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Assessing What We Value: Engineering Students' Perceptions of Calculus Exams and Connections to their Future in Engineering

Catherine M. Kenyon

Florida Polytechnic University, United States of America

Lisa C. Benson

Clemson University, United States of America

Abstract: Assessments of learning should showcase what knowledge is valued in a field; however, the purpose and value of assessments may differ. This research explores how first-year engineering (FYE) students perceive the purpose of assessments in their Calculus I course and how those perceptions are connected to their future in engineering. This mixed methods study involves qualitative data (survey and interviews) and quantitative data (surveys) with FYE students enrolled in a Calculus I course. Surveys were distributed to all students in the course while interview participants came from a homogenous sample, determined by cluster analysis, of those students to adhere to the tenets of an interpretative phenomenological analysis (IPA). Factor analysis showed FYE students perceive the purpose of Calculus I exams in four ways: with a performance-driven purpose, a future-oriented purpose, an external purpose, or an adverse purpose. IPA revealed that connections between these perceptions of Calculus I exams and a student's perceptions of their future in engineering were driven by the student's perceived instrumentality of Calculus itself and the perceived instrumentality of the exams. Math test anxiety also played a role as an outcome of students' identified future goal paths contingent on Calculus exams. These findings exemplify how students' perceptions of the purpose of assessments differ from those reported by instructors and researchers within the literature. Being explicit in communicating the purpose of assessments is a step toward ensuring those assessments align with what is valued in a curriculum and in the professional formation of engineers.

Keywords: Calculus assessment, first-year engineering, future time orientation, interpretative phenomenological analysis, math test anxiety
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Introduction

Engineering students are required to complete a sequence of Calculus courses in which they are assessed via exams that typically constitute a majority of their course grade (Burn & Mesa, 2015). There are various perceptions of the purpose of Calculus exams among instructors which may or may not be shared with students. Given that assessments communicate to others what is valued in a curriculum (Riley, 2016), and that a student's experience in calculus will have a substantial effect on their persistence to remain in an engineering major (Puruhito et al., 2011), it is imperative to consider what messages these exams are communicating to engineering students and how those messages may be interacting with their perception of their future as students and as practicing engineers.

This study examines the interactions between first-year engineering (FYE) students' perceptions of Calculus exams and their perceptions of their future in engineering. Particularly, we are interested in how FYE students who lack a clear perception of their future in engineering view the purpose of Calculus assessments with respect to their future. Understanding connections between students' perceptions of Calculus exams and their futures will help instructors create assessments that are relevant and meaningful to students, which can then assist students in forming clearer perceptions of course content as relevant to their future.

Background Literature

Assessments

Purposes of Assessments

Assessments have been described as having multiple purposes, for example to provide proof of achievement to the instructor and/or institution and to facilitate learning (Boud & Falchikov, 2006); and to evaluate programs (National Research Council, 2001). Another purpose of assessment is to foster life-long learning (Boud & Falchikov, 2006; Black & William, 2005). Other interpretations of an assessment's "purpose" reflect only its end-use: *judgement* (determining the user's level of knowledge), *decision making* (such as gaining entry into a university or continuing in a course sequence, which can be viewed as the most common interpretation), and *impact* (such as establishing that students have learned the core subject) (Newton, 2007). The purpose of an assessment depends on what it tells users about student learning and how these results are used (Looney, 2018).

As the primary end-users of assessments (Brown & Hirschfeld, 2008) and arguably the most important individuals involved in classroom assessments (Scott, 2007; Rea-Dickens, 1997; Kirkland, 1971), students' voices should be included in this discourse and should be considered when discussion the validity of assessments (Black, 2018). The way students perceive assessments is reported to affect how they learn and vice versa (Stuyven et al., 2005). Students may perceive the purposes of assessments in four ways: (1) as improving achievement and learning, (2) as keeping students accountable, (3) as irrelevant, and (4) as enjoyable (Brown & Hirshfeld, 2008). With respect to Calculus courses specifically, researchers have found that students with differing intentions for continuing in the Calculus sequence may hold different perceptions toward the purpose of classroom activities (Ellis et al., 2014). However, more work is needed to understand student perceptions of assessments, particularly regarding Calculus exams.

Issues with Assessments

Some limitations of assessments include the inability to gather information about complex knowledge, the inability to pinpoint a learner's strengths and weaknesses, and the stagnant nature of the assessment in relation to time (Pellegrino & Chudowsky, 2003; Looney, 2018). Asking students to answer questions on tests can be ineffective at capturing information about what is going on behind the scenes, for example, how students organize knowledge, represent problems, or determine how to solve problems (Pellegrino & Chudowsky, 2003; Glaser et al., 1997; National Research Council, 1999a). Many assessments do not identify students' strengths and weaknesses, which would be helpful to advance learning, and may not adhere to "the heart of learning," which is one's understanding over time, not just at a single instance (Pellegrino & Chudowsky, 2003, p. 108).

Assessments can also wrongly focus on the goal of "getting students through" to the next phase of their learning path (for example, the next class or the next institution) and not on evaluating what was learned (Sadler, 2007;

Torrance, 2007). This may be due in part to an intense focus on grades rather than the content learned to advance, thus perpetuating the idea that learning is about indicating achievement over understanding content, particularly for high-stakes assessments, that can increase extrinsic motivation in students, rather than the desired intrinsic motivation (Sadler, 2007; French et al., 2024). Others warn against high-stakes assessments from an equity perspective based on concerns about unfair learning opportunities (National Research Council, 1999b; Pellegrino & Chudowsky, 2003). For example, high-stakes exams can have negative effects on student well-being. Taking this into account that these exams can have significant effects for students' futures, which are tied closely to gender, socio-economic status, race, ethnicity, and disability, high-stakes exams can be disadvantageous for marginalized groups and contribute to existing inequities (Ballen et al., 2017; French et al., 2024).

Math Test Anxiety

Math anxiety is the feeling of internal tension when doing mathematics and is made up of numerical anxiety, abstraction anxiety, and math test anxiety (Ferguson, 1986). Math anxiety can affect students' performance, achievement, learning behaviors, and academic and career choices (Luttenberger et al., 2022). Math test anxiety is the experience of feeling tension when thinking about, preparing for, or taking a math exam (Richardson & Suinn, 1972). While math anxiety and math test anxiety are correlated and both are learned conditions, the two are distinct and can be investigated separately (Hembree, 1990; Alexander & Martray, 1989; Ferguson, 1986; Rounds & Hendel, 1980).

Researchers warn that math courses should be a place of learning without cultivating a stressful environment, particularly stressful math testing environments, which could lead students to struggle in engineering curricula and be more likely to avoid math related futures (Moran & Benson, 2016). Math anxiety is connected to negative emotional responses such as fear, dread, uncertainty, and helplessness, as well as math avoidance (Hembree, 1990), which in turn could limit a student's future career path options.

Future-Oriented Motivation

Future Time Perspective

A person's Future Time Perspective (FTP) describes how their perceived futures and goals interact with their current tasks and motivations (Husman & Lens, 1999; Husman & Shell, 2008; Hilpert et al., 2012). Constructs that form one's FTP include extension, value, perceptions of the future, clarity, alignment, and perceived instrumentality. Extension refers to how far into the future one thinks when considering plans, goals, and their career (Daultrey & Langer, 1984; DeVolder & Lens, 1982). Value is how much importance one places on their future and on thinking of the future (Husman & Lens, 1999). One's perception of the future concerns how they think about their future to a degree of certainty (Kirn & Benson, 2015). The level of detail with which one's future goals are described (ill-defined or well-defined) comprise clarity (McGough, 2019). Alignment refers to how closely aligned one's ideal future (what they desire to achieve) and realistic future (what they believe is attainable) are (McGough, 2019). Finally, perceived instrumentality (PI) is the usefulness an individual perceives for a present behavior and reflects how a specific task is related to an individual's perceived future (Van Calster et al., 1987; Husman & Shell, 2008; Husman & Lens, 1999). PI is often split into two types: endogenous and exogenous (Husman & Lens, 1999; Husman et al., 2004). Endogenous PI is the perception that a present task is relevant to both one's future goals and the path to reach those goals; the task has intrinsic relevancy to one's future. Exogenous PI is when a task is perceived as relevant to the path to reach one's future goals but is not necessarily connected to the future goals; it is more focused on the task outcome than on future goals (Husman & Lens, 1999; Husman et al., 2004). Researchers have recently begun to explore a third type of PI, extrinsic PI, that focuses specifically on the performative outcome of a task, such as a grade earned (Puruhito, 2017).

