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Exploring the potential of exit tickets as formative assessments of student affect

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ABSTRACT

This study investigates the use of exit tickets as formative assessments in maths-integrated computer science (CS) lessons for grade 5 students. Exit tickets are brief surveys administered immediately after instructional activities. Using structural equation modelling (SEM), we analysed data from 1,067 students to examine the reliability and validity of exit tickets in predicting summative pre/post survey results. The study found that the exit ticket responses consistently assessed student affect at two administration points, meeting strict measurement invariance criteria ($\chi2(21) = 1.34$, $p = 1.00$). Confirmatory factor analysis revealed that exit tickets predicted student self-efficacy and interest in CS, which are key educational outcomes. These findings suggest that exit tickets can be valuable tools for enhancing instructional practices and supporting student learning and engagement in CS education. The study concludes with recommendations for effectively implementing exit tickets in educational settings.

Introduction

There has been a growing emphasis on the role of formative assessment in classroom learning (see, e.g. Allal, 2021; Cai et al., 2022; Yan & King, 2023; Yan et al., 2021). However, most studies on formative assessment focus on cognitive aspects of learning, such as knowledge, skills, and abilities (Cowie & Bell, 1999). Very few studies have systematically explored the use of formative assessments to measure student affect (Shen, 2002). This lack of research is problematic, as student affect, also referred to as students' emotions and attitudes, plays an important role in the learning process. Indeed, affect has been shown to significantly influence students' motivation, engagement, and ultimately their academic success (Ainley, 2006; Pekrun et al., 2002).

Exploring how we can use formative assessments to measure affect has the potential to provide useful information to teachers. Emotions such as enjoyment, frustration, and perceived difficulty play a crucial role in shaping students' classroom experiences and learning outcomes. Understanding and addressing these emotional responses can provide teachers with valuable insights to tailor their instructional strategies more effectively (Brookhart et al., 2004; McDonald & Boud, 2003).

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The purpose of this study is to present a formative assessment model that focusses on measuring student affect through exit tickets. Exit tickets are short surveys given at the end of instructional units (Raza et al., 2021). They provide immediate, contextually relevant insights for ongoing instructional practices (Yeager et al., 2013). The aggregated results from exit tickets can be visualised in charts and tables, making them useful for teachers to inform improvements to their instructional practices (Raza et al., 2024). We present findings from a study in which elementary students responded to a short, three-question exit ticket regarding their perceptions of the maths-integrated computer science lesson. Analyses of responses using structural equation modelling (SEM) showed that the instrument is a reliable and valid measure of students' affective responses to classroom lessons. We discuss ways that teachers can leverage the use of exit tickets to enhance their instructional practices to better support student learning and engagement.

Literature Review

Formative assessments

Although the definitions of what constitutes a formative assessment vary (see, e.g. Bennett, 2011; Black & Wiliam, 2018; Kyaruzi et al., 2019), its main purpose is to gather information about students' understanding during instruction. For example, Black & Wiliam defined formative assessments in their seminal paper as activities by teachers or students that provide feedback for modifying instruction (Black & Wiliam, 1998). In the same vein, we define affective formative assessments as tools to record students' perceptions of their own learning. This information serves a dual purpose: it can be used to modify or inform instruction (Black & Wiliam, 1998; Shepard et al., 2005) and ultimately to improve student learning (Black & Wiliam, 1998, 2018; Moss, 2008). Formative assessments encompass a variety of formats and approaches, are specific to a discipline, and have been shown to enhance educational outcomes (Andrade & Valtcheva, 2009; Yan & King, 2023; Yan et al., 2021). Formative assessments include methods such as quizzes (Zainuddin et al., 2020), polls, and worksheets (Cusi et al., 2017), and tasks such as free-write or open-ended questions (Furtak et al., 2019). Students' responses to these assessments help teachers identify areas where students struggle, adjust their teaching strategies accordingly, and support student learning in real time (Carless, 2007). Additionally, formative assessments can enhance instructional practices, and self-assessments empower students by involving them in their own learning process and promoting self-regulation and autonomy (Brookhart et al., 2004; Dignath et al., 2023; Wylie & Lyon, 2015; Yan & Carless, 2022). Asking students to reflect on their enjoyment or difficulty of a lesson provides valuable feedback to teachers to improve classroom instruction and has the potential to send a message that teachers value students' input.

