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Exploring Practical Measures as an Approach for Measuring Elementary Students' Attitudes Towards Computer Science

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Abstract

This paper presents a novel approach for predicting the outcomes of elementary students' participation in computer science (CS) instruction by using exit tickets, a type of practical measure, where students provide rapid feedback on their instructional experiences. Such feedback can help teachers to inform ongoing teaching and instructional practices. We fit a Structural Equation Model to examine whether students' perceptions of enjoyment, ease, and connections between mathematics and CS in an integrated lesson predicted their affective outcomes in self-efficacy, interest, and CS identity, collected in a pre- post- survey. We found that practical measures can validly measure student experiences.

Objectives

Historically, outcome measures have been used in education for evaluative purposes as part of accountability systems or for advancing theoretical constructs (Yeager et al., 2013). Although outcome measures serve a purpose in the larger educational ecosystem, they were not designed to inform classroom instruction and practices in real time. This shortcoming of outcome measures has catalyzed the emergence of what are called *practical measures*, measures that are intimately linked with the processes of teaching and learning, and capable of predicting outcomes relating to these practices (Penuel et al., 2018).

Practical measures diverge from their outcome counterparts primarily in their applicability. While outcome measures are summative, focusing on end results, practical measures adopt a formative approach, offering immediate feedback that can shape ongoing teaching and classroom instruction. One form of practical measures used in educational research is student exit tickets. Penuel et al. (2018) defined student exit tickets as short surveys administered at the end of each instructional unit, providing educators with insights to inform their ongoing instructional practices (Raza et al., 2021). Further, these practical measures, used recurrently, are not just informative but can also be predictive of essential educational outcomes (Yeager et al., 2013).

The present study builds on the validity argument of practical measures as articulated by Penuel et al. (2018), while addressing the challenges associated with their validation. We used exit tickets to measure students' experiences and statistical modeling to analyze predictive relationships between exit tickets and pre-post surveys that measured outcomes linked to attitudes towards computing. The present study is guided by the following research questions:

RQ1: Can exit tickets serve as valid measures of students' classroom learning experience?

RQ2: How well do the lesson-specific exit tickets predict student affective outcomes?

The first question aims to identify valid exit ticket items that measure students' learning experiences and can be embedded within the learning process. The second question builds on the first, aiming to predict students' CS affective outcomes based on students' reported experiences using exit tickets. It seeks to these practical measures, moving beyond previous attempts that were either impractical due to length of practical measures (Kosovich et al., 2015) or unsuccessful in establishing a connection between student exit tickets and learning outcomes (Penuel et al., 2018).

By identifying useful student experience measures, we seek to fill a noted gap in the motivational literature, which currently lacks methods for systematically capturing student emotions related to their learning experiences in real-time (Graham, 2020). Exit tickets are administered directly post-instruction, and can serve as a vehicle to record these momentary affective states, capturing their cumulative and recursive changes (Eccles & Wigfield, 2020). Thus, we examine what extent can CS educators use easy-to-administer exit tickets as reliable and valid proxies of important student affective outcome measures related to their perceptions of CS.

Background and Context

Practical Measures

Practical measures are closely tied to teaching and learning processes, providing insights on instructional effectiveness (Penuel et al., 2018). Practical measures are administered during instruction; thus, they provide contextually relevant, real-time insights supplementing the longer-term perspectives of outcome measures (see Table 1 for a comparison between practical and outcome measures). Practical measures can better support daily classroom needs while being less resource-intensive (Bryk et al., 2015; Yeager et al., 2013). Despite their advantages, validation of practical measures can be challenging to interpret due to their brevity (Penuel et al., 2018).