These constructs combine to visualize an individual's FTP as a conical shape on a set of three axes: extension, PI, and the number of ideal future possible careers being considered (Kirn, 2014; McGough, 2019). Researchers found that, with mid-year engineering students, four characterizations of students' FTP emerge as conical shapes of varying depths and widths: Dish, Bowl, Cup, and Cone (Kirn, 2014; McGough, 2019; McGough Spence et al., 2022). These shapes are placed on our set of three axes and are further categorized into the four types by students' levels of alignment and clarity. These conical characterizations were not developed to "bin" students into permanent categorizations of their FTP (Kirn, 2014; McGough, 2019). Students typically shift between the four types as they move through their degree programs (McGough, 2019). Similar work with FYE students revealed two present characteristic types: Bowl and Cone (Major et al., 2016). Our study, conducted with FYE students, our population of interest were students within the Bowl characterization of FTP (Figure 1). These students consider many present tasks as useful for their future goals. While these students also consider many possible future careers, their future goals may not be clear (McGough, 2019), and thus their extension into the future is relatively short (indicated by the truncation of the conical shape into a bowl). Alongside the other FTP types, students characterized as being in the Bowl group also have ideal and realistic goals that are in closer alignment, not seeing many differences between what they want to ideally achieve and what they can realistically achieve (Kirn, 2014; McGough, 2019; McGough Spence et al., 2022).

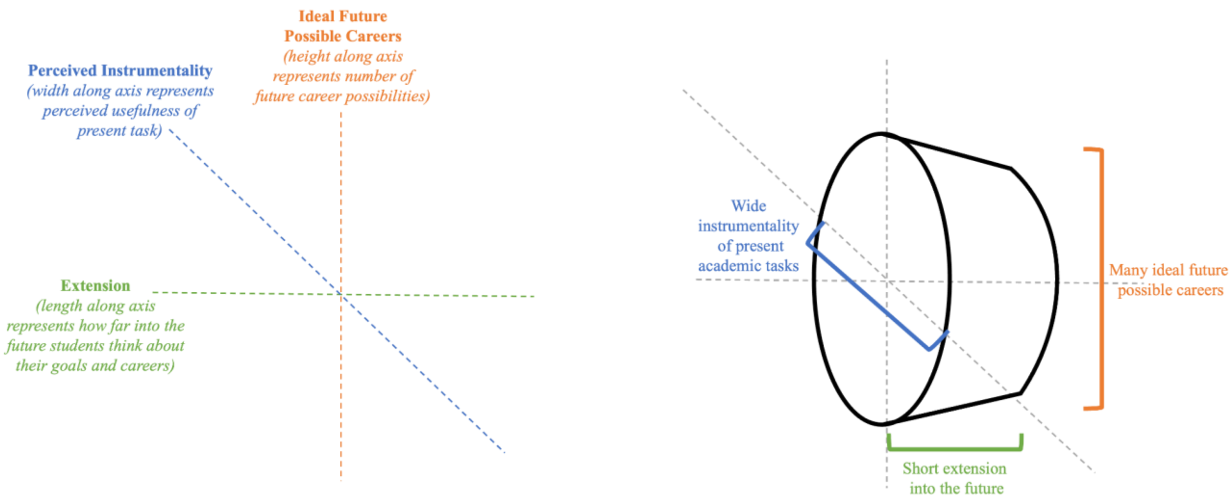
Contingent Goal Paths

Another aspect of future-oriented motivation is the contingent goal path, a sequence of goals that are dependent on one another where movement forward in the sequence depends on successfully achieving the previous goals (Raynor, 1978a, 1981). Failure to achieve a goal means not moving forward to the next goal, and the path is broken (Raynor, 1978a, 1981). Raynor argues that contingent paths in relation to one's career goals can be dependent on "gatekeepers" (for example, qualifications, certifications, and promotions) within the path, and the goals within the contingent path are then focused around "earning the opportunity to continue" (Raynor, 1978b, p. 202).

This study seeks to investigate the convergence of these three topics (assessments, math test anxiety, and future-oriented motivation) to better understand the interactions between FYE students' perceptions of Calculus exams and their perceptions of their future in engineering.

Figure 1

FTP Axes and Bowl Characteristic Type



Note: The axis system on the left visualizes characteristic student FTPs along three axes: extension, perceived instrumentality, and perceived ideal future possible careers. Students in the characteristic FTP type selected for this study ("Bowl") tend to not think too far into the future (short extension), may consider many present tasks as relevant to their future (wide perceived instrumentality), and may possess many ideal future possible careers (high number of ideal future possible careers). Image adapted from Kirn (2014), McGough (2019) and McGough Spence et al. (2022).

Purpose, Positionality, and Paradigm

To investigate interactions between FYE students' perceptions of Calculus exams, their levels of math test anxiety, and their perceptions of the future, we conducted a mixed methods study at a Southeastern, land-grant, R1 institution (Carnegie Foundation for the Advancement of Teaching, 2001) by addressing the following research questions:

> **RQ1.** How do FYE students describe the purpose of taking Calculus exams?
>
> **RQ2.** What are the interactions between FYE students' perceptions of Calculus exams and their perceptions of their future?
>
>> **RQ2a.** How do FYE students' perceptions of Calculus exams and math test anxiety interact with their perceptions of the future?
>>
>> **RQ2b.** In what ways are Calculus exams a part of the perceptions of the future for these FYE students?

The lead researcher on this project is a university Calculus instructor and course coordinator, as well as an engineering education researcher. They recognize Calculus as a powerful tool with concepts woven deeply into science, technology, engineering and mathematics (STEM) students' future courses and careers, while also noticing that Calculus exams don't reflect that same importance. The second author is an engineering education researcher whose main focus is on engineering student motivation and how it affects their learning experiences. Both authors prioritized the voices and perspectives of the student participants to ensure a student-centered approach.

We approached this work from a pragmatic research paradigm as our aim is to inform policy and practice (Creamer, 2018). We chose our methods and procedures to help make sense of the FYE students' experiences and elevate their voices. We understand knowledge to be subjective and that no person's individual reality is absolute; our drive is to understand what is happening within the participants' experiences (Creswell, 2014). The analysis of the last qualitative strand of this study was built from the structure of interpretative phenomenological analysis (IPA). IPA is a qualitative method that centers the voices of participants through data collection and analysis (Smith et al., 2009). Applying IPA in this study allows us to focus on these students' experiences and do our duty as researchers to interpret their experiences as authentically as possible. IPA is an appropriate method for examining a homogenous sample of participants and being "systematic and detailed" when exploring data describing their experiences in context (Smith et al., 2009, p. 23).

Methods

Overview

This mixed methods study was conducted in two phases: a sequential exploratory phase followed by a sequential explanatory phase (Figure 2). Data collection involved one qualitative survey (Survey 1), two quantitative surveys (Surveys 2 and 3), and individual interviews with participants. Data analysis included qualitative coding techniques, factor analysis, multiple linear regression, cluster analysis, and Interpretative Phenomenological Analysis (IPA). The methods and results presented in this paper take a particular focus on the final qualitative strand of data and integrated analysis to better understand interactions between students' perceptions of exams and their futures.

Participants and Institutional Context

Participants in this study were enrolled in a common FYE program and coordinated Calculus I courses. FYE students could earn credit for Calculus I through a single-semester course or a year-long sequence. The Calculus I courses all had three unit exams and a final exam that comprised 70% of students' final course grades. These were closed-book, calculator-free exams and all had a multiple-choice portion (~45%) and a free response portion (~55%). Students were awarded nominal extra credit for completion of each survey in their Calculus course (Survey 1, Survey 2) or their common FYE course (Survey 3).