Measuring the affect

The intricate interplay between student perceptions, attitudes, and academic performance highlights the importance of considering affect alongside traditional measures of achievement. Wu et al. (2021) revealed a complex interplay between academic self-concept (ASC) and achievement. They found a reciprocal relationship, with the influence of each on the

other growing stronger as the students mature. However, the impact of achievement on ASC is more pronounced in younger children. Furthermore, the effect of ASC on achievement varies depending on age, achievement level, and assessment method. In particular, low-achieving students exhibit a weaker relationship between ASC and achievement (Wu et al., 2021). Wang and Yu (2023) found that while academic self-concept improves achievement, motivation, and self-efficacy, the relationship is moderated by gender. They found that gender stereotypes have a negative influence on female students' self-concept and self-efficacy in maths. Enjoyment, which is a part of students' perceived intrinsic value of a task, has been shown to predict self-assessed productivity (Bradley & Lang, 1994) and increase self-efficacy (Kinnunen & Simon, 2011). In the field of computer science education, research has found that enjoyment leads to positive attitudes towards learning (Cabada et al., 2018). The perceived difficulty of a task is another affective construct that also correlates with enjoyment. Perceived difficulty can have both positive and negative effects. It can negatively impact expectancies for success and self-efficacy (Eccles & Wigfield, 2020; Weiner, 2010), leading to motivational deficits and frustration (Graham, 2020; Rattan et al., 2012). This frustration, in turn, can negatively affect performance (Lishinski et al., 2017; Weiner, 2010). However, success in difficult tasks can foster pride and positive emotions (Weiner, 2010). Additionally, perceived difficulty can enhance intrinsic value and interest (Eccles & Wigfield, 2020). The key is to find the right balance of difficulty. Tasks of intermediate difficulty are preferable to maintain motivation without external incentives (Weiner, 2010). Tasks perceived as too easy can lead to boredom, whereas overly difficult tasks cause frustration.

Exit tickets vs. Affective outcomes surveys

Educational researchers have long relied on comprehensive surveys to gain insights into students' affect towards learning in a specific context. However, these traditional methods have limitations. Exit tickets offer advantages over long-form surveys. They provide an 'in-the-moment' perspective on student motivation and engagement, potentially reflecting students' current attitudes and experiences with more precision (see Table 1 and Figure 1 comparing the two forms of assessments). Moreover, exit tickets are quick to administer, minimally impact instructional time while allowing more frequent data collection (Bryk et al., 2015; Yeager et al., 2013).

Table 1. A comparison of affective outcomes surveys and exit tickets (Duckworth & Yeager, 2015; Kosovich et al., 2015; Yeager et al., 2013)

| Affective Outcomes Surveys	Exit tickets
Assesses change over time	Informs practice decisions
Provides more in-depth examination of learning	Is less time consuming to administer
Parses out influences of overlapping constructs	Is geared towards improvement
Targets long-term change	Can be administered frequently
Users answer by recalling and reflecting on a collection of experiences	Measures student experience
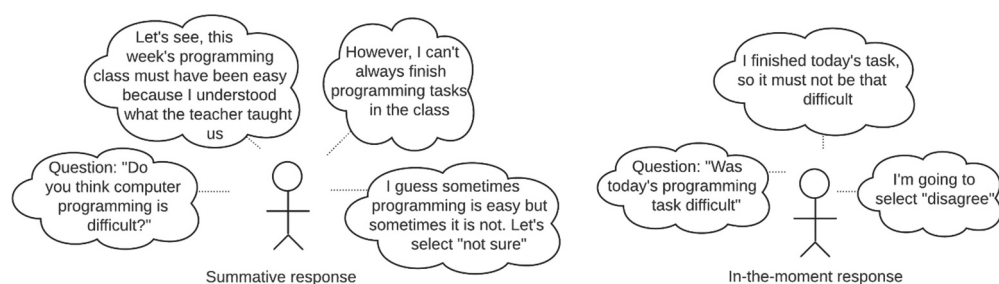
Figure 1. The process by which students respond to summative and in-the-moment surveys. Adapted from Duckworth and Yeager (2015)