Table 1

A Comparison of Different Advantages of Practical Measures and Outcome Measures

Practical Measures Advantages	Outcome Measures Advantages
Informs practice decisions	Assesses change over time
Less time consuming to administer	More in-depth examination of learning
Geared toward improvement	Parses out influences of overlapping constructs
Can be administered frequently	Targets long-term change
Experience is measured	Users answer by recalling and reflecting on a collection of experiences

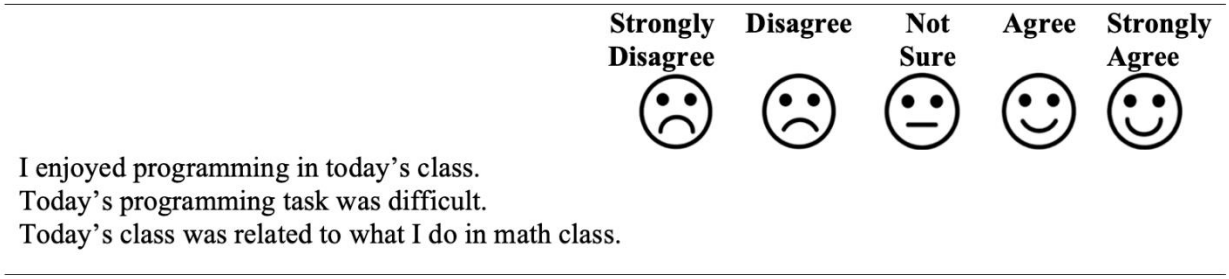
Penuel et al. (2018) outline three validity criteria for practical measures:

1. Improvement Focus: Measures should prioritize enhancing educational practices, addressing challenges faced by learners.
2. Predictive Ability: Measures need to predict student outcomes and validate these early predictions over time (Kosovich et al., 2015).
3. Integration with Learning: Measures should be part of educational activities, thus tied to student progress in those activities.

This study examines the adherence of the exit ticket items (See Figure 1) to the three selection criteria outlined by Penuel et al. (2018). The broader project (Shehzad et al., 2023) aligns with the first criterion by targeting improved instructional practices. For the second, a statistical model gauges the predictive relationships between exit tickets and affective outcomes. Surveys administered during the learning process satisfy the third criterion. Unlike Penuel et al.'s (2018) study which assessed learning outcomes, this research measures learners' attitudes towards computing across various parameters.

Figure 1

Student exit tickets on a 5-point Likert scale



Methods

Research Context

This study is part of a larger research project collaborating with a rural school district with 17 elementary schools. The research team collaborated with district content leaders and educators to co-design instructional units for Grade 5 that integrated mathematics and CS concepts across two instructional contexts, the regular classroom and the computer lab. Across all 17 schools, students participated in math-integrated CS lessons in the computer lab and CS-integrated math lessons in their regular classrooms. The present study focuses on the computer lab lessons.

Data Sources

Data sources include the exit tickets (practical measures) and pre-post surveys (affective outcome measures).

Affect Outcome measures

The outcome measures used in this study include constructs identified in the literature that relate to students' attitudes towards computing. It incorporates items from previous works (Clarke-Midura et al., 2019; Hulleman, 2007) and its design prioritizes practicality over precision. This is evident in the fact that it includes a total of only 9 items related to self-efficacy, interest, and computer science identity (see Table 2).

Table 2

Student Affect Survey Items Measured On A 5-point Likert Scale (1 = Strongly Disagree to 5 = Strongly Agree) and Respective Constructs

Survey Item	Construct
I am a good computer programmer.	Self-Efficacy
I could do more challenging computer programming.	Self-Efficacy
I can program computers well.	Self-Efficacy
The programming we are learning in the computer lab is interesting.	Interest
Computer programming is boring.	Interest
I am interested in computer programming outside of the computer lab.	Interest
Computer programming is interesting.	Interest
I could become a computer programmer one day.	CS Identity
I can be a computer programmer.	CS Identity

Data Collection

The exit tickets (see Figure 1) were administered in the computer lab twice in one academic year, once after the first lesson implementation in the fall and then in the spring after a second lesson implementation. We administered the affect outcome survey (see Table 2) before and after the two-lesson implementation. Table 3 below shows the number of students, classes, and schools that participated in the surveys and exit tickets.