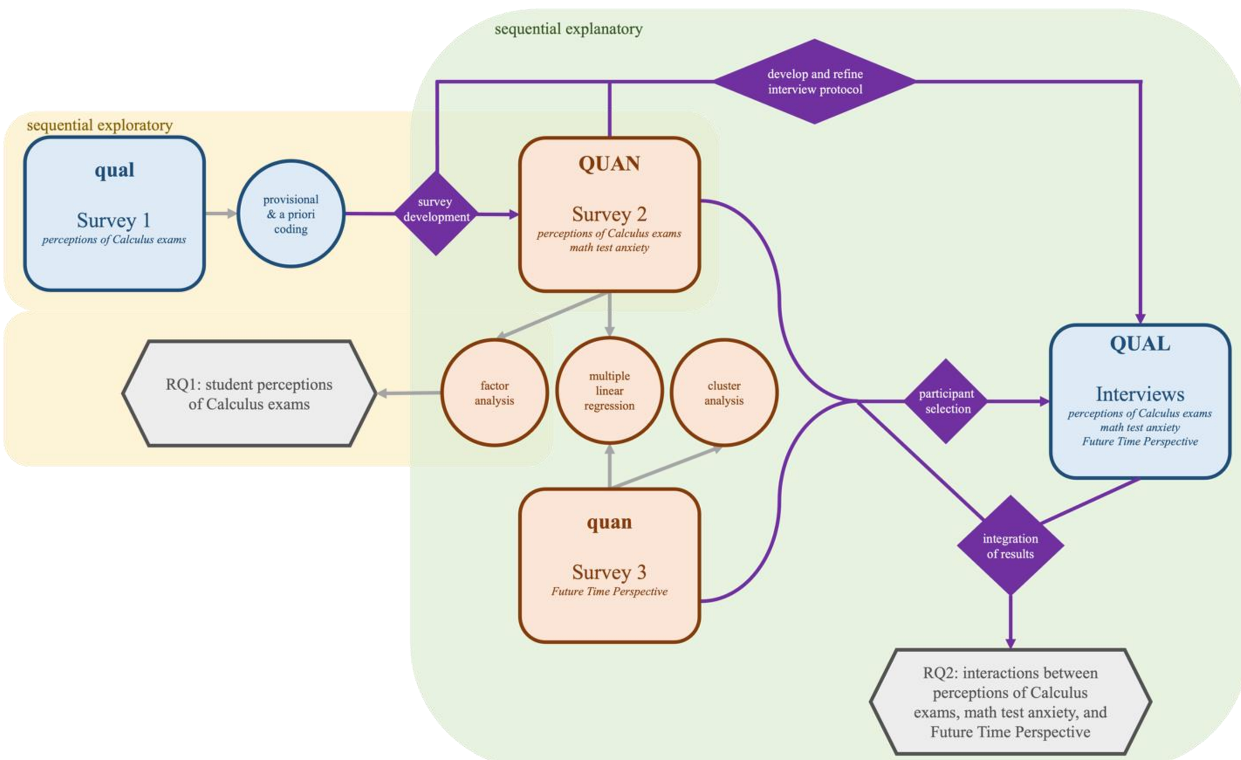
The students who were in our population of interest (FYE students enrolled in Calculus I) did not all complete the surveys administered. From the 1,244 students (all majors) enrolled in Calculus I, we had a 75% response rate on Survey 1 (935 responses) and an 89% response rate on Survey 2 (1,105 responses). Only FYE majors were included in our samples for each survey. Additionally, FYE students selected for individual interviews after completing the three surveys were of the previously discussed Bowl FTP type with high levels of math test anxiety (Bowl–High

MTA). We wanted to know more about this subset of FYE students as we believed they may be susceptible to having their future plans contingent on these high-stakes exams.

The R1 land-grant university for this study was selected for its coordinated Calculus I courses and its common FYE program. However, we note that this university is a predominantly White institution (over 70% of the student population and students in the FYE program identify as White according to the university's most recent enrollment data). Approval for conducting this study was granted by the university's Institutional Review Board.

Figure 2

Mixed Methods Design



Note: The mixed methods research design, beginning with a sequential exploratory phase followed by a sequential explanatory phase. Blue squares indicate qualitative data collection; blue circles indicate qualitative data analyses. Orange squares and circles indicate quantitative data collection and analyses respectively. Within a quantitative or qualitative phase are gray arrows indicating chronology and directionality of the use of each data source. Purple arrows indicate mixing phases and dark purple diamonds indicate how mixing was conducted. Gray hexagons represent how each RQ was addressed through these analyses.

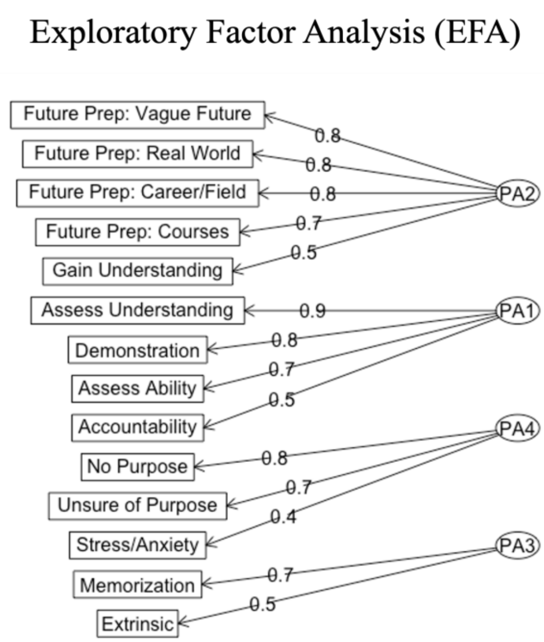
Phase 1: Sequential Exploratory Design

A sequential exploratory design (Creswell et al., 2003) was employed to develop a survey to uncover how FYE students perceive the purpose of taking Calculus exams (RQ1). We first collected open-ended survey data (Survey 1, n = 307) from FYE students enrolled in a Calculus I course, each section with a class size around 30 students, after their first exam was graded and returned near the beginning of the Fall 2022 semester. This sample reflects the majority of FYE students in Calculus I at this university; limitations on students not in the sample are discussed in the following section. The question “What do you believe is the purpose of taking Calculus exams?” was asked in the context of their Calculus I course (Kenyon, 2023).

Data were coded and used to create items on a subsequent quantitative survey (Survey 2) as a means of developmental mixing (Greene et al., 1989), and the survey was distributed in the middle of the Fall 2022 semester, after the second Calculus exam. Students responded to 14 items on Likert-type scales from 1 to 5 to indicate their level of agreement with statements such as “A purpose of taking Calculus exams is to demonstrate that a student understands the material” and “A purpose of taking Calculus exams is for a student to earn a grade” (Kenyon, 2023). Survey 2 data ($n = 375$) were randomly split to conduct exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), each on half of the split data, ensuring that appropriate assumptions were met before performing each analysis and checking the criteria for confirming the appropriate number of factors (Hu & Bentler, 1999; Bialosiewicz et al., 2013; Zaman et al., 2020). More details on the statistical analysis can be found in published Pilot Study results as well as the full study (Kenyon et al., 2022; Kenyon, 2023). Results from these analyses are displayed in Figure 3 as well as in Table 1, showing how perceptions of the purpose of Calculus exam items fell into four groups: a Performance-Driven Purpose, a Future-Oriented Purpose, an External Purpose, or an Adverse Purpose.

Figure 3

Factor Analysis Results



Note: After checking the data for multivariate skewness and kurtosis, the data were split into two groups without replacement to perform an EFA and CFA, each on half of the split data. After checking additional through additional criteria (Scree Plot, Parallel Analysis, Tucker Lewis Index, and Root Mean Square Error of Approximation), four factors with the shown groupings were deemed sufficient. The resultant factors and loadings for the EFA are displayed in the figure above and these factor groupings were confirmed by a CFA. The resultant factors and the items sorted into each factor can be found in Table 1.