Assessing affect via exit tickets

The exit tickets in this study differ from typical formative assessments that measure student achievement (Lajoie, 2008; Leighton et al., 2012) and reasoning (Hondrich et al., 2016). Instead of direct achievement measures, these exit tickets capture students' self-reported perceptions of their learning. We posit that this approach will help reduce anxiety and fear of failure often associated with traditional assessments, making it more inclusive for students with low self-efficacy (Zheng et al., 2023). Despite their simplicity, establishing the validity of brief formative assessments is a challenging task due to the lack of variance in the small number of items (Bryk et al., 2015; Penuel et al., 2018; Yeager et al., 2013). This leads to difficulties in establishing internal reliability, resulting in scarce research on testing their validity. Penuel et al. (2018), along with other scholars, have established specific criteria to evaluate the validity of short affective assessments, such as exit tickets. These criteria are as follows:

(1) Focus on improving practice: The chosen measures should centre on improving educational practices. To achieve this, they need to be fundamentally linked to the underlying issues encountered during the learning process. This connection ensures that these measures serve to directly address and overcome challenges experienced by learners (Yeager et al., 2013). In our study, the instructional unit focused on topics and concepts recommended by the mathematics and CS teachers in the district. The unit was co-designed to help teachers communicate these ideas while addressing barriers in providing high-quality computer science instruction given constraints in their local educational infrastructures.

(2) Embeddedness in the learning process: These assessments should be integrated within the learning process. They should not function as isolated tools, but should actively be a part of educational activities, informing teachers about the progression of learning of the students. In our study, we hoped to achieve this by providing aggregated student response feedback from the first classroom implementation with their teachers before the next implementation. As this was an ongoing project, feedback from the second implementation was provided to help teachers prepare for the following year's implementation.

(3) Ability to predict student outcomes: The final criterion stresses the predictive capacity of these measures. This means that the measures selected should be able

to predict specific student outcomes (Bryk et al., 2015; Yeager et al., 2013). Furthermore, establishing hypothesised relationships through measurement equivalence across times (Kosovich et al., 2015) will validate these measures as early indicators of these outcome measures (Penuel et al., 2018).

As described below, the present study builds on the validity argument of exit tickets as articulated by Penuel et al. (2018), while addressing the challenges associated with their validation. In the selection and administration of exit ticket measures, we adhered to the first two criteria set forth by Penuel et al. (2018) and others. The study also examines the third validity criterion.

We used exit tickets to measure student affect and employed statistical modelling to examine relationships between responses to exit tickets and pre-post surveys that measured student attitudes towards computer science. The present study is guided by the following research questions:

RQ1: How can the exit tickets serve as valid measures of students' classroom learning experience?

RQ2: Can 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, with the objective of predicting the affective outcomes of CS of the students based on their experiences as reported on exit tickets.

By identifying useful student experience measures, we seek to fill a noted gap in the assessment 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 to what extent CS educators can use easy-to-administer exit tickets as reliable and valid proxies of important student affective outcome measures related to their perceptions of CS.

Methods

Participants and context

This study was conducted as a part of a larger research project in collaboration with Western U.S. public university and a local school district with 17 elementary schools serving rural and small-town communities. Our research team collaborated with district content leaders and educators to co-design instructional units for Grade 5 that integrated mathematics and computer science (CS) concepts during both maths instruction in the regular classroom and CS instruction in the computer lab (Shehzad, Clarke-Midura et al., 2023). The unit framed mathematics topics within CS lessons in ways that highlighted the conceptual understanding of mathematics topics. Teachers involved in co-design identified the topics of exponents and fractions as ideal concepts to target, as they are

foundational and challenging for students to learn. The exponents unit was implemented in the fall of 2022 and the fractions unit was implemented in the spring of 2023. A more complete description of the curriculum is available in (Beck et al., 2024).

The student participants in the present study were the 1,067 Grade 5 students enrolled in 17 schools, who participated in maths-integrated CS lessons during their computer lab instruction. The data reported in this manuscript were collected in accordance with a protocol approved by the Institutional Review Board at Utah State University and participants provided their informed consent.

Research instruments

Attitudes towards computer science survey

One of the validity criteria for the exit tickets described above is their ability to predict student outcomes. To test this criterion, we needed a measure of student outcomes. To this end, a survey was administered at the beginning and end of the unit which included constructs that relate to the attitudes of the students towards computer science. It incorporated items from previous work (Clarke-Midura et al., 2019; Hulleman, 2007) and comprised a total of 9 items related to self-efficacy, interest, and computer science identity (see Table 2).

