Jiang, B. et al. (Eds.) (2025). Proceedings of the 33rd International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Persistence in Electronic-Making Projects: A Socio-Cognitive Perspective

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Abstract: Persistence is crucial in maker-based learning, where challenges are inherent to the creative process and persistence is one of the important behavioral markers of motivation. This study examines how students respond to troubles during making activities, reflecting persistence, using the socio cognitive theory framework of triadic reciprocal causation. Our focus research question is how do the personal beliefs, and environmental factors that influence students' persistence during trouble in making activities? To answer this, we conducted a multi-level video analysis of two student teams engaged in electronic-making projects as case studies. At the macro level, we visualized 16.5 hours of making activities segmented into 1-minute intervals using making-process rugs. At the micro level, we analyzed the identified trouble and repair episodes using interaction analysis, focusing on verbal and embodied actions with peers, facilitators, and the environment. By integrating micro-level interaction data, we observed that persistence is not uniformly distributed among team members, with personal factors prominently shaping responses early in projects, while environmental influences become increasingly significant over time.

Keyword: Persistence, Motivation, Makerspace, Interaction analysis, making process rug

1. Introduction

Sustaining motivation in environments where failure is integral requires a nuanced understanding of motivational processes during making activities to scaffold or design intervention. Existing research has predominantly measured motivation using self-reported survey, interviews, and observation. Self-reports capture cross-sectional motivational states and interviews provide retrospective accounts, yet these methods frequently fail to capture the detailed, real-time processes through which motivation unfolds in situ (DiBenedetto & Schunk, 2022). Observational methods, particularly those involving video data, facilitate repeated and systematic micro-analysis, providing deeper insight into motivational processes as they are enacted (Derry et al., 2010). Unlike self-report surveys and retrospective interviews, video analysis captures immediate, fine-grained interactions, providing insights into how motivation fluctuates during making activities. The observable measures of motivation include task choice, effort, and persistence, which help in understanding how motivation unfolds (Schunk & DiBenedetto, 2021). Choice of task is not always a reliable measure of motivation, as external factors such as social influences or task constraints can shape decision-making (Patall, 2013). Effort is often associated with motivation, but its reliability as an indicator is limited by skill level—as proficiency increases, individuals may require less effort to achieve the same level of performance (Schunk et al., n.d.). Another behavioral index is persistence and from early on, researchers viewed persistence as an objective measure of one's underlying motivation to achieve. Persistence is defined as "*sustained engagement with a task despite encountering obstacles, challenges, or difficulties*" (Feather, 1962). Despite research on motivation in makerspaces (discussed in section 2 – related work), little is known about how persistence is enacted through real-time interactions while working on a project. *RQ: How do the personal beliefs, and environmental factors that influence students' persistence during trouble in making activities?*

2. Related Work

In makerspace research a few studies have attempted to understand persistence. According to Petrich, Wilkinson, and Bevan in the Learning Dimensions Framework, persistence is considered as an important learning outcome in making (Petrich et al., 2013). Hilppö and Stevens conducted a year-long video ethnography of a FUSE Studio makerspace, showing how explicit framing of failure as learning opportunities influenced students' persistence (Hilppö, 2020). They studied persistence through interviews, where students reported that they came to perceive failed attempts not as indications of inadequacy, but as integral steps toward eventual success, reinforced by teachers who celebrated persistence and experimentation. Brahms and Crowley (2016), through their analysis of MAKE magazine describe making as a cycle —marked by purposeful play, experimentation, and refinement—inherently demands persistence. Regalla (2016) identifies persistence as a key attribute of the maker mindset, emphasizing its importance in navigating the complexities of making activities. The maker mindset promotes a failure-positive approach, viewing setbacks as learning opportunities rather than endpoints (Vongkulluksn, Matewos & Sinatra, 2021). The literature reviews on research in makerspaces emphasizes persistence's role in developing problem-solving skills and resilience (Mersand ,2021; Nikou, 2024). Yuan and Murai note that designing context-relevant activity helps learners overcome frustration and develop persistence (Yulis San Juan & Murai, 2022). Given the limitations of previous research on motivation, that largely relies on retrospective accounts or static measures, this study uniquely employs real-time video-based interaction analysis to capture persistence dynamics as they naturally unfold during trouble and repair episodes in makerspaces. This will contribute to extending our understanding of persistence by providing empirical insights into the dynamics of persistence in natural settings.