Table 1

Student Perceptions of the Purpose of Calculus Exams

Factors from EFA and CFA	Focus of the Items Within Each Factor
Performance-Driven Purpose (PDP)	Assess Understanding
Purpose is to gauge the	Demonstration
student's understanding.	Assess Ability
	Accountability
Future-Oriented Purpose (FOP)	Future Prep: Vague Future
Purpose is related to the	Future Prep: Career
student's future in some way.	Future Prep: Real World
	Future Prep: Coursework
	Gain Understanding
External Purpose (EXT)	Extrinsic Purpose
Purpose is for extrinsic reasons	Memorization
(external to the student and their understanding).	
Adverse Purpose (ADV)	Unsure of Purpose
Purpose is nonexistent, uncertain,	No Purpose
or harmful to the student.	Stress/Anxiety

Note: The four factors resulting from the EFA and confirmed by the CFA for the 14 items on Survey 2 about students' perceptions of the purpose of Calculus exams.

Survey 2 also included 8 items from the Math Anxiety Rating Scale (MARS-30; Suinn & Winston, 2003) concerning students' levels of math test anxiety, with responses also on a 5-point Likert-type scale. Only items from MARS-30 pertaining to math test anxiety were selected for Survey 2, replacing the words "mathematics test" with "Calculus test."

Phase 2: Sequential Explanatory Design

The sequential explanatory design phase aimed to explore how student perceptions of the purpose of Calculus exams play a role in their perceived futures in engineering (RQ2). This included quantitative data collected from Survey 2 and Survey 3. Survey 3 (n = 331) was distributed in a required FYE course during the same semester as the previous surveys and included items concerning students' perceptions of their future on a 7-point Likert scale. Survey items such as "I have a clear idea of what my first job after graduation will be" and "I think I will be satisfied with the career I will be able to achieve" were included based on previous research on FTP characterization (Kirn, 2014; McGough, 2019; McGough Spence et al., 2022). Demographic data were also collected, including students' self-described gender and sexual identities, transfer status, disability and accommodations status, and racial and ethnic identities (Kenyon, 2023).

Data collected from Survey 3 were combined with data from a previous Pilot Study from Fall 2021 (total $n = 573$) to conduct cluster analyses to characterize students' FTP (Kenyon, 2023) to ensure an appropriate sample size for the cluster analysis techniques used (Siddiqui, 2013). Survey 3 was used for both this study and the Pilot Study, in different semesters with different participants. Two types of cluster analyses, k-means and latent profile, confirmed that two of the four previously identified characteristic FTP types (Bowl and Cone) applied to this population of FYE students, as found in previous literature (Major et al., 2016; Kenyon, 2023). To address our research questions, we restricted our participant selection for the subsequent qualitative portion of this phase to only include students with Bowl characteristic FTPs because we seek to know more about students who may not have details of their future planned out in advance (Kirn, 2014), specifically how they interpret the purpose of performing required tasks in the present (such as Calculus exams) and how math test anxiety could serve as a barrier to envisioning their future goals.

The qualitative strand of this phase involved adapting an existing interview protocol to capture student experiences in the intersection of these three spaces: FTP (McGough, 2019), Calculus exams, and math test anxiety. Students were invited to participate in interviews based on results from the cluster analysis and responses to Survey 2 items concerning math test anxiety as a means of developmental mixing (Greene et al., 1989). As choosing a homogenous sample of participants is a tenet of IPA (Smith et al., 2009), we selected FYE students in Calculus I who were in the Bowl FTP characteristic group and had high levels of math test anxiety (MTA). Out of a potential 31 students who answered all three surveys and met our homogeneity constraints (Bowl—High MTA), 22 students were contacted for potential interviews in descending order from the highest levels of math test anxiety until an appropriate number of participants for an IPA (Smith et al., 2009) were selected. Five students (three male, two female) were selected based on the homogeneity criteria and their willingness to participate. Individual interviews were conducted with the selected participants to uncover the interactions between students' FTP, perceptions of Calculus exams, and math test anxiety. Following results from our Survey 1 analysis, our interview protocol also included perceptions of Calculus as related to students' future in engineering to ensure we were able to discern differences between student perceptions of the course and its exams (Kenyon, 2023). Interview participants were asked to provide their own pseudonym (Andrew, Connor, Maria, Ollymars, and Susan). The results from these individual interviews were analyzed via IPA and combined with results from the previous quantitative strand to answer RQ2 as a means of expansion (Greene et al., 1989).

Limitations

External Limitations

Because the institution where this study was conducted is predominantly White, the perceptions and experiences for this FYE student population may differ from a population of students who more closely reflect the demographics of those who earn engineering degrees in the U.S. (Roy et al., 2020) or the demographics of the general U.S. population.

Additionally, the Calculus students in this population came from two different Calculus I course structures: the single-semester course and the year-long sequence, with each section having a cap of about 30 students. In the initial qualitative strand and the following quantitative strands, students from both course structures were included. However, all students involved in the interviews were from the single-semester Calculus I course. So, although there are engineering students in both versions of the course, students may have different experiences in them, and we acknowledge this may influence our understanding of students' perceptions.

Internal Limitations

Students who did not participate in a survey may hold different perceptions about Calculus exams than what is reported, depending on their motivation for not completing the survey. While we did our best to promote the surveys and provide incentives for participating, we acknowledge that the resulting four characteristic ways students perceive the purpose of taking Calculus exams (Survey 2) may not encapsulate the entire reality of the population. This same limitation holds for Survey 3 measuring FTP constructs.

Additionally, recruitment for the individual interviews was robust, yet arduous, in that while most students in the Bowl—High MTA category were contacted, students that identified the highest levels of math test anxiety did not all respond to our request for an interview. Thus, we may be lacking additional connections or other motivations contributing to connections within our model. Additionally, our study focused on these students in the Bowl—High MTA category, but future work should include students with differing perceptions of their future and math test anxiety levels for a more holistic understanding of FYE perceptions. Finally, we acknowledge that this study does not include students from certain demographics; all five of our interview participants identified as heterosexual, non-transfer students. Our model could potentially be expanded by including voices from groups not present in our study.

Results

FYE Student Perceptions of Calculus Exams (RQ1)

The sequential exploratory phase of this study revealed how FYE students perceive the purpose of taking Calculus Exams in their Calculus I course: with a Performance-Driven Purpose, a Future-Oriented Purpose, an External Purpose, and/or an Adverse Purpose. (Note that students could identify more than one of these purposes.) These quantitative results have been expressed in Figure 3 and Table 1. However, combining analysis from the interview phase of the study gave further insight to these student perceptions of exams, particularly by breaking down the Performance-Driven Purpose into two sub-purposes (Table 2).

Students who perceive a Performance-Driven Purpose of their Calculus I exams view this task to be focused on what they are actually showing on the exam as a gauge of their understanding and abilities. Items from Survey 2 within this factor were assessing one's understanding, demonstrating one's abilities, assessing one's abilities, and holding one accountable. From analysis of interview data, we found this Performance-Driven Purpose can be broken down into an individual level and a curricular level. The individual level concerns a student's drive to perform for the benefit of their own understanding (i.e., their performance tells *themselves* what they do or do not know) and the curricular level concerns a student's drive to perform for *others* (i.e., their performance demonstrates to the professor or the university what they understand). The Future-Oriented perception of Calculus exams' purpose included preparing themselves for their future in general, their future courses, their future career in engineering, or the real world. The External Purpose indicates that Calculus exams may serve or contribute to an extrinsic reason such as simply earning a grade or testing memorization skills. Students with this perception view these exams as a task external to their understanding. Students who perceived an Adverse Purpose held the view that Calculus exams do not have a purpose, were uncertain of the purpose of exams, and/or perceived exams as deliberate sources of stress or anxiety.