Exit ticket items

For our study, we carefully selected three exit ticket items, each corresponding to well-established constructs in the motivational literature. This approach aims to balance brevity with meaningful data collection, addressing the need for efficient yet insightful assessment tools in educational research.

The three exit ticket items (see Table 3) and their theoretical rationale are as follows:

(1) Enjoyment: The students rated their agreement with the statement 'I enjoyed programming in today' class on a Likert scale. Enjoyment often influences the value students find in a task (Eccles & Wigfield, 2020). In CS education, higher enjoyment has been associated with increased self-efficacy (Kinnunen & Simon, 2011), as a positive learning context can foster a favourable attitude and increase self-assessed ability (Koenka, 2020).

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 could become a computer programmer one day.	CS Identity
I can be a computer programmer.	CS Identity
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 am a good computer programmer.	Self-Efficacy
I could do more challenging computer programming.	Self-Efficacy
I can program computers well.	Self-Efficacy

Table 3. Student exit tickets on a 5-point likert scale.

	Strongly Disagree ☹	Disagree ☹	Not Sure 😐	Agree 🙂	Strongly Agree 😊
I enjoyed programming in today's class.					
Today's programming task was difficult.					
Today's class was related to what I do in maths class.					

(2) Perceived Difficulty/Ease: Students rated their agreement with 'Today's programming task was difficult' on a Likert scale (scale reversed during analysis). Perceptions of task difficulty can shape students' expectations for success and their intrinsic interest (Eccles & Wigfield, 2020). While high perceived difficulty can adversely affect students' perceptions (Rattan et al., 2012) and cause frustration (Graham, 2020), overcoming challenges can also stimulate positive emotions such as pride (Weiner, 2010). Some studies have found that higher difficulty in programming tasks correlates with higher learning (Durak et al., 2019; Von Wangenheim et al., 2017).

(3) Perceived Connection between Computer Science and Maths: Students responded to the question 'Today's class was related to what I do in maths class'. Recent literature (Israel & Lash, 2020; Shehzad et al., 2023b; Weintrop et al., 2020; Wong & Cheung, 2020) emphasises the importance of explicitly linking computer science and maths in education. The instructional approach used in this study, grounded in the concept of Expansive Framing (Engle et al., 2012), encourages students to build on their prior knowledge and engage in authorship by broadly contextualising and connecting maths and computer science concepts.

Data collection

The pre-post affective survey was administered to students in the computer lab in the fall at the start of the school year and then towards the end of the school year. The exit tickets were administered in the computer lab after the first implementation of the maths-integrated CS lessons in the fall and then in the spring after the second lesson implementation. Table 4 shows the number of students, classes, and schools that participated in surveys and exit tickets.

Table 4. Frequencies of students, classes, and schools that took the two types of surveys.

Type	Instrument	# Schools	# Classes	'n' students
Affective survey	Pre-survey September 2022	17	49	1153 (574 girls, 522 boys)*
	Post-survey April 2023	12	35	848 (431 girls, 395 boys)*
Exit tickets	CS exit tickets October 2022	17	47	1067 (513 girls, 486 boys)*
	CS exit tickets March 2023	15	45	929 (478 girls, 414 boys)*

*Gender information could not be retrieved for all students.

Table 5. Results of the exploratory factor analysis of affective survey conducted for establishing construct validity.

	Factor1 (Interest)	Factor2 (Self-Efficacy)	Factor3 (CS Identity)
CS identity item 1			0.72
CS identity item 2			0.69
Interest Item 1	0.69		
Interest Item 2 (reversed)	0.66		
Interest Item 3	0.45		
Interest Item 4	0.79		
Self-efficacy item 1		0.63	
Self-efficacy item 2		0.59	
Self-efficacy item 3		0.71	

Factor values smaller than 0.4 are hidden in the table.

Analysis

Data diagnostics

Before the analysis that was required for answering our research questions, we performed an exploratory factor analysis (EFA) with varimax rotation (Kaiser, 1958; Lawley & Maxwell, 1971) for the 9-item affect survey to establish the validity of the constructs. The EFA results demonstrated that the items related to self-efficacy, interest, and computer science identity had the highest loading values for their corresponding constructs (see Table 5).

We then checked the skewness and kurtosis values of the measures, ensuring that they were within the acceptable ranges of −2 and + 2 for all student response items recorded on the 5-point Likert scale.

