Microlearning Loops in Software Engineering Syllabi: An Exploratory Qualitative Case Study

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ABSTRACT: This full paper in the research category explores how the field of software engineering education is changing by examining a redesigned course delivery that combines microlearning and interactive engagement strategies to understand how students perceived its influence on participation and conceptual understanding. The framework emphasizes short, focused instructional segments (e.g., five-minute videos) paired with immediate active engagement strategies (e.g., debates, games, and collaborative exercises). We conducted semi-structured interviews (45-60 minutes) using an exploratory qualitative research design with five undergraduate students who participated in this course to understand their experiences and perception of this approach. Data collection took place during Fall 2025, and thematic analysis of transcribed data resulted in pattern emergence from data related to concepts such as motivation, autonomy, and conceptual clarity. The preliminary findings suggest that students experienced microlearning loops as helpful for resetting attention and deepening conceptual clarity. Participants reported that frequent, short learning activities created more opportunities for more reflection and engagement with theoretical concepts in relation to practice. Crucially, the inductive analysis identified an emergent pattern: students spontaneously utilized Generative AI as a support tool to scaffold their own autonomy within the self-paced structure. The results suggest that concise, student-centered delivery models may help students feel more engaged and may better support diverse learning preferences in software engineering classrooms. Ultimately, this study suggests that participants experienced microlearning architectures as doing more than managing cognitive load. Students described the redesign as creating a classroom environment that felt collaborative, practice-oriented, and supportive of professional engineering identity required by the software industry.

Keywords: Active Learning, Cognitive Load Theory, Generative AI, Interactive Pedagogy, Microlearning, Professional Identity Formation, Software Engineering Education, Student Engagement, Thematic Analysis

INTRODUCTION:

Software Engineering (SE) courses must support students in mastering complex technical concepts while fostering professional identity formation required for industry practice [1, 2]. Yet many SE courses rely on extended lecture-based delivery that can induce cognitive overload [3, 4] and fail to capture the high-velocity and collaborative nature of the software industry. As a result, it is important for engineering educators to seek instructional methods to improve engagement, feedback, and application [5, 6]. Microlearning organizes instruction into short, focused units, though literature remains heterogeneous in definitions, complicating design guidance [7]. Evidence syntheses also frame microlearning in terms of minutes-long modules and describe design dimensions such as time, content, form, and process [8]. Implementation suggests short segments can be effective when paired with immediate practice: bite-sized lecture designs that interleave mini-lectures with tutorials and exercises show improved outcomes [9], and a microlearning approach in an introductory database programming course reports statistically significant improvement in quiz performance [10]. However, microlearning effectiveness is context-dependent and shaped by learner goals and applicability of content [11].

In parallel, active learning improves participation and learning processes [12], with studies reporting positive effects of active learning environments and adapted instructional methods on learning outcomes [13] and fine-grained interactive designs built around frequent questions, quizzes, and feedback loops [14]. In SE, flipped classroom designs supported by diagnostic systems have also been shown to improve achievement and motivation [15]. Despite these advances, prior work emphasizes performance outcomes rather than explaining how they leverage emerging digital support tools to sustain the rhythm of a semester-long microlearning architecture. The redesigned course operationalizes microlearning loops as simulated 'sprints' intended to approximate aspects of the rhythm of professional practice. This model replaces long-form lectures with rapid cycles of briefing (micro-content) and execution (active engagement) encouraging students to transition from passive listeners to active and practice-oriented roles during class. This study addresses that gap by examining student perception of microlearning loops as a syllabus-embedded course delivery model in an undergraduate SE course. The redesign pairs five-minute video modules with structured interactive engagement. By foregrounding learners' accounts, this paper contributes qualitative evidence about how microlearning functions when enacted as an interactive framework. As instructors fragment content into micro-units to manage cognitive load, students are simultaneously adopting Generative AI (GenAI) tools to manage learning workflows [16], serving as 'just-in-time' scaffolds for the brief, autonomous activities that microlearning requires [17].

LITERATURE REVIEW:

A. Microlearning: Definitions, Design Dimensions, and Evidence of Impact

Monib et al. [7] characterize microlearning as delivering small, digestible, targeted units and emphasize that the field lacks a universally accepted definition, with the term appearing in multiple variants and related nomenclatures across studies, complicating synthesis and design guidance. This definitional variability matters for instructional research in software engineering, where intervention fidelity and repeatability are central concerns. For example, how short is "short," what constitutes a "unit," and what loop frequency is implied. Where definitions diverge, quantitative synthesis can help clarify whether microlearning works despite heterogeneity. Senadheera et al. [8] frames microlearning as small, well-planned modules and short-term activities and argue that higher education often remains dominated by longer "macro-learning" sessions. The paper's motivation is to quantitatively synthesize evidence comparing microlearning and macro-learning on academic performance. It also operationalizes microlearning duration using prior definitions, such as "ideally two to seven minutes" and not exceeding 15 minutes and describes microlearning using dimensions such as time, content, form, and process. By grounding microlearning in explicit time and design-oriented criteria, this meta-analytic framing supports course-level redesign decisions, for example, as to whether a five-minute segment is consistent with microlearning conventions. However, while synthesis can establish whether effects exist, it typically does not explain how students experience repeated microlearning cycles embedded in authentic course structures, yet this is important in software engineering courses where teamwork, practice, and conceptual integration are core outcomes.

B. Microlearning Implementations: Bite-Sized Lectures and Structured Micro-Units

A second cluster of work focuses less on defining microlearning and more on instructional form factors that mirror microlearning principles. Koh et al. [9] evaluate bite-sized lectures structured as a combination of mini lecture, tutorial, and practical exercises, comparing this approach to regular lecture delivery. The results show