Table 2

Student Perceptions of the Purpose of Calculus Exams

Acronym	Perception of Exam's Purpose	Definition	Example *"A purpose of taking Calculus exams is to…"*
PDP-I	Performance-Driven Purpose–Individual	Purpose is to ensure the student is able to gauge their own understanding.	*... demonstrate [to themselves] that they understand the material."*
PDP-C	Performance-Driven Purpose–Curricular	Purpose is to ensure someone else other than the student is able to gauge student's understanding.	*... demonstrate [to the professor] that a student understands the material."*
FOP	Future-Oriented Purpose	Purpose is related to the student's future in some way.	*... prepare a student for their future courses."*
EXT	External Purpose	Purpose is for extrinsic reasons.	*... earn a grade."*
ADV	Adverse Purpose	Purpose is nonexistent, uncertain, or harmful to the student.	*"There is little to no purpose to taking Calculus exams."*

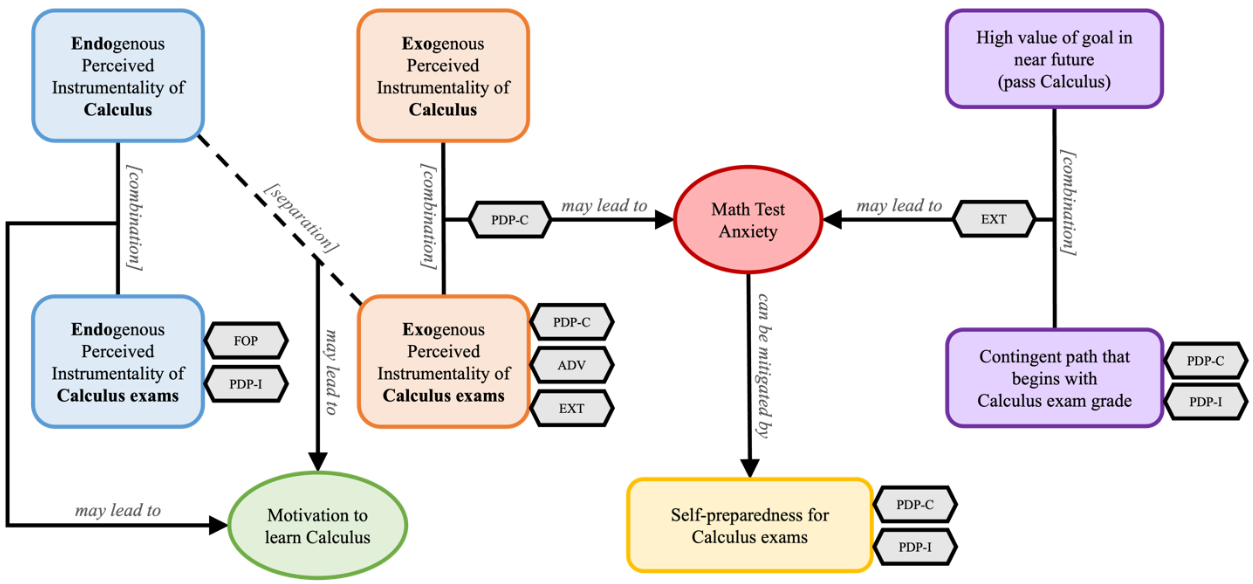
Note: This table shows acronyms used in our model summarizing students' perceptions of the purpose of Calculus exams, with definitions and example quotes from interviews for each purpose. These results detailing FYE students' perceptions of the purpose of Calculus exams were taken from the factor analysis during the sequential exploratory phase of the study and were supported and expanded on via the qualitative analysis of the interview data during the sequential explanatory phase.

FYE Students' Interactions between Perceptions of Calculus Exams and their Future Outlooks (RQ2)

We created a model (Figure 4) of the interactions between students' perceptions of the future, perceptions of Calculus exams, and math test anxiety by considering students' survey responses alongside their individual interview responses. The quantitative survey data indicated their levels of math test anxiety, perceived instrumentality of tasks, and valuing of future goals. The subtle differences we observed in the compiled quantitative data pieces helped us make sense of students' perceptions voiced during their interviews.

Figure 4

Resultant Model



Note: The model of how students in the Bowl FTP characteristic group with high math test anxiety levels experience and make sense of the interactions between their future, their perceived purpose of exams, and their math test anxiety was developed based on the analysis of the quantitative and qualitative strands of data. Hexagons contain perceptions of exams (Table 2), placed where students identified these perceptions of exams as relevant to the topic being discussed during the interview. The left side of the model represents students' perceived instrumentality of Calculus and Calculus exams. Solid lines between boxes indicate a combination or alignment of perceived instrumentalities; the dashed line indicates separation of instrumentalities; arrows indicate directionality of these combinations or separations and their outcomes. The right side of the model represents how students' contingent paths and high value goals may lead to increased math test anxiety. The outcome along the lower portion of the model illustrates how some students can mitigate math test anxiety by preparing for an exam.

Endogenous PI of Calculus and Calculus Exams

One subset of participants recognized Calculus itself (the content, material, learning outcomes) as relevant to their future in engineering and also viewed Calculus exams as a present task useful for their future. Although these students still experienced math test anxiety, this alignment of present instrumentalities and future goals does not contribute to their anxiety but rather is a motivator to learn Calculus. Maria had a very high individual Performance-Driven Perception (PDP-I) and Future-Oriented Perception (FOP) of Calculus exams which helped define her endogenous PI. Maria's PDP-I is exemplified in her acknowledging that Calculus itself was relevant to her future in engineering and viewing Calculus exams as a task that "*helps [her] understand what [she does] and [doesn't] know.*"

Endogenous PI of Calculus, Exogenous PI of Calculus Exams

Another subset of participants held an endogenous PI of Calculus and an exogenous PI of Calculus exams. These students saw Calculus itself as relevant to their future in engineering, but not the task of taking exams in this course. They saw Calculus exams as simply a way to earn a grade (External Purpose, EXT), a means to prove to others what you know (Performance-Driven Purpose—Curricular, PDP-C), or a task meant to cause students stress (Adverse Purpose, ADV). As long as students are able to separate these instrumentalities, they can still be motivated to learn Calculus. Susan, Ollymars, and Andrew were three participants who viewed Calculus itself as relevant to their future in engineering, like Maria, but did not perceive Calculus exams with similar instrumentality. Susan, who held a high EXT for Calculus exams noted that she did not see these exams as relevant to her future: "*I feel like the exams are, it's just a grade that I'm getting.*" Ollymars felt that the purpose of these exams is to demonstrate his understanding to someone other than himself. Andrew's ADV perception of Calculus exams is exemplified when he mentioned, "*You're just answering questions and sometimes, like, I might have mentioned earlier, [Calculus exams are] just excessively complicated to try and see if you mess up on this, like, minor concept.*" Despite their perceptions of the purpose of Calculus exams and these exams' relation to their future, all three of these participants were still motivated to continue learning Calculus. Ollymars best summarizes this when he said,

> "*Even though I do feel, like, stressed or have some anxiety towards these exams, I don't necessarily love it, but I do like learning and doing the Calculus there. But even though the exams do kind of suck sometimes, it doesn't disturb me from actually liking what I do.*"

Exogenous PI of Calculus and Calculus Exams

Another subset of participants perceived neither Calculus nor Calculus exams as relevant to their future. This alignment drove their PDP-C perception of exams as they resigned themselves to these exams being just barriers or tasks they needed to overcome, like Calculus itself. This alignment in exogenous PI of both Calculus and Calculus exams influenced their increased levels of math test anxiety. Connor identified this exogenous PI of both Calculus and Calculus exams, while also expressing the highest levels of math test anxiety of all interview participants. Connor had trouble viewing the relevancy of Calculus to his future in engineering, being unable to describe any aspect of Calculus in relation to engineering. At one point, Connor stated, "*I'm still not sure how [Calculus is] used* *in real world jobs*" and "*There's probably a few sections in [Calculus] that we learned that are probably like, 'What does this have to do with anything?'*" Like Ollymars, Connor also had a strong perception of the purpose of Calculus exams as allowing students to show what they know to someone else. However, this combination of exogenous PI for both Calculus and Calculus exams contributed to his high levels of math test anxiety. Connor did not see Calculus or Calculus exams as useful to his future, yet he knew he was supposed to perform well on them to continue in engineering. He became anxious and frustrated when he was not able to fulfill his perceived purpose of exams (demonstrating his knowledge to someone else), leading to his math test anxiety.