Confirmatory factor analysis

For the analysis, we used confirmatory factor analysis (CFA), which falls under the larger umbrella of structural equation modelling (SEM). SEM allows simultaneous estimation of multiple interrelated relationships (Kline, 2016), providing a comprehensive view of the data landscape. SEM also allows for the analysis of latent variables and measurement error, allowing for a more precise and nuanced understanding of the underlying constructs and relationships within the data. We used the Lavaan package (Rosseel, 2012) in R (R Core Team, 2024) to specify the path model shown in Figure 2 as a structural equation model.

As mentioned above, exit tickets met two of the criteria of Penuel et al. (2018): they are related to the learning task and are integrated into the learning process. To address the third criterion of statistical validity, we employ a two-step approach. Each step answers one of the two research questions. For answering research question 1, we tested the measurement invariance for our CFA model. Measurement invariance evaluates whether the same constructs are measured in the same way across different measurement time points. We tested measurement invariance across the two time points when exit ticket data was collected. Of the 1,067 students who completed the exit ticket survey in October 2022, only a subset of these students ($n = 557$) completed it again in March 2023. Thus, the measurement invariance test only included data for students who responded to exit tickets at both time points. This step is crucial to establish their validity (Kosovich et al.,
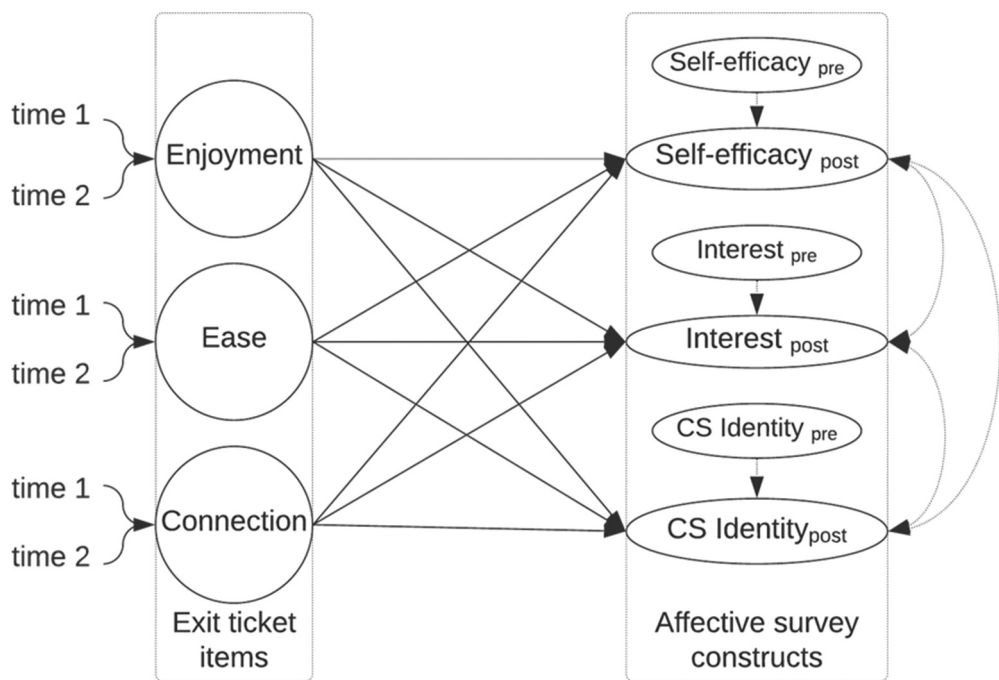
Figure 2. SEM model diagram.

2015), as exit tickets are defined as measures that are linked with the processes of teaching and learning and are capable of predicting outcomes related to these practices (Penuel et al., 2018).

Path diagram

For answering research question 2, the hypothesised relationships between affect measures on the post-survey and student exit ticket measures while controlling for pre-survey measures were included in the CFA. The two instances (fall and spring) of administering each exit ticket item were represented by a latent variable of combined effect for the items of enjoyment, ease, and connection. The exit ticket items served as independent variables, and the affective outcomes of interest, self-efficacy, and computer science identity functioned as dependent variables in our model with predictive relationships tested through regression between all independent and dependent variables as part of the CFA (see Figure 2).

Diagnostics

The model fit statistics for the model tested in Figure 2 were: χ^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 cut-offs, 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 6. Standardised 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	–	–

***$p < .001$.
We used the CS maths connection item as an observed variable (an average of the two time points), a decision influenced by the issues of model convergence.

