Multimodal Learning Analytics for Measuring Creative Engagement in Arts-Based Classrooms

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Abstract

This study develops a multimodal learning analytics model to measure creative engagement in arts-based classrooms through process-oriented and quantifiable indicators. The study is designed to collect data from approximately 420 students in 20 arts-based classes over a 16-week semester, including 6,000 classroom interaction records, 3,500 verbal participation entries, 2,800 digital portfolio submissions, 1,200 peer-feedback records, and 840 reflective journals. Based on these data, the study constructs a Creative Engagement Index covering five dimensions: attention, experimentation, persistence, collaboration, and self-expression. Specific variables include attendance rate, task completion rate, revision frequency, peer interaction frequency, verbal contribution count, portfolio update interval, reflective text length, and teacher-rated engagement score. The research applies exploratory factor analysis, confirmatory factor analysis, cluster analysis, multiple regression, and natural language processing to examine how different forms of classroom behavior predict creative engagement. It also compares teacher evaluation scores with analytics-based engagement scores to test whether multimodal data can provide a more stable and transparent assessment of creative participation. The innovation of this study lies in transforming creative engagement from a subjective classroom impression into a multidimensional and data-supported measurement framework, offering a practical method for evaluating learning processes in arts-based education.

Keywords: multimodal learning analytics; creative engagement; arts-based classroom; digital portfolio; process evaluation; natural language processing; student participation

1. Introduction

Creative engagement is an important but difficult-to-measure dimension of arts-based learning. Unlike general academic engagement, it cannot be adequately represented by attendance, task completion, or grades alone. In visual arts, design, and interdisciplinary arts classrooms, engagement is also expressed through sustained attention, repeated revision, peer response, verbal participation, portfolio development, experimentation, and personal expression. Students often develop ideas through cycles of practice, trial, feedback, adjustment, and reflection, meaning that

the quality of learning is embedded in the process as much as in the final product. Previous studies have shown that well-designed arts-based learning can strengthen participation, confidence, collaboration, and student agency [1,2]. Research on public art education has also emphasized the importance of monitoring teaching quality while validating educational equity, suggesting that assessment should capture not only final outcomes but also differences in learning opportunities, participation, and educational experience across students [3]. Related work has further demonstrated that arts-based learning can support active involvement and creative development when instructional activities encourage exploration and meaningful participation [4,5]. These findings indicate that creative engagement should be examined as a multidimensional learning process rather than as a single classroom outcome. Despite this broader understanding, many assessment practices in arts education still rely heavily on rubrics, teacher observation, and evaluation of completed artworks [6,7]. These methods remain valuable because teachers can interpret artistic intention, contextual difficulty, and the quality of creative decisions. However, they may also be influenced by subjective judgment and may not capture changes that occur throughout the learning process. A final artwork may show technical quality without revealing how many alternatives were tested, how feedback was used, or how much persistence was required to complete the task. Similarly, a highly verbal student may appear more engaged than a quieter learner whose engagement is expressed through sustained revision or portfolio development [8,9]. Creative participation therefore contains behaviors that are visible, partially visible, and difficult to observe directly. This creates a measurement problem: classroom evaluation needs to preserve the contextual richness of arts learning while introducing more systematic evidence about how engagement develops over time.

Learning analytics provides a possible way to address this problem by using classroom records, digital submissions, interaction data, feedback records, and written reflections to describe learning processes more continuously. Multimodal learning analytics has received growing attention because it combines different forms of evidence instead of relying on a single data source [10,11]. Depending on the learning context, these data may include behavioral traces, speech, text, interaction sequences, digital artifacts, physiological signals, or teacher-generated records. Existing studies have applied multimodal approaches in online learning, collaborative learning, programming education, medical training, and classroom interaction analysis [12,13]. The results suggest that combining behavioral, verbal, textual, and interaction data can provide a more detailed account of how students participate, regulate their learning, communicate with others, and respond to instructional activities [14,15]. However, the transfer of these approaches to arts-based classrooms remains limited. Many existing learning analytics models are designed around general academic engagement or performance prediction and therefore emphasize indicators such as clicks, login frequency, time on task, assignment completion, and platform activity [16,17]. These indicators are convenient because they can be collected automatically and compared across large groups, but they have limited value when the target construct involves