Contingent Paths with High Valued Goals

When one has a highly valued goal in the near future, that goal and the contingent path to reach it may be fragile. Achieving goals within a short extension (within 6 months — 1 year) and on a contingent path will be highly valued, but this may cause anxiety around achieving steps within that contingent path because the end goal is so important to the individual. This emerged when our participants explained what they considered to be contributing to their high levels of math test anxiety. Passing their Calculus course was a highly valued goal in their near future and the grades they received on these exams began a contingent path toward that goal and toward their future in engineering. This made any EXT perceptions of Calculus exams more prominent and led to feelings of high math test anxiety, as depicted on the right side of our model (Figure 4). All five participants mentioned a clear or implied contingent path that depended on their Calculus exam grade and contributed to their levels of math test anxiety. Our participants described these contingent paths as beginning with their Calculus exam grade and affecting things like their scholarships, their engineering coursework, and their future in engineering. For example, Susan described "*the idea that I'll get a bad grade. I'll lose my scholarship, it's all over, I'm going back home.*" Another example of a contingent path was described by Ollymars:

"*I think it's because a lot depends on that [exam] grade. The grade itself in the course depends on it, the grade in that course [determines] whether or not you get the credit for it. That credit [determines] if you can graduate. It kind of chains together a bunch of dependencies on that exam and it adds a lot of stress to it.*"

Mitigating Math Test Anxiety with Thorough Self-Preparation

Two of our participants connected their own preparation for a Calculus exam to their math test anxiety levels, explaining that they sometimes are able to mitigate their anxiety levels by preparing themselves more thoroughly and extensively for an upcoming exam. The more they felt like they were prepared, the less anxiety they felt they might experience. Ollymars states plainly,

> "*I feel like if I study more or study earlier in the week or study more extensively through the night, I'll be better and it would lower my stress and anxiety towards [the Calculus exam], you know?*"

Discussion

Implications for Research

Contributions to Future-Oriented Motivation Literature

These findings support previous work to characterize engineering students' FTP (Kirn, 2014; McGough, 2019; McGough Spence et al., 2022) by confirming the quantitative assessment of FTP constructs and the cluster analysis procedure are applicable for FYE students (Major et al., 2016). This study also considered this population of interest (FYE students) not in the context of their engineering coursework, but rather in the context of their experiences in Calculus I, a course that is instrumental to engineering (SEFI Mathematics Working Group, 2002).

The findings support Puruhito's initial work about a third type of PI, extrinsic PI, as distinct from endogenous and exogenous PI. Puruhito described extrinsic PI as heavily focused on grades in a course (Puruhito, 2017). Extrinsic PI is represented in the right side of our model (Figure 4) where the highly valued goal of passing Calculus is combined with students' contingent paths beginning with their Calculus exam grade. This combination influences students' EXT perception of exams and leads to high math test anxiety. Their intense focus on the exam grade drives this consequence and potentially deters students from using knowledge building strategies, as Puruhito's work suggests.

All interview participants identified some type of contingent path to their future that began with exams, perceiving these high-stakes exams as "gatekeepers" (Raynor, 1978b). While "gatekeepers" are reported to possibly sustain an individual's motivation to achieve the goals in their path (Raynor, 1978b), this study sheds light on how students understand Calculus exams as "gatekeepers" that are not relevant to engineering practice. Andrew highlights this disconnect between Calculus exams and his future in engineering when he explains,

> "*The questions [on a Calculus exam] you're answering, you don't know, like, there's not really a task behind it or a reason behind it. It's just numbers on a screen that you gotta answer. It's not like you're trying to find the most efficient way to make a product or something like that.*"

The fact that participants recognized this disconnect provides supporting evidence for instructors to increase the relevancy of their course material and assessments.

Contributions to Assessment Literature and Students' Well-Being

By considering perceptions from students alongside researcher and instructor perceptions of assessments, conversations to align these purposes can begin and lead to curricular changes that promote learning. These findings also confirm issues with assessments identified in the literature, particularly a shift in focus from the content learned to ensuring students get through a program, likely due to an intense focus on grades (Sadler, 2007) Evidence from our final qualitative analysis showed that students who held EXT, ADV or PDP-C perceptions of exams were apt to see the Calculus exams as a task with exogenous PI. Perhaps instructors can help reduce students' math test anxiety by shifting the focus from simply passing Calculus exams to viewing exams as one part of the multi-faceted, multi-step learning process.

Another issue with assessments identified in the literature was how high-stakes assessments create unfair learning opportunities from an equity lens (National Research Council, 1999b; Pellegrino & Chudowsky, 2003). This issue is highlighted in our model (Figure 4) where math test anxiety is an outcome of the high-stakes nature of these Calculus exams within students' described contingent paths. This is evident in Susan's description of how she would lose her scholarship and have to drop out of college if she did not do well on Calculus exams. Perhaps with the well-being and success of our most vulnerable students in mind (those who rely on scholarships to attend college), we can mitigate the intense, high-stakes nature of the Calculus exam grade to reduce students' math test anxiety and not prevent them from continuing toward their future goals.

The high-stakes nature of Calculus exams also plays into students' social well-being and their thoughts about the impact they can have in society. McArthur et al. (2022) highlight how assessments later in a student's college career may be more obviously tied to a social orientation, but they come after being long "enculturated into a high stakes assessment culture" (McArthur et al., 2022, p. 708). The authors urge educators to "challenge the formation of self-worth purely on the basis of summative assessment results" because the complete absence of social contribution is harmful to a student's own individual well-being (McArthur et al., 2022, p. 709). Reducing the weight of a single exam in the overall course grade and emphasizing the societal contributions of students' achievements (i.e., providing specific examples of how learning Calculus content will help students become better engineers) will elevate students' social well-being.

Implications for Practice

Relevancy of Present Tasks

Our results point back to the motivation behind this study: to assess what we value. The first step to achieving this is ensuring Calculus instructors are able to identify what they value in collaboration with STEM faculty and that our assessments communicate that value. This gives way to the idea of relevance, which can be defined as meaningful connections that educators can foster between the students and the content to uncover personal significance and increase motivation to learn (Priniski et al., 2017; Lynam & Cachia, 2017). This increased integration of STEM topics throughout courses is necessary (Grimes & Gardner, 2023), and an example of this is the Wright State Model for Engineering Mathematics Education which shifts the traditional Calculus sequence to a course that presents relevant math topics within the context of engineering for FYE students (Klingbeil & Bourne, 2015; Finfrock & Klingbeil, 2023).

Design, Weight, and Language Surrounding Exams

Reflective practices that showcase the longitudinal nature of the learning process can be incorporated into assessments through altering their design, weight and the language used to describe them. For example, designing self-reflection components into assessments could allow students to recognize the usefulness and relevance of what they were asked to do on the assessments. Another assessment design is providing an opportunity for students to correct and learn from mistakes they made on an exam. Instructors can encourage the importance of this reflective process by awarding points for such assignments and providing in-depth feedback to emphasize the value of learning from errors. This would take away some of the high-stakes nature of exams as the weight of the exam towards the course grade could be distributed with reflective assignments, emphasizing that learning is valued. This aligns with suggestions to "detangle'' the purposes of assessment and feedback to ensure learning is central (Winstone & Boud, 2020). However, we recognize this pedagogical suggestion for reflective feedback is dependent on class size, where large enrollment classes may not have instructor support for grading and providing constructive feedback on additional assignments. These limitations can be mitigated with support for student-centered learning such as graders, employing peer grading or self-assessments, and formative feedback (which can be ungraded).

The language we use around assessments and the emphasis we place on them within our course structure could also steer students towards desired perceptions of assessments focused on the learning process. An actionable step could first be to investigate what instructors are communicating in our syllabi as they usually contain descriptive information about an assessment's weight in the overall course grade. However, an explicit statement of each assessment's purpose and *why* students are required to complete assessments could be included in our syllabi.