3. Methods

3.1 Participants

The study was conducted as a part of the workshop designed to engage students in hands-on electronics projects, allowing for observation and analysis of their behavior and interaction. Initially, 33 ninth-grade students enrolled in the workshop, but 24 participants remained until the end, comprising 9 females and 15 males. All participants were approximately 14 to 15 years old and attended the same secondary school. They had limited prior experience in makerspace settings, especially electronic making. Participants formed teams autonomously (2 or 3 in a team), resulting in a total of eight teams, including one individual who chose to work independently. In this paper we focus on two teams – Ace (3 girls) and Atoms (3 boys). We selected these two teams because their projects represented contrasting conditions (imitation vs. creation), allowing deeper exploration of persistence dynamics under different task conditions and team compositions.

3.2 Data Collection

The entire project-making sessions during Week 3 were video-recorded, capturing approximately 11 to 14 hours of footage per group. Cameras were positioned to unobtrusively record both verbal and non-verbal interactions among participants and between participants and the facilitator. This study was approved by the Institute Review Board (IRB) and informed consent was obtained from all participants and their guardians, explaining the purpose of the recordings and ensuring confidentiality.

3.3 Teams' Description

The Ace group (team name given by the participants) consisted of three participants – P1, P2, P3. They undertook an imitation project, building a smoke detector prototype based on a tutorial found on YouTube. This project involved replicating an existing design, with students following step-by-step instructions to construct the digital model in Tinker cad and assemble the physical components using Arduino. They extended YouTube project by creating a casing for the prototype and decorating it. The useful video data of this making process consisted of 8 hours and 55 minutes. The Atoms group consisted of three participants – P4, P5 and P6. Atoms worked on a creation-based project to develop a prototype of a cane equipped with multiple ultrasonic sensors for visually impaired users. They aimed to create a cane that would allow the user to sense objects at different height level from ground. This project involved conceptualizing a design, building a digital model in Tinker cad, coding for sensor functionality in Arduino, and creating a physical prototype. The useful video data of this creation process consisted of 7 hours and 23 minutes.

3.4 Analysis

The analysis employed a two-level approach (macro, micro). At the macro-level, we segmented videos into one-minute intervals, categorizing each interval based on observed activities aligned with the making design framework (Davies et al., 2024). At the micro-level, SCT guided detailed interaction analyses to identify how personal, behavioral, and environmental factors influenced persistence. Video data were annotated using ELAN software to systematically track verbal and embodied interactions. At the macro level, we utilized the making-process rug visualization method (Paavola et al., 2021) to map the sequence of making design activity over time. This involved segmenting 16.3 hours of video data into one-minute intervals and coding each segment based on the verbal and embodied process based on the making design process framework (Davies, Seitamaa-Hakkarainen, & Hakkarainen, 2024). Due to limited space, we show a few interesting segments of making process rug of team Ace (see Figure 1) where the participants move into off-task action after facing troubles. Time axis runs vertically from top to bottom, the rug on the left shows team Ace's complete making process rug (Figure 1a) and the figures on the right (Figure 1b, 1c) shows segments of team Ace's making process rug. Each cell represents a one-minute interval, color-coded to indicate different making processes. Px, where x = 1,2,3 represents the participants in team Ace. Px_V represents the verbal making process and Px_E represents the embodied making process. To maintain confidentiality, all participants were anonymized using participant codes (e.g., P1, P2), and personal identifiers were removed from video transcripts and analysis logs. In addition to the making process, we also noted down instances of troubles and facilitators or peers' involvement in making as shown in the Figure 1b and Figure 1c.

