contained three items (Q8_15, Q8_17, Q8_8) related to how students felt that the tool promoted deeper understanding, as items were related to a more profound cognitive understanding of concepts. Thus, we label this factor "Deeper Understanding." Cronbach's alpha was 0.95, noting excellent internal consistency.

Factor 3 contained four items (Q8_1, Q8_2, Q8_5, Q8_4) that describe more surface-level aspects of sensemaking, leading to "Impacts to Sensemaking." Cronbach's alpha was 0.89, indicating good internal consistency.

Factor 4 contained three items (Q8_14, Q8_3, Q8_6), which included students' feelings of stress and discontent with the time/effort involved with the tool, which is why we label this factor "Negative Affect." Cronbach's alpha was 0.76, noting acceptable internal consistency.

Factor correlations, shown in Table IX, showed that most factors have low to moderate correlations with one another. Factors 1 and 3 show a more significant correlation. No factors were correlated to Factor 4, Negative Affect. Figure 3 shows the final EFA diagram.

TABLE IX
FACTOR CORRELATIONS

Factor	1	2	3	4
1	1	0.59	0.80	0.20
2	0.59	1	0.56	0.12
3	0.80	0.56	1	0.23
4	0.20	0.12	0.23	1

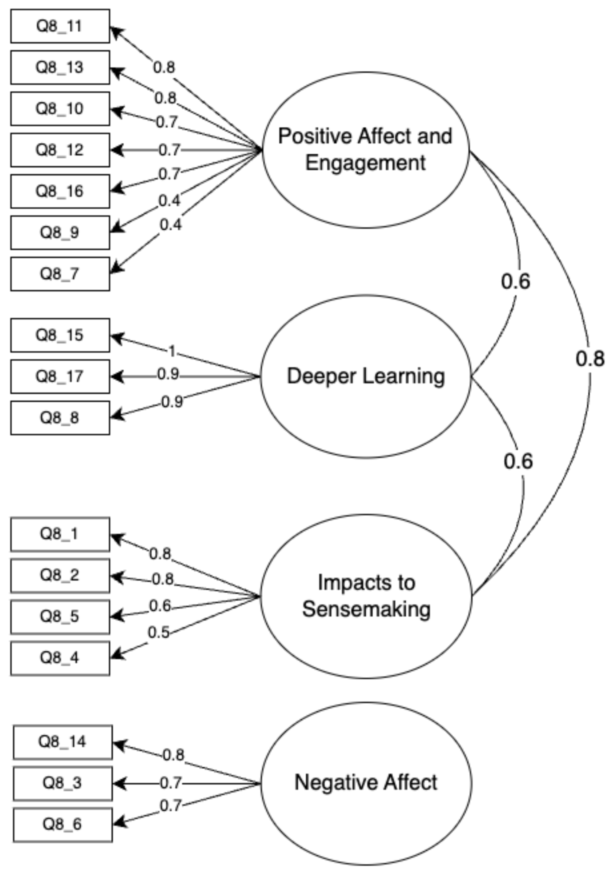


Fig. 3. EFA diagram for Research Question 2

Research Question 3

As shown in Table X, some Spearman correlations between student practice and perception factors display a moderate positive correlation (bolded) or strong positive correlation (bolded and italicized).

TABLE X
SPEARMAN'S CORRELATIONS FOR FACTOR LOADINGS FOR PRACTICES (PRAC) AND PERCEPTIONS (PCPT)

Factor	**PRAC 1**	**PRAC 2**	**PCPT 1**	**PCPT 2**	**PCPT 3**	**PCPT 4**
PRAC 1	1.00	0.89	**0.49**	0.29	**0.50**	-0.01
PRAC 2		1.00	**0.51**	***0.69***	**0.51**	-0.04
PCPT 1			1.00	0.42	0.84	-0.11
PCPT 2				1.00	0.63	-0.02
PCPT 3					1.00	-0.05
PCPT 4						1.00

Perception factors involving positive affect, sensemaking, and deeper understanding (PCPT 1-3) were correlated with generally more involved practices. There was little to no correlation between the factor describing more negative emotions (PCPT 4) to either factor related to student practices. The strongest correlation was between Practice Factor 2, effort to understand, and Perception Factor 2, deeper understanding.

Discussion and Implications

In this study, we used EFA to understand the dimensions of student practices and perceptions as an educational technology tool. The EFA for Research Question 1 revealed a two-factor solution including 1) framing and 2) effort to understand. The EFA for Research Question 2 revealed a four-factor solution: 1) positive affect and engagement, 2) deeper learning, 3) impacts on sensemaking, and 4) negative affect. We then used Spearman's correlations to analyze the relationship between practice and perception factor loadings.