Table 3

Frequencies of students, classes, and schools that took the two types of surveys

Type	Instrument	# Schools	# Classes	'n' students
Outcome measure	Pre-survey September 2022	17	49	1153
	Post-survey March 2023	12	35	848
Practical measure	CS Exit Tickets Fall 2022	17	47	1067
	CS Exit Tickets Spring 2023	15	45	929

Analysis

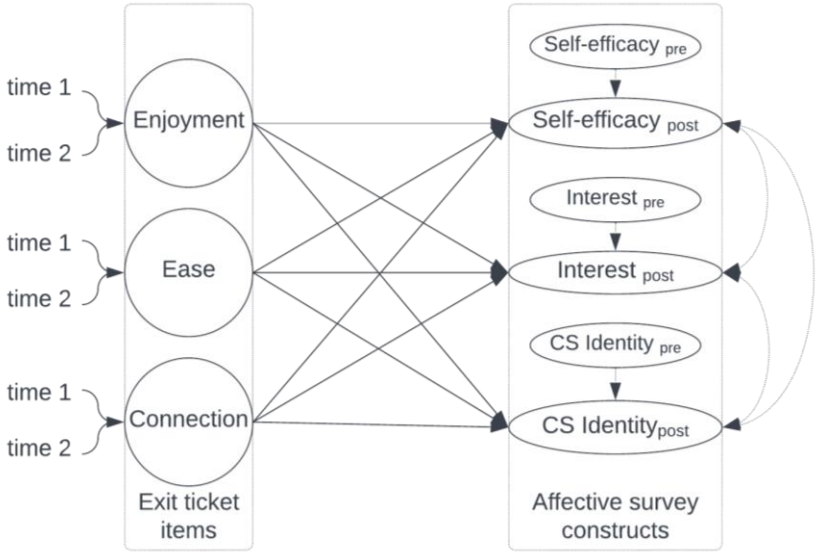
For analysis, we used Structural Equation Modeling (SEM) over analysis of variance (ANOVA) or linear regression due to its distinctive advantages. SEM allows for simultaneous estimation of multiple, interrelated relationships (Kline, 2016), hence providing a comprehensive view of the data landscape. Furthermore, SEM allows for the analysis of latent variables and measurement error, permitting a more precise and nuanced understanding of underlying constructs and relationships within the data.

Path diagram

Figure 2 shows a path diagram demonstrating the hypothesized relationships between affect measures on the post-survey and student exit ticket measures. The two instances (fall and spring) of administering each exit ticket item were represented by a combined effect latent variable for the items of enjoyment and ease. We used the CS math connection item as an observed variable (an average of the two time points), a decision influenced by the issues of model convergence. The exit ticket items served as the independent variables, and the affective outcomes of interest, self-efficacy, and computer science identity functioned as dependent variables in our model.

Figure 2

SEM model diagram based on working theory



Results

We conducted our analysis using the lavaan package (Rosseel, 2012) in R (R Core Team, 2023) to specify the path model shown in Figure 2 as a structural equation model. First, we tested the measurement invariance of our model across the two timepoints when the exit ticket data was collected. The test included data for the students who responded to exit tickets at both timepoints (n = 557). This step is crucial for establishing the statistical validity of practical measures (Kosovich et al., 2015).

Chi-square results (Table 4) indicate that none of the three comparisons were significant, thereby affirming strict measurement invariance across timepoints.

The resulting model fit statistics were: $\chi 2$ (201, N = 1564) = 569.9, $p < .001$; CFI = 0.952; TLI = 0.945; RMSEA = 0.038; SRMR = 0.040. Based on Hu and Bentler's (1999) stringent cutoffs, the metrics—CFI, SRMR, and RMSEA—indicate a good model fit, as they fall within the acceptable ranges (CFI > 0.95; RMSEA < .08; SRMR < .08).

Table 4

Chi-square Tests for Measurement Invariance Across Timepoints

Models compared	DF	$\chi 2$	p-val
Variable factor loadings Restricted factor loadings	12	0.13	1
Restricted factor loadings Restricted factor loadings and intercepts	15	10.26	.803
Restricted factor loadings and intercepts Restricted factor loadings, intercepts, and error variances	21	1.34	1

The regression results of this model are reported in Table 5, showing predictive relationships between exit ticket items and post-survey measures of Self-efficacy, Interest, and CS Identity.