experimentation, revision, collaboration, persistence, and self-expression. In creative learning, repeated modification of an artwork may represent productive exploration rather than inefficiency, while a long period of low digital activity may still involve concentrated sketching, discussion, or material experimentation [18,19]. The meaning of a learning trace therefore depends strongly on the instructional context. Simple activity counts may describe how much a student interacts with a system, but they do not necessarily explain whether the student is deeply engaged in a creative process [20,21]. The available evidence also presents several methodological limitations. Many studies use relatively small samples, short observation periods, or data from a single course or platform, making it difficult to determine whether observed patterns are stable across learners and learning settings [22]. Text, portfolio, peer-interaction, and classroom participation data are also often analyzed separately rather than combined within one measurement framework. This separation is particularly problematic for arts-based education because creative engagement is distributed across different forms of activity. A student may demonstrate persistence through repeated portfolio revision, collaboration through peer feedback, attention through regular classroom participation, and self-expression through reflective writing [23,24]. An assessment model based on only one of these sources may underestimate the student's overall engagement or overemphasize one visible behavior. The relationship between teacher-rated engagement and data-derived engagement is also insufficiently examined. Teacher judgments provide important contextual knowledge, but data-based measures may reveal less visible patterns that accumulate across time. Comparing the two forms of evidence may therefore help identify where professional judgment and observable learning traces converge and where they differ.

The present study addresses these limitations by developing a multimodal learning analytics model for measuring creative engagement in arts-based classrooms. The study includes approximately 420 students enrolled in 20 arts-based classes over a 16-week semester. The dataset contains about 6,000 classroom interaction records, 3,500 verbal participation entries, 2,800 digital portfolio submissions, 1,200 peer-feedback records, and 840 reflective journals. These data are used to construct a Creative Engagement Index consisting of five dimensions: attention, experimentation, persistence, collaboration, and self-expression. The observed variables include attendance rate, task completion rate, revision frequency, peer-interaction frequency, verbal contribution count, portfolio update interval, reflective text characteristics, and teacher-rated engagement scores. Exploratory factor analysis is used to identify the underlying structure of the engagement indicators, while confirmatory factor analysis evaluates the stability and construct validity of the proposed measurement model. Multiple regression is used to examine the relationships between multimodal learning behaviors and creative engagement, and cluster analysis is applied to identify different learner engagement profiles. Natural language processing is further used to analyze reflective journals and feedback records so that textual evidence can be incorporated into the broader engagement framework. The study is intended to make both methodological and educational contributions. At the methodological level, it examines whether

heterogeneous classroom data can be integrated into a coherent and interpretable measure of creative engagement rather than being treated as unrelated activity indicators. It also tests whether multimodal evidence can distinguish between learners who appear similar in conventional assessment but follow different patterns of experimentation, persistence, collaboration, or reflection. At the educational level, the model provides a process-oriented alternative to assessment based primarily on final products or general teacher impressions. By comparing teacher-rated engagement with data-derived engagement scores, the study evaluates whether multimodal evidence can complement professional judgment and improve the consistency of engagement assessment. The framework also has potential implications for teaching-quality monitoring and educational equity because it can reveal whether students differ systematically in their access to participation, feedback, collaboration, and opportunities for creative expression. In this way, the study seeks to move creative engagement from a largely subjective classroom judgment toward a multidimensional, process-based, and empirically supported construct that can inform assessment design, instructional adjustment, and more equitable arts-based learning environments.

2. Materials and Methods

2.1 Sample and Study Setting

The study was conducted in 20 arts-based classes during a 16-week semester. A total of 420 students were included. All classes were practice-based courses involving classroom participation, creative tasks, peer discussion, digital portfolio work, and reflective writing. Data were collected during regular teaching activities, so the classroom setting was not changed for the study. The dataset contained 6,000 classroom interaction records, 3,500 verbal participation entries, 2,800 digital portfolio submissions, 1,200 peer-feedback records, and 840 reflective journals. Students were excluded if they had missing attendance records or no portfolio submission for more than four consecutive weeks. The study measured five aspects of creative engagement: attention, experimentation, persistence, collaboration, and self-expression.