All factors were determined to have good to excellent internal consistency as measured by Cronbach's alpha. Factors related to student practices and perceptions highlighted potential impacts on students' learning processes. Factors related to student practices centered on different levels of effort and kinds of understanding that students associated with their experiences. Three of the four factors for student perceptions were feelings related to sensemaking, increased participation, confidence, and deeper understanding. This is consistent with findings that report students' perceptions around EdTech and note that students feel they have increased productive social interactions and confidence through educational technology [16] - [22]. In the fourth perception factor, some students express that doing concept questions through the tool requires more effort or that their experiences would be better if instructors provided correct answers. Researchers have observed that students "reported exerting more effort with tasks that were authentic and held meaning for them personally" [16, p. 331]. However, in this study, we see that the effect associated with engaging in more effort can be stressful or frustrating for students. Correlations between perception and practice factor loadings show that involved student practices, such as framing and effort to understand, are associated with positive perceptions of doing concept questions and engaging with the tool. On the other hand, negative affect did not correlate with any of the factors investigated here. Future research should identify aspects associated with negative affect, such as the students' approaches to learning [44], [45].

There are several limitations in this study. We did not collect cumulative grades, so we cannot associate EFA with measures of student outcomes; however, we chose to focus on student practices and perceptions using EFA. Future studies can focus on analyzing the relationship between student practices and perceptions of EdTech tools and measures of academic outcomes. EFA involves decision-making around the most reasonable set of conditions applied to the model. We consulted the literature to guide our choices around the appropriateness of data, determination of the number of factors, factor extraction method, and rotation method. Future qualitative studies can be conducted regarding these factors to triangulate the findings [19], [22]. Finally, these findings should be taken only as an exploratory measure of student practices and perceptions around using an educational technology tool. In some way, instructional practice impacts student practices and perceptions, so confirmatory studies of these factors must account for the clustering of students based on their instructors. In future work, we plan to use hierarchical linear modeling to account for the nested structures of this data.

Conclusion

This study used EFA to analyze 448 survey responses completed by students in statics and mechanics undergraduate courses at twelve diverse institutions to understand their perceptions of using the CW in their classes. We found two factors associated with students' practices and four factors that detail student perceptions around their experiences using the tool. While correlations between practice and perception were found for positive learning experiences, the factor representing negative affect did not correlate with any of the other factors. This exploratory work serves as a gateway to understanding student practices and perceptions while using an educational technology tool and begins to answer the call to improve quantitative analyses of EdTech tools in the classroom. Further studies can be done to validate and expand upon these conceptualizations.

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Appendix A

TABLE XI
ALL SURVEY ITEMS

Item Number	**Item Description**	
Q1	Internal Review Board (IRB) Consent	
Q2	Institution and Instructor Selection	
Q3_1	How do you work with the CW in this course? YES or NO for each item.	Work on CW questions individually in class
Q3_2		Discuss CW questions in pairs or small groups in class
Q3_3		Answer CW questions as a group (one answer per group)
Q3_4		Work on CW questions outside of class (e.g., homework)
Q4_1	How does your instructor use the CW? Check YES or NO for each item.	Instructor shows us how the class responded to the question
Q4_2		Instructor discusses the different ways people answered the question
Q4_3		Instructor has us answer the same question again, after we discuss it.
Q4_4		Instructor has us write justifications (reasons for our answer)
Q5_1	When I am working on a CW question...	I usually try to really understand the CW question.
Q5_2		I would like to know the answer so I can check my understanding
Q5_3		When doing a CW question, I really just want to know the answer
Q5_4		Chegg is a good resource to use on CW questions
Q5_5		I try to see how the CW question fits with things we are learning in the course
Q5_6		I try to see how the CW question relates to things I know from outside the course
Q6	Do you ever work with peers on CW questions, either in class or out of class?	
Q8_1	Finally, we would like to know your opinions about using the CW in this course. How much do you agree with each statement?	Things make more sense after we do a CW question
Q8_2		I pay more attention to the instructor's explanation if I have done a related CW question
Q8_3		Doing CW questions is often a waste of time.
Q8_4		I'm more actively involved when we use CW in class
Q8_5		After we do a CW question, I can understand the concepts better
Q8_6		CW questions increase my stress level

Item Number	Item Description	
Q8_7		Seeing the class responses to CW questions helps increase my confidence
Q8_8		Discussing CW questions in class helps me make sense of challenging ideas.
Q8_9		When we use CW in a class I have to think more
Q8_10		I wish more of my instructors used the CW or something similar
Q8_11		CW questions are often interesting
Q8_12		Writing explanations for CW questions helps me think more about the question and answer that I chose
Q8_13		Using the CW makes me more aware of my misunderstandings.
Q8_14		I wish my instructor would just tell us how to solve the CW questions
Q8_15		Using the CW helps me learn difficult concepts
Q8_16		Discussing CW questions in class is enjoyable
Q8_17		I remember concepts better after working on them in the CW.
Q20_1	Some people have difficulty accessing the CW due to lack of reliable internet or reliable devices. Please tell us how easy it is for you to access the CW	How easy is it for you to access the CW OUTSIDE of class?
Q20_4		How easy is it for you to access the CW INSIDE of class?