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

Results

RQ1: How can the exit tickets serve as valid measures of students' classroom learning experience?

To establish the statistical validity of exit tickets, we performed a chi-square test to assess measurement invariance between the fall and spring time points. The nonsignificant results, $p > 0.05$ (Table 7), indicate that exit tickets demonstrated similar patterns of correlation with the affective survey constructs (self-efficacy, interest, and CS identity) illustrated in Figure 2, regardless of when they were administered. These findings suggest that exit tickets measured the same constructs in a comparable manner at both time points.

RQ2: Can the lesson-specific exit tickets predict student affective outcomes?

Table 7. Chi-square tests for measurement invariance across timepoints.

Models compared	DF	χ2	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

Table 8. 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

Estimates are standardised.

We used regression results from the CFA to explore the relationship between the exit ticket constructs of enjoyment, ease, and connection, and the affective outcomes on the post-survey, self-efficacy, interest, and CS identity (see Table 8).

As shown in Table 8, perceived enjoyment 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 significantly predicted post-survey self-efficacy measurement (Std β = 0.26, SE = 0.16, $p = .013$) while controlling for the pre-survey self-efficacy measurement. We did not find significant relationships between the rest of the variables when controlling for pre-survey variables.

Taken together, our findings suggest the following.

- The exit tickets used in our study can be used to make valid inferences about students' perceptions of the activities during instruction, as demonstrated by the invariance of measurements across two timepoints (Kosovich et al., 2015).
- Student responses to exit tickets during instruction are related to their longer-term affective outcomes. For example, we found that student's perceived enjoyment of the lesson predicted their self-efficacy, interest, and CS identity and that their perception of the lesson's ease predicted their self-efficacy.
- While students' perceived connection between maths and CS did not predict any of the affective outcomes measured, it remains a statistically valid measure that aligns with the overall instructional goals and the theory of the lessons.

Discussion

This study explored the use of exit tickets as formative assessments to measure student affect in maths-integrated computer science lessons in grade 5. The findings provide valuable insights into the validity and predictive power of these brief surveys, which has implications for both research and practice in education.

Validity of exit tickets as measures of student experience

The results demonstrate that exit tickets can serve as valid measures of students' classroom learning experiences. The measurement invariance observed across two time

points (fall and spring) suggests that these brief assessments consistently capture students' perceptions regardless of when they are administered. This stability is crucial for educators and researchers who wish to track changes in student affect over time. The consistency of exit tickets aligns with Penuel et al. (2018) criteria for validity, particularly in terms of their embeddedness in the learning process and focus on improving practice.

Predictive power of exit tickets

The present study revealed significant relationships between exit ticket responses and longer-term affective outcomes, even when controlling for presurvey measures. In particular, students' perceived enjoyment of lessons predicted their self-efficacy, interest, and CS identity, while their perception of lesson ease predicted self-efficacy. These findings underscore the potential of exit tickets as early indicators of important affective educational outcomes.

Our findings align with findings from studies that examine longer surveys (Eccles & Wigfield, 2020; Graham, 2020) that also found similar relationships between enjoyment, difficulty, interest, and self-efficacy, suggesting that shorter surveys can provide similarly valuable insights. Furthermore, the findings are consistent with the literature indicating a correlation between enjoyment and attitude towards computer programming (Cabada et al., 2018) and related constructs (Eccles & Wigfield, 2020; Kinnunen & Simon, 2011). Additionally, previous research has shown that difficulty can adversely affect students' attitudes when measured as expectancies for success (Weiner, 2010) and motivation (Rattan et al., 2012), and can potentially lead to frustration (Graham, 2020).

The present study also revealed a complex relationship between task difficulty and attitudes towards computer science. This multifaceted relationship is not entirely new in research. Weiner (2010) suggested that when tasks are perceived as too easy, students might deem them as mundane, and conversely, the completion of challenging tasks may spark feelings of pride and other positive emotions. Furthermore, some research has shown that a higher level of difficulty in programming tasks can be associated with greater learning outcomes (Durak et al., 2019; Von Wangenheim et al., 2017).

Implications for practice

The findings of this study have several implications for teachers. By incorporating exit tickets as a tool for formative assessment, educators can gain valuable insights into their students' affect towards lessons, which can inform and improve instructional practices. We highlight these below.