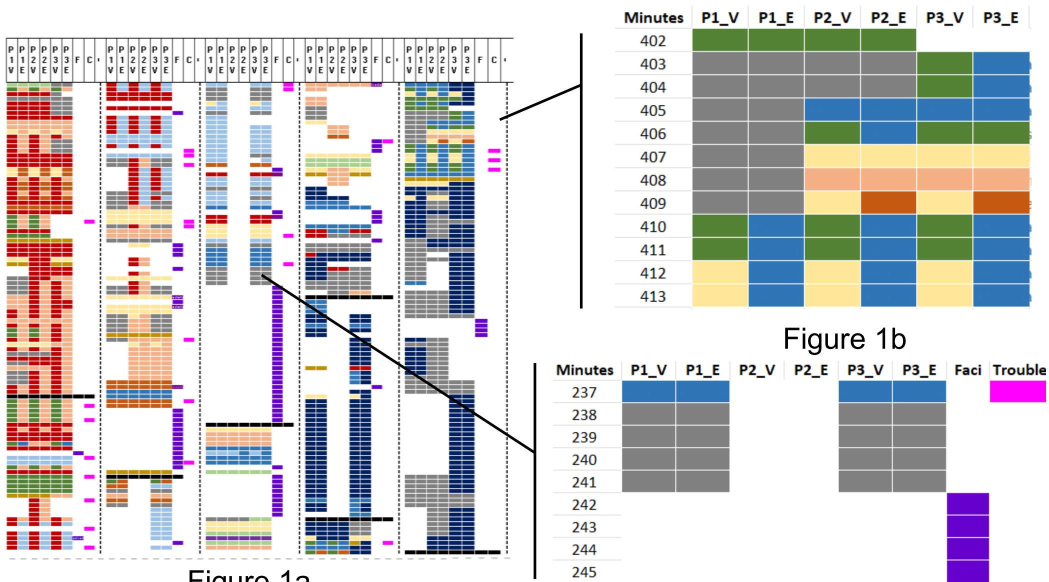

Figure 1a

Figure 1b

Figure 1c

Ideation	Discussion about manufacturing	Sketching	Making presentation material
Analysis & evaluation	Process Organizing	Material experimenting	Digital experimenting
Seeking information	Off-task action	Material model making	Digital model making

Figure 1a. Making-Process Rug of team Ace; *Figure 1b.* Peer role in sustaining motivation; *Figure 1c.* Facilitator's role in sustaining persistence.

From the macro-level data, we identified episodes where participants faced troubles. Operationally, a 'trouble episode' was identified by observable disruptions such as tinker cad, hardware circuit either partially working or not working, explicit requests for assistance, or clear verbal/non-verbal frustration signals. An episode start was defined as a sequence where a disruption or a perceived challenge occurred and end was defined as when the trouble was resolved, ignored or erased. At the micro level, we conducted a detailed interaction analysis focusing factors influencing persistence on the identified episodes of trouble and repair. The video recordings were repeatedly attended to by the authors and conducted the operations of interaction analysis (Jordan & Henderson, 1995). This multi-level approach provided a comprehensive understanding of how participants respond to troubles and the factors influencing their persistence.

4. Findings

4.1 Personal Factors that Influence Persistence

To address the research question, we conducted a micro-level interaction analysis of the identified trouble and repair episodes, deductively coding them through an SCT lens to understand the factors contributing to persistence. We present exemplar episodes to illustrate how persistence is influenced by different factors. The below transcript is of team Ace, during the initial phase of the making process. The team was working on creating a tinker cad digital circuit of smoke detector by following a YouTube video. The simulation was not working as intended, the buzzer did not beep when smoke was within the threshold value.

Time	Actor	Verbal and non-verbal
01:26:15	P1, P2, P3	*[P1 is simulating the tinkercad circuit, the buzzer doesn't ring. P2 and P3 are observing*]
01:26:21	P3	Teacher! [*P1 pauses, turns to P3]*
01:26:24	P1	Wait……wait, wait
01:26:26	P2	It is not working *[P2 and P3 overlap]*
01:26:26	P3	That's why
	P1	"Teacher" *[imitating P3*] You both are same, for everything you call "teacher! teacher!"
01:26:50	P1	What did the teacher tell? We have to think about logic. First, we'll try.

In this instance P3 and P2 want to seek help to overcome this trouble. But P1 exhibits the desire to solve the problem by themselves, without relying solely on the facilitator. The team then moves on to the analysis phase followed by digital modelling, where they try to debug the block-based program. Using YouTube video as reference they check their block-based codes and all three are convinced that code is correct, but there is some error in connections. At the end of this episode the team Ace was able to partially resolve the trouble – narrowed down the source of trouble. This instance brings out the self-efficacy of P1 in resolving the issues that arise while making (K et al., 2024). This verbal exchange externalized her personal attitude towards making.