Table 5

Results showing predictive relationship between student exit ticket items and post-survey constructs (Self-efficacy, Interest, and CS Identity)

		Self-efficacy post-survey		**Interest** post-survey		**CS Identity** post-survey	
N = 848		# Items = 3		# Items = 4		# Items = 2	
Predictor	N (time1, time2)	Std β	SE	Std β	SE	Std β	SE
--	1153	0.30***	0.07	-0.62	0.87	0.27***	0.06
Enjoyment	1062,926	0.34**	0.14	1.98*	1.53	0.41***	0.15
Ease	1058,926	0.26*	0.16	-0.79	0.9	0.07	0.16
Connection	1056,925	0.01	0.05	-0.39	0.27	-0.01	0.05

Note: Estimates are standardized

As shown in Table 5, perceived enjoyment, as reported in the exit tickets, significantly predicted post-survey measurements of self-efficacy (Std β = 0.34, SE = 0.14, p = .001), interest (Std β = 1.98, SE = 1.53, p = .05), and CS identity (Std β = 0.41, SE = 0.15, p < .001) —while controlling for the respective pre-survey measurements. Perceived ease, also recorded in the exit tickets, significantly predicted post-survey measurement of self-efficacy (Std β = 0.26, SE = 0.16, p = .013) while controlling for the pre-survey measurement of self-efficacy. The relationships of ease with Interest and CS Identity were not significant while controlling for their respective pre-survey measurements. The perceived connection between math and CS, reported in the exit tickets, did not significantly predict any of the affective constructs measured on the post-survey, when pre-survey measures were taken into account.

Table 6 presents the standardized values of factor loadings. It shows that all items loaded strongly (> 0.5) onto their corresponding constructs, demonstrating construct validity of the model.

From the findings, we can conclude:

- Exit tickets are valid tools for capturing students' real-time perceptions of instructional activities, as demonstrated by the invariance of measurements across two timepoints (Kosovich et al., 2015).
- Exit tickets can predict the summative measures of student affect outcomes, i.e., enjoyment predicts self-efficacy, interest, and CS identity and ease predicts self-efficacy.
- While the perceived connection between math and CS did not predict any of the affective constructs measured, it remains a statistically valid measure that aligns with the overarching instructional goals and theory of the research project.

Table 6

Standardized values of factor loadings

		Pre-survey		Post-survey	
Construct	Item	Std β	SE	Std β	SE
Self-Efficacy	item 1	0.75	0	0.84	0
Self-Efficacy	item 2	0.67***	0.05	0.73***	0.04
Self-Efficacy	item 3	0.72***	0.05	0.78***	0.03
Interest	item 1	0.71	0	0.84	0
Interest	item 2	0.68***	0.06	0.76***	0.04
Interest	item 3	0.65***	0.06	0.76***	0.04
Interest	item 4	0.87***	0.06	0.9***	0.03
CS Identity	item 1	0.74	0	0.87	0
CS Identity	item 2	0.87***	0.05	0.87***	0.03
Student exit tickets					
enjoyment	time 1	0.62	0	--	--
enjoyment	time 2	0.62***	0.08	--	--
ease	time 1	0.5	0	--	--
ease	time 2	0.53***	0.18	--	--

*** $p < .001$

Significance

These findings confirm that student exit tickets can serve as easy-to-administer and reliable practical measures, capable of being embedded in the learning process to capture students' immediate learning experiences. The study revealed that items on exit tickets, specifically those regarding students' perceived enjoyment and ease of tasks, can accurately predict affective outcomes, thus demonstrating their predictive capacity and utility in educational practice. The findings also make a case for using exit tickets as a proxy for more time intensive measures of student affect.

By providing immediate, actionable feedback on students' experiences, educators can dynamically respond to the changing needs of their students, ultimately enhancing their learning outcomes. The study's results also contribute to the broader understanding of the interplay between students' in-the-moment experiences and their broader affective outcomes in an educational context.

These results show that incorporating student exit tickets into CS instructional activities can be an effective means for capturing cognitive and emotional experiences in real-time.

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