TABLE XII
DESCRIPTIVE STATISTICS FOR PRACTICE ITEMS

Item No.	When I am working on a CW question...	Mean
Q5_1	I usually try to really understand the CW question.	1.68
Q5_2	I would like to know the answer so I can check my understanding	1.52
Q5_3	When doing a CW question, I really just want to know the answer	2.65
Q5_4	Chegg is a good resource to use on CW questions	3.43
Q5_5	I try to see how the CW question fits with things we are learning in the course	1.8
Q5_6	I try to see how the CW question relates to things I know from outside the course	2.05

TABLE XIII
DESCRIPTIVE STATISTICS FOR PERCEPTION ITEMS

Item No.	**Finally, we would like to know your opinions about using the CW in this course. How much do you agree with each statement?**	**Mean**
Q8_1	Things make more sense after we do a CW question	2.30
Q8_2	I pay more attention to the instructor's explanation if I have done a related CW question	2.26
Q8_3	Doing CW questions is often a waste of time.	3.40
Q8_4	I'm more actively involved when we use CW in class	2.50
Q8_5	After we do a CW question, I can understand the concepts better	2.25
Q8_6	CW questions increase my stress level	3.27
Q8_7	Seeing the class responses to CW questions helps increase my confidence	2.51
Q8_8	Discussing CW questions in class helps me make sense of challenging ideas.	1.80
Q8_9	When we use CW in a class I have to think more	2.40
Q8_10	I wish more of my instructors used the CW or something similar	2.52
Q8_11	CW questions are often interesting	2.30
Q8_12	Writing explanations for CW questions helps me think more about the question and answer that I chose	2.23
Q8_13	Using the CW makes me more aware of my misunderstandings.	2.14
Q8_14	I wish my instructor would just tell us how to solve the CW questions	3.10
Q8_15	Using the CW helps me learn difficult concepts	1.98
Q8_16	Discussing CW questions in class is enjoyable	2.36
Q8_17	I remember concepts better after working on them in the CW.	1.92

Appendix B

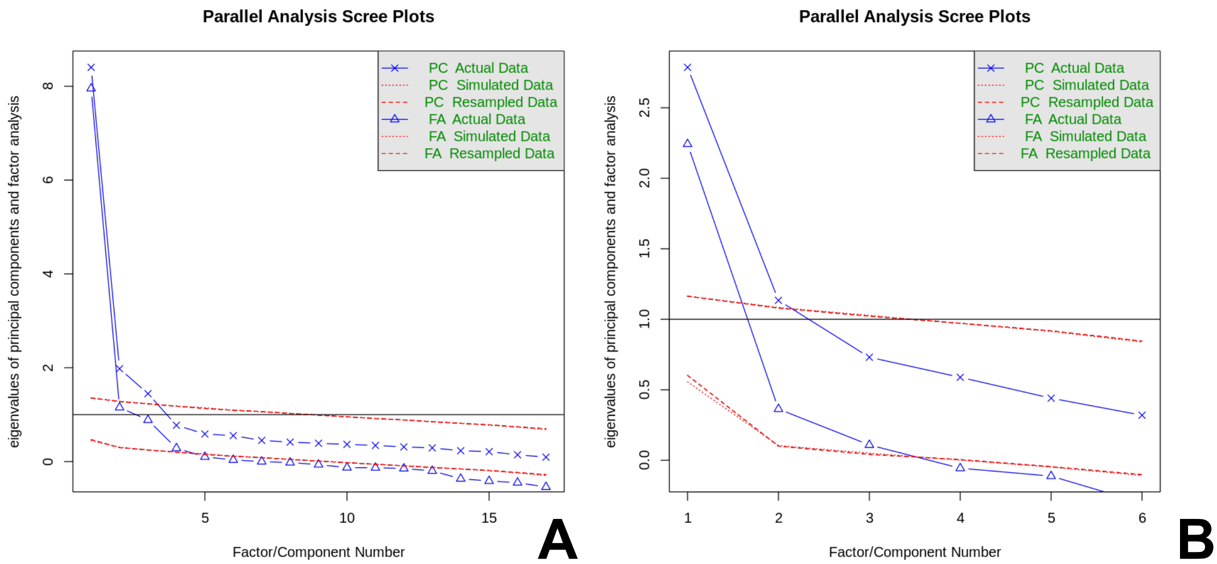

Fig. 4. Parallel analysis Scree plots for student perception (A) and practice (B) items.