2.2 Experimental Design and Control Setting

A quasi-experimental design was used. The experimental group was assessed with classroom interaction records, verbal participation data, portfolio updates, peer-feedback records, reflective journals, and teacher-rated scores. The control group was assessed with conventional methods, including attendance, task completion, final artwork evaluation, and teacher observation. Both groups followed the same teaching schedule, course content, classroom tasks, and assessment period. This design was used because creative engagement is not fully shown by final works or attendance alone. The comparison between the two groups was used to examine whether classroom data from different sources could measure creative engagement more consistently than teacher evaluation alone.

2.3 Measurement Methods and Quality Control

Creative engagement was measured using classroom records, portfolio data, peer feedback, reflective journals, and teacher scores. Classroom interaction records were obtained from observation sheets and teaching logs. Verbal participation was recorded by trained observers based on contribution frequency and task relevance. Digital portfolio data included submission time, update interval, revision frequency, and task completion status. Peer-feedback records were coded by feedback frequency, response type, and relevance to the creative task. Reflective journals were measured by text length, keyword frequency, and topic relevance. Teacher-rated engagement was scored with a five-point rubric covering attention, effort, collaboration, revision, and self-expression. Before data collection, all observers received the same training. A coding manual was used for classroom records and peer-feedback records. Ten percent of the records were coded by two observers. Inter-rater agreement was checked before formal analysis. Missing values were checked weekly. Abnormal records were removed. All data were matched by anonymous student IDs.

2.4 Data Processing and Model Formulas

All variables were cleaned, coded, and standardized before analysis. Continuous variables, including verbal contribution count, revision frequency, portfolio update interval, reflective text length, and peer interaction frequency, were converted into z-scores. This step reduced the effect of different measurement scales. The Creative Engagement Index was calculated from five dimension scores: attention, experimentation, persistence, collaboration, and self-expression. The formula was:

$$CEI_i = w_1 A_i + w_2 E_i + w_3 P_i + w_4 C_i + w_5 S_i$$

where CEI_i is the Creative Engagement Index of student i, A_i is attention, E_i is experimentation, P_i is persistence, C_i is collaboration, S_i is self-expression, and w_1 to w_5 are the weights of the five dimensions. A regression model was used to test the association between classroom variables and teacher-rated engagement:

$$TES_i = \beta_0 + \beta_1 AR_i + \beta_2 TC_i + \beta_3 RF_i + \beta_4 PI_i + \beta_5 VC_i + \beta_6 RL_i + \varepsilon_i$$

where TES_i is the teacher-rated engagement score, AR_i is attendance rate, TC_i is task completion rate, RF_i is revision frequency, PI_i is peer interaction frequency, VC_i is verbal contribution count, RL_i is reflective text length, and ε_i is the error term.

2.5 Statistical Analysis and Model Validation

Exploratory factor analysis was first used to identify the structure of creative engagement. Confirmatory factor analysis was then used to test the five-dimension structure. Cluster analysis was used to divide students into different engagement types. These types included low engagement, task-completion engagement, collaborative engagement, and high creative engagement. Multiple regression was used to examine the effects of classroom variables on

teacher-rated engagement. Natural language processing was used to extract simple text features from reflective journals, including word count, topic frequency, and reflection-related terms. Model validity was examined using factor loadings, internal consistency, model fit indices, and the correlation between data-based scores and teacher-rated scores. Statistical significance was set at $p<0.05$. The analysis was used to test whether the Creative Engagement Index could measure creative participation in arts-based classrooms in a stable and interpretable way.