Real-time feedback

Exit tickets are formative assessments that can be integrated into regular instructional routines with less impact on instructional time. These can provide teachers with immediate feedback on students' affect, allowing for timely adjustments to instructional strategies.

Enhancing student engagement and motivation

The study found that the students' perceptions of the lesson predicted their self-efficacy and interest in CS. Teachers can use exit tickets to gauge students' enjoyment and perceived ease of lessons. By identifying students who consistently report low enjoyment or high difficulty, educators can provide targeted support to improve their learning experiences.

Supporting all learners

Exit tickets capture the affective responses of all students, including those who might be reluctant to speak up in class. By using exit tickets, teachers can ensure that the voices of all students are heard, not just those who are more vocal and confident.

Replacing long-form surveys with exit tickets

The present study demonstrates that a single item measure of enjoyment is a predictor of students' self-efficacy, interest, and measure of CS identity. Furthermore, the perception of ease by students also predicts self-efficacy and can reveal information about the interest of students. The use of exit tickets that capture the perceived enjoyment and ease of students can replace the administration of long-form surveys. The use of such lengthy surveys is standard in the field of educational research as it allows researchers to reliably measure student affect. Teachers can essentially get similar information without going through the hassle of administering these surveys. With more research on the validity of exit tickets, they can offer a potential replacement for the onerous research instruments commonly used in educational research.

Overall, we hope that future research will expand the inventory of validated exit ticket items, allowing teachers to choose items based on their needs and priorities. The exit ticket questions can address several aspects related to learning and can be administered as many times as the teacher finds appropriate to help adjust their content and instructional practices to meet the needs of their students. A teacher could either focus on improving the overall classroom average over the duration of the course or could focus on students with negative or the least positive perceptions at the outset.

Limitations and directions for future research

Our study has several limitations to consider. One key limitation is the lack of direct assessment of student learning outcomes, limiting the analysis to exit ticket measures predicting only affective outcomes. Further research could address this by incorporating direct assessments of learning outcomes, thereby examining the predictive strength of exit tickets on learning.

The administration of exit tickets was confined to two time points in our study, leaving little room for exploration of measurement consistency across multiple time points. We also attempted to test for measurement invariance across various student groups. It required dividing data among groups, thereby reducing the sample size, which was already impacted by a high number of missing data points. Thus, the model did not converge. Future studies should consider a larger sample size or reduce missingness in data to test measurement invariance among different student groups more robustly.

The research setting, centred on grade 5 students from 17 rural-serving elementary schools in the western US, might not reflect the wider population of elementary students. The generalisability of these findings could be expanded in future research by including different grades, school types, and geographical locations, thus testing the measures' robustness across various student populations. It would also be valuable to investigate the applicability of exit tickets in different subjects outside of computer science education to establish their broader validity.

Additionally, the varying predictive power of different exit ticket items was observed, with the perception of a connection between maths and CS not predicting any affective outcomes. This points to the potential need for more comprehensive measures, such as administration and inclusion of learning assessments into the research design, to better understand the effects of the connection item.

To capture students' experiences more holistically, future research should investigate validating additional practical measures. For example, similar studies would apply the validity criteria to measures capturing students' engagement, perceived relevance of the material, or their sense of belonging in the classroom. Such research can help improve our understanding of student experiences. Further research should also consider how educators interpret and utilise the feedback provided by exit tickets and their subsequent effects on student learning and affective outcomes.

Conclusion

The present study highlights the potential of exit tickets as formative assessment tools for measuring student affect in educational settings. By capturing immediate affective responses, such as enjoyment, perceived difficulty, and the connection between subjects, exit tickets provide valuable insights that can inform and improve instructional practices. Our findings indicate that exit tickets are reliable and valid measures and capable of predicting longer-term educational outcomes of self-efficacy, interest, and computer science identity.

Integration of formative affective assessments, such as exit tickets, into regular teaching routines offers a practical approach to understanding and addressing student emotions. This study contributes to the growing body of literature on formative assessment by underscoring the importance of affect in the learning process and providing evidence for the effectiveness of exit tickets in capturing and responding to student emotions.

Future research should continue to explore the application of exit tickets in diverse educational contexts and subject areas, as well as their long-term impact on student learning and development. By embracing affective formative assessments, educators can better support their students' emotional and academic growth, ultimately leading to more positive and productive educational experiences.

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Data availability statement

The data supporting the findings of this study are available from the corresponding author, U.S., upon reasonable request.

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