In another episode of team Atoms, we noticed that after they encounter challenge P5 and P6 move to off-task action, but P4 persists. Team Atoms were in the material modelling and prototyping process, but the model was not working. As they had tried a few times to power two ultrasonic sensors with one Arduino and it was not working, P5 and P6 wanted to change their entire project (giving up). But P6 persuades them to continue the same project, but they disagree. After some discussion when they don't arrive at a conclusion, P5 and P6 get involved in off-task action. The idea of building a cane for visually challenged people was proposed by P4, and he expresses a sense of ownership in the discussion by trying to persuade them. This episode again brings out the personal processes of his attachment towards the idea which made P4 persist.

4.2 Environmental Determinants that Influence Persistence

In figure 1c, we can notice that P1 and P3 of Team Ace face a trouble and go into off-task action for nearly 4 minutes till the facilitator arrives. The facilitator now tries to debug the circuit along with the participants. After a few minutes of interaction, they find the error in circuit connection and rectify it. As they troubleshoot the error with the facilitator P1 exclaims "*Now I'm confident*". P1 and P3 proceed to material experimenting and presentation material. Here even though they had given up, interaction with facilitator brought them back on track and we can also witness P1 verbalizing her boost in confidence. Here the environmental determinant affected the personal determinant, after which a change in behaviour is noticed.

In the following episode we look at figure 1b in detail. Team Ace was nearing the completion of project. The prototype was working during previous session, but now it was malfunctioning. The buzzer beeps every 2 seconds without smoke. P1, P2 and 3 try to solve the issue.

Time	Actor	Verbal and non-verbal
06:38:14	P1	There is something wrong! Urrghh! *[expresses frustration]*
06:38:49	P2	What happened? *[looking at P1]*
06:38:53	P1	Let's change position *[P1 moves towards P3 ans asks her to change. P3 is reluctant to change, then P1 and P2 exchange places – change in participation structure]*
06:39:00	P3	Don't do like this repeatedly.
06:39:24	P1	*[off-task action – fiddling with paper]*
06:39:30	P3	*[Checks the circuit connections, reconnects a couple of wires]*
06:40:35	P2	Give it here *[Points to the circuit and connects the circuit to the CPU]*
	P2, P3	*[P2 and P3 continue to work on the prototype. 5 minutes of trial and error. Still the buzzer beeps every 2 seconds]*
06:45:45	P1	*[Notices the serial monitor]* Change the value to 200.

After trying to troubleshoot for some time, P1 gets frustrated and shifts the position. Initially, P1 was controlling the mouse, now P1 wants to move away and does not work on this prototype anymore. P2 is now in control of the computer system. P2 and P3 try to troubleshoot, they go through this analysis and material experimenting phase for seven minutes. They then try digital model making and testing during which P1 notices the serial monitor and joins them making process. This episode shows how the behaviour of P2 and P3 brought back P1, a part of the environment as peer, into the making process. It is also important to note here that, it was the same P1 who exhibited self-efficacy in episode 1, gave up in this episode. Episode 1 took place when the team had just started off their project and this episode occurred towards the end of their project, after facing multiple troubles. This serves as evidence that there is a varying effect of these personal and environmental determinants on persistence and that persistence is not solely influence by personal determinants.

5. Conclusion

Addressing the call in contemporary research to analyse motivation in real-time, we employed interaction analysis to reveal how persistence unfolds through trouble and repair episodes in authentic makerspace activities. We observed that persistence is not uniformly distributed among team members, with personal factors prominently shaping responses early in projects, while environmental influences become increasingly significant over time. Our findings highlight the value of combining visual representations (making-process rugs) and micro-level analysis to capture both immediate and longitudinal motivational responses. Also, the findings extend SCT by highlighting how the temporality of persistence, evident through fluctuating self-efficacy and environmental support, suggests a need to better theorize moment-to-moment motivational dynamics. However, the study is limited by its analysis of two teams and the context-specific nature of the projects. To strengthen the generalizability of these findings and to better understand the causal mechanisms underlying persistence, future research would benefit from employing controlled experimental designs that systematically manipulate prominent factors influencing persistence. Additionally, examining a broader range of participant characteristics could further enrich our understanding of how persistence develops and is sustained in makerspace environments.

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