3. Results and Discussion

3.1 Structure of the Creative Engagement Index

The factor analysis showed a five-factor structure for creative engagement. The five factors were attention, experimentation, persistence, collaboration, and self-expression. Each factor had acceptable factor loadings and internal consistency. Attention was mainly related to attendance, task completion, and classroom focus. Experimentation was closely related to portfolio revision and changes in creative work. Persistence was reflected in continuous portfolio updates and repeated task improvement. Collaboration was mainly linked to peer interaction and peer-feedback records. Self-expression was related to verbal participation and reflective writing. This result agrees with recent studies showing that student engagement should not be measured only by activity counts or simple online traces [25,26]. It also supports the view that learning behaviour can be better explained when classroom, verbal, portfolio, feedback, and text records are examined together. The structure shown in Fig. 1 indicates that creative engagement in arts-based classrooms is a multi-dimensional construct, not a single teacher impression.

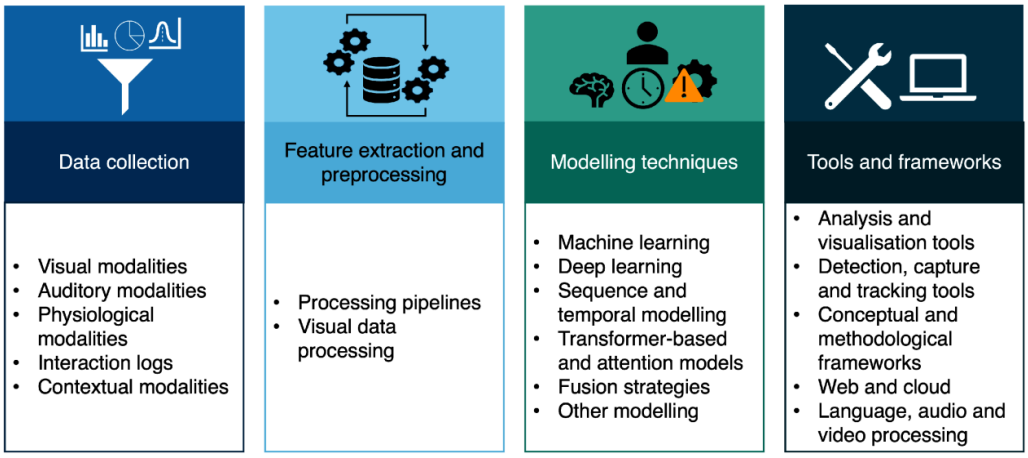

Fig. 1. Data sources and analysis steps used to calculate the Creative Engagement Index.

3.2 Engagement Patterns in Arts-Based Classrooms

The cluster analysis identified four student groups: low engagement, task-completion engagement, collaborative engagement, and high creative engagement. The low-engagement group had weak scores across most indicators. The task-completion group showed good attendance and task submission, but had limited revision and peer interaction. The collaborative

group had frequent peer response and verbal participation, but its portfolio revision records were uneven. The high-engagement group showed strong performance in all five dimensions. These results show that task completion alone cannot represent creative engagement. Some students finished assignments on time but showed little idea development or revision. Some students were active in discussion but did not improve their portfolio work. This finding differs from many learning analytics studies that rely mainly on clicks, login records, time-on-task, or submission frequency [27,28]. In arts-based classrooms, engagement should be judged by both participation and creative work. Revision, feedback, reflection, and expression are therefore necessary indicators.

3.3 Relationship Between Record-Based Scores and Teacher Evaluation

The regression results showed that revision frequency, peer interaction frequency, verbal contribution count, and reflective text length were strong predictors of teacher-rated engagement. Attendance rate and task completion rate were also related to teacher scores, but their effects became weaker after creative-process variables were added. This means that teacher ratings were not only affected by visible participation. They were also related to students' revision, feedback, and reflection. The record-based engagement score showed a moderate to high correlation with teacher-rated scores. However, the two scores were not fully the same. Some quiet students received higher record-based scores because they had strong portfolio revision and regular reflective writing. Some active speakers received higher teacher scores, although their revision records were limited. This pattern is shown in Fig. 2. The result is consistent with previous studies arguing that classroom assessment should combine teacher judgement with learning records [29,30], especially in courses where learning is shown through practice and repeated improvement.