Conclusions

Our study focused on how FYE students with a generally open perception of their future possible careers and high levels of math test anxiety make connections between Calculus exams and their future in engineering based on how useful they perceive the exams and the course content to be. The findings that these students perceive the purpose of Calculus exams in specific ways (a performance-driven purpose, a future-oriented purpose, an external purpose, or an adverse purpose) can inform how instructors explicitly communicate the purpose of assessments to align with what is valued in a curriculum and in the professional formation of engineers. When these students perceived their goals for the future as being contingent on their performance on Calculus I exams, math test anxiety was amplified, which could adversely impact their learning. Students take their cues from the high-stakes nature of exams in required courses and their perceptions of the purpose of exams differ not only from those reported in the literature but likely those of engineering educators as well. We can expand on these conclusions to ensure that all FYE students, even those with differing perceptions of their future, clearly understand the intended purpose of assessments and are able to connect assessment tasks to their perceived future in a constructive way. It is important for educators to determine what they deem valuable and then explicitly communicate this value through the tasks they assign such that students can view a course's assessments as reflections of what is valued in their discipline.

References

Alexander, L., & Martray, C. (1989). The development of an abbreviated version of the mathematics anxiety rating scale. *Measurement and Evaluation in Counseling and Development*, 22, 143–150. doi: https://doi.org/10.1080/07481756.1989.12022923

Ballen, C.J., Salehi, S., & Cotner, S. (2017). Exams disadvantage women in introductory biology. *PLoS ONE*, 12(10). doi: https://doi.org/10.1371/journal.pone.0186419

Bialosiewicz, S., Murphy, K., & Berry, T. (2013). Do our measures measure up? The critical role of measurement invariance. *American Evaluation Association Demonstration Session*.

Black, P., & William, D. (2005). The formative purpose: Assessment must first promote learning. *Yearbook of the National Society for the Study of Education*, 103(2), 20–50. doi: https://doi.org/10.1111/j.1744-7984.2004.tb00047.x

Black, P. (2018). Helping students to become capable learners. *European Journal of Education*, 53(2), 144–159. doi: https://doi.org/10.1111/ejed.12273

Boud, D., & Falchikov, N. (2006). Aligning assessment with long-term learning. *Assessment and Evaluation in Higher Education*, 31(4), 399–413. doi: https://doi.org/10.1080/02602930600679050

Brown, G., & Hirschfeld, G. (March 2008). Students' conceptions of assessment: Links to outcomes. *Assessment in Education*, 15(1), 3–17. doi: http://dx.doi.org/10.1080/09695940701876003

Burn, H., & Mesa, V. (2015). The calculus I curriculum. In Bressoud, D., Mesa, V., and Rasmussen, C. (Eds.), *Insights and Recommendations from the MAA National Study of College Calculus*, (pp. 45–57). The Mathematical Association of America (Incorporated), Washington, D.C.

Carnegie Foundation for the Advancement of Teaching (2001). *The Carnegie classification of institutions of higher education*. Menlo Park, CA. https://carnegieclassifications.acenet.edu/

Creamer, E. (2018). *An introduction to fully integrated mixed methods research.* SAGE Publications, Inc., Thousand Oaks. doi: https://doi.org/10.4135/9781071802823

Creswell, J. (2014). *Research design: Qualitative, quantitative and mixed methods approaches (4th ed.)*. SAGE, Thousand Oaks.

Creswell, J., Plano Clark, V., Gutmann, M., & Hanson, W. (2003). Advanced mixed methods research designs. In Tashakkori, A. and Teddlie, C. (Eds.), *Handbook of mixed methods in social and behavioral research*, (pp. 209–240). Sage, Thousand Oaks, CA.

Daultrey, M., & Langer, P. (1984). Development and evaluation of a measure of future time perspective. *Perceptual and Motor Skills*, 58(3), 719–725. doi: https://doi.org/10.2466/pms.1984.58.3.719

De Volder, M., & Lens, W. (1982). Academic achievement and future time perspective as a cognitive-motivational concept. *Journal of Personality and Social Psychology*, 42(3), 566–571. doi: http://dx.doi.org/10.1037/0022-3514.42.3.566

Ellis, J., Kelton, M.L., & Rasmussen, C. (2014). Student perceptions of pedagogy and associated persistence in calculus. *ZDM The International Journal on Mathematics Education*, 46(4), 661–673. doi: http://dx.doi.org/10.1007/s11858-014-0577-z

Ferguson, R. (1986). Abstraction anxiety: A factor of mathematics anxiety. *Journal for Research in Mathematics Education*, 17(2), 145–150. doi: https://doi.org/10.2307/749260

Finfrock, R., & Klingbeil, N.W. (2023). Examining the impacts of the Wright State Model for engineering mathematics education through curricular analytics. *American Society for Engineering Education Conference and Exposition 2023*, (Paper ID: 40066), 1–15. doi: http://dx.doi.org/10.18260/1-2--43521

French, S., Dickerson, A., & Mulder, R.A. (2024). A review of the benefits and drawbacks of high-stakes final examinations in higher education. *Higher Education*, 88, 893–918. doi: https://doi.org/10.1007/s10734-023-01148-z

Glaser, R., Linn, R., & Bohrnstedt, G. (1997). *Assessment in transition: Monitoring the nation's educational progress*. National Academy of Education, New York.

Greene, J., Caracelli, V., & Graham, W. (1989). Toward a conceptual framework for mixed-method evaluation designs. *American Educational Research Association*, 11(3), 255–274. doi: https://doi.org/10.3102/01623737011003255

Grimes, Z.T., & Gardner, F. (2023). Conceptions of disciplinary anxiety across science, technology, engineering, and mathematics (STEM) contexts: A critical and theoretical synthesis. *Journal of Research in Science, Mathematics and Technology Education*, 6(SI), 21–46. doi: http://dx.doi.org/10.31756/jrsmte.212SI

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 21(1), 33–46. doi: https://doi.org/10.2307/749455

Hilpert, J., Husman, J., Stump, G., Kim, W., Chung, W., & Duggan, M. (2012). Examining students' future time perspective: pathways to knowledge building. *Japanese Psychological Research*, 54(3), 229–240. doi: https://doi.org/10.1111/j.1468-5884.2012.00525.x

Hu, L., & Bentler, P. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, 6(1), 1–55. doi: https://doi.org/10.1080/10705519909540118

Husman, J., Derryberry, W., Crowson, H., & Lomax, R. (2004). Instrumentality, task value, and intrinsic motivation: Making sense of their independent interdependence. *Contemporary Educational Psychology*, 29(1), 63–76. doi: http://dx.doi.org/10.1016/S0361-476X(03)00019-5

Husman, J., & Lens, W. (1999). The role of the future in student motivation. *Educational Psy- chologist*, 34(2), 113–125. doi: https://psycnet.apa.org/doi/10.1207/s15326985ep3402_4

Husman, J., & Shell, D. F. (2008). Beliefs and perceptions about the future: A measurement of future time perspective. *Learning and Individual Differences*, 18(2), 166–175. doi: https://doi.org/10.1016/j.lindif.2007.08.001

Kenyon, C. (2023). *Assessing what we value: Interactions between student perceptions of assessments in the calculus classroom and their future-oriented motivation*. [Doctoral dissertation, Clemson University]. Clemson Open All Dissertations.

Kenyon, C., Benson, L., & Bridges, W. (2022). First-year engineering student perceptions of calculus exams and future-oriented motivation. *American Society for Engineering Education Conference and Exposition 2022*, (Paper ID: 37156), 1–15. doi: https://doi.org/10.18260/1-2--41021

Kirkland, M. (1971). The effect of tests on students and schools. *Review of Educational Research*, 41(4), 303–350. doi: https://doi.org/10.3102/00346543041004303

Kirn, A. (2014). *The influences of engineering student motivation on short-term tasks and long-term goals*. [Doctoral dissertation, Clemson University]. Clemson Open All Dissertations.

Kirn, A., & Benson, L. (2015). Engineering students' perceptions of the future: Exploratory instrument development. *American Society for Engineering Education Conference and Exposition 2015.* (Paper ID: 11470), 1–14. doi: http://dx.doi.org/10.18260/1-2--20398

Klingbeil, N.W., & Bourne, A. (2015). The Wright State Model for engineering mathematics education: longitudinal impact on initially underprepared students. *American Society for Engineering Education Conference and Exposition 2015*, (Paper ID: 13229), 1–11. doi: http://doi.org/10.18260/p.24917

Looney, J. (2018). Are student assessments fit for their purposes? *European Journal of Education*, 53(2), 129–132. doi: https://doi.org/10.1111/ejed.12276

Luttenberger, S., Wimmer, S., & Paechter, M. (2022). Spotlight on math anxiety. *PsychologyResearch and Behavior Management*, pages 311–322. doi: https://doi.org/10.2147/PRBM.S141421

Lynam, S., & Cachia, M. (2017). Students' perceptions of the role of assessments at higher education. *Assessment & Evaluation in Higher Education*, 43(2), 223–234. doi: https://doi.org/10.1080/02602938.2017.1329928

Major, J., Boone, H., Tsugawa, M., McGough, C., Kirn, A., & Benson, L. (2016). Engineering students' perceptions of the future: Transferability and replication of time perspective classifications. *Proceedings of the National Association for Research in Science Teaching Conference (NARST) 2016*.

McArthur, J., Blackie, M., Pitterson, N., & Roswell, K. (2022). Student perspectives on assessment: connections between self and society. *Assessment & Evaluation in Higher Education*, 47(5), 698–711. doi: https://doi.org/10.1080/02602938.2021.1958748

McGough, C. (2019). *A mixed methods study on mid-year engineering students' perceptions of their future possible careers*. [Doctoral dissertation, Clemson University]. Clemson Open All Dissertations.

McGough Spence, C., Kirn, A., & Benson, L. (2022). Perceptions of future careers for middle year engineering students. *Journal of Engineering Education*, 111(3), 595–615. doi: https://doi.org/10.1002/jee.20455

Moran, G., & Benson, L. (2016). Effects of an intensive mathematics course on freshmen engineering students' mathematics anxiety perceptions. *American Society for Engineering Education Conference and Exposition 2016*, (Paper ID: 15276), 1–10. doi: https://doi.org/10.18260/p.26915

National Research Council (1999a). *Grading the nation's report card: Evaluating NAEP and transforming the assessment of educational progress*. National Academy Press, Washington, DC.

National Research Council (1999b). *High stakes: Testing for tracking, promotion, and graduation*. National Academy Press, Washington, DC.

National Research Council. (2001). *Knowing what students know: The science and design of educational assessment.* Committee on the Foundations of Assessment. Pellegrino, J., Chudowsky, N., & Glaser, R. (Eds.), Board on Testing and Assessment, Center for Education. Division of Behavioral and Social Sciences and Education. Washing, DC: National Academy Press.

Newton, P. (July 2007). Clarifying the purpose of educational assessment. *Assessment in Education*, 14(2), 149–170. doi: https://doi.org/10.1080/09695940701478321

Pellegrino, J., & Chudowsky, N. (2003). The foundations of assessment. *Measurement Interdisciplinary Research and Perspective*, 1(2), 103–148. doi: http://dx.doi.org/10.1207/S15366359MEA0102_01

Priniski, S. J., Hecht, C. A., & Harackiewicz, J. M. (2017). Making learning personally meaningful: A new framework for relevance research. The Journal of Experimental Education, 86(1), 11–29. doi: https://doi.org/10.1080/00220973.2017.1380589

Puruhito, K. (2017). *Connecting to the future: A revised measure of exogenous perceptions of instrumentality*. [Doctoral dissertations, Arizona State University]. ASU Library Keep.

Puruhito, K., Husman, J., Hilpert, J. C., Ganesh, T., & Stump, G. (2011). Increasing instrumentality without decreasing instructional time: An intervention for engineering students. *41st ASEE/IEEE 2011 Frontiers in Education Conference.* F2J-1–F2J-6. doi: https://doi.org/10.1109/FIE.2011.6143091

Raynor, J. O. (1978a). Future orientation in achievement motivation: A more general theory of achievement motivation. In Atkinson, J. & Raynor, J. (Eds.), *Personality, Motivation, and Achievement*, (pp. 71–115). Hemisphere Publishing Corporation, Washington, D.C.

Raynor, J.O. (1978b). Motivation and career striving. In Atkinson, J .and Raynor, J. (Eds.), *Personality, Motivation, and Achievement*, (pp. 199–219). Hemisphere Publishing Corporation, Washington, D.C.

Raynor, J. (1981). Future orientation and achievement motivation: Toward a theory of personality functioning and change. In d'Ydewalle, G. & Lens, W. (Eds.), *Cognition in human motivation and learning*, (pp.199–231). Leuven University Press and Lawrence Erlbaum Associates, Inc., Leuven, Belgium and Hillsdale, NJ.

Rea-Dickins, P. (1997). So, why do we need relationships with stakeholders in language testing? A view from the UK. *Language Testing*, 14(3), 304–314. doi: https://doi.org/10.1177/026553229701400307

Richardson, F., & Suinn, R. (1972). The mathematics anxiety ratings scale: Psychometric data. *Journal of Counseling Psychology*, 19(6), 551–554. doi: https://psycnet.apa.org/doi/10.1037/h0033456

Riley, D. (2016). We assess what we value: “evidence-based” logic and the abandonment of “non-assessable” learning outcomes. *American Society for Engineering Education Conference and Exposition 2016*, (Paper ID: 16346), 1–22. doi: https://doi.org/10.18260/p.27187

Rounds, J., & Hendel, D. (1980). Measurement and dimensionality of mathematics anxiety. *Journal of Counseling Psychology*, 27(2), 138–149. doi: http://dx.doi.org/10.1037/0022-0167.27.2.138

Roy, J., Wilson, C., Erdiaw-Kwasie, A., & Stuppard, C. (2020). Engineering and engineering technology by the numbers 2019. American Society for Engineering Education.

Sadler, D. (November 2007). Perils in the meticulous specification of goals and assessment criteria. *Assessment in Education*, 14(3), 387–392. doi: http://dx.doi.org/10.1080/09695940701592097

Scott, C. (March 2007). Stakeholder perceptions of test impact. *Assessment in Education*, 14(1), 27–49. doi: http://dx.doi.org/10.1080/09695940701272807

SEFI Mathematics Working Group (2002). *Mathematics for the European engineer: A curriculum for the twenty-first century*. SEFI HQ, Brussels, Belgium.

Siddiqui, K. (2013). Heuristics for sample size determination in multivariate statistical techniques. *World Applied Sciences Journal*, 27(2), 285–287. doi: 10.5829/idosi.wasj.2013.27.02.889

Smith, J., Flowers, P., & Larkin, M. (2009). *Interpretive phenomenological analysis: Theory, method and research*. SAGE Publications Ltd.

Stuyven, K., Dochy, F., & Janssens, S. (August 2005). Students’ perceptions about evaluation and assessment in higher education: a review. *Assessment and Evaluation in Higher Education*, 30(4), 325–341. doi: https://doi.org/10.1080/02602930500099102

Suinn, R., & Winston, E. (2003). The mathematics anxiety rating scale, a brief version: Psychometric data. *Psychology Reports*, 92(1), 167–173. doi: https://doi.org/10.2466/pr0.2003.92.1.167

Torrance, H. (November 2007). Assessment as learning? How the use of explicit learning objectives, assessment criteria and feedback in post-secondary education and training can come to dominate learning. *Assessment in Education*, 14(3), 281–294. doi: http://dx.doi.org/10.1080/09695940701591867

VanCalster, K., Lens, W., & Nuttin, J. (1987). Affective attitude toward the personal future: Impact on motivation in high school boys. *American Journal of Psychology*, 100(1), 1–13. doi: https://doi.org/10.2307/1422639

Winstone, N.E., & Boud, D. (2020). The need to disentangle assessment and feedback in higher education. *Studies in Higher Education*, 47(3), 656–667. doi: https://doi.org/10.1080/03075079.2020.1779687

Zaman, N., Bibi, Z., Sheikh, S.R., & Raziq, A. (2020). Manualizing factor analysis of Likert scale data. *Journal of Management Sciences*, 7(2), 56–67.

Corresponding Author Contact Information:

Author name: Catherine M. Kenyon

Department: Department of Applied Mathematics

University, Country: Florida Polytechnic University, United States of America

Email: ckenyon@floridapoly.edu

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