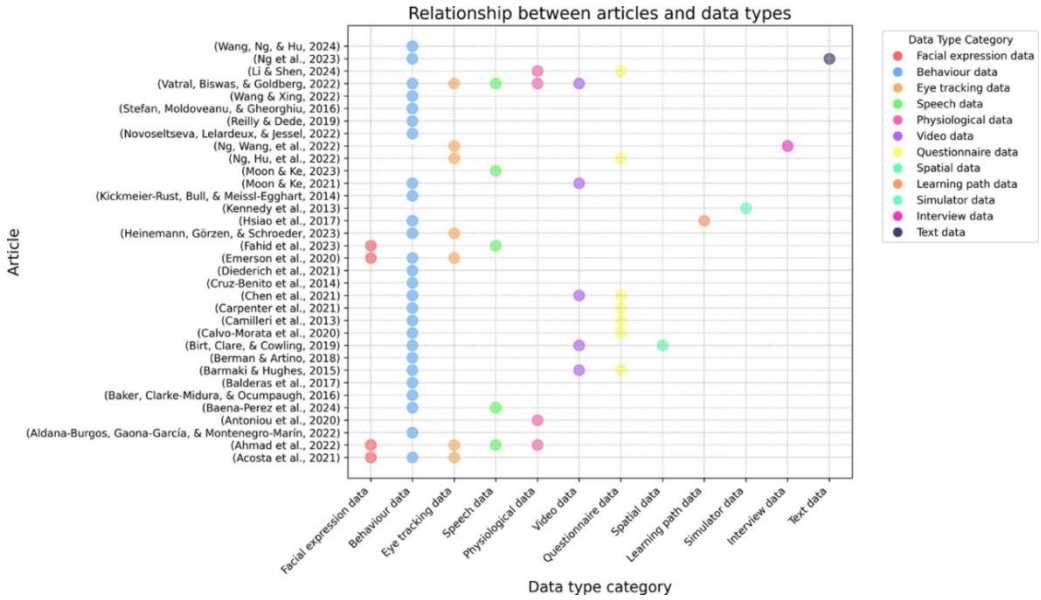

Fig. 2. Relationship between data-based engagement scores and teacher-rated engagement scores in arts-based classrooms.

3.4 Comparison With Previous Studies and Teaching Implications

Compared with previous studies, this study moves learning analytics from general academic engagement to creative engagement in arts-based classrooms. Earlier studies mainly focused on online learning, programming, medical training, virtual learning, and collaborative learning. Many of them used short study periods, small samples, or data from one platform only. The present study used data from 420 students across 20 arts-based classes over a 16-week semester. It included classroom interaction records, verbal participation entries, digital portfolio submissions, peer-feedback records, reflective journals, and teacher scores. This design gives a more complete view of how students take part in creative learning. The results suggest that arts teachers should pay attention not only to final artworks but also to revision, discussion, feedback, and reflection. The Creative Engagement Index can help identify students who are quiet in class but active in creative revision. It can also identify students who speak often but show limited improvement in their work. Therefore, this study offers a practical measure for arts-based courses and adds new evidence to engagement research.

4. Conclusion

This study measured creative engagement in arts-based classrooms using data from classroom interaction, verbal participation, digital portfolios, peer feedback, reflective journals, and teacher scores. The results showed that creative engagement included five dimensions: attention, experimentation, persistence, collaboration, and self-expression. Revision frequency, peer interaction, verbal contribution, and reflective writing were closely related to engagement. These findings indicate that final artwork scores and teacher observation alone cannot fully reflect students' creative learning process. The proposed Creative Engagement Index helps describe how students participate, revise, discuss, and express ideas during classroom activities. The study adds evidence to engagement research by changing creative engagement from a mainly subjective judgment into a measurable classroom variable. In teaching practice, this method may help teachers identify different engagement patterns and improve feedback, portfolio assessment, and course design. This study also has limitations. The data were collected from one semester and a limited number of arts-based classes. Future studies should test the model in different schools, age groups, and art subjects, and should include longer-term data to improve the reliability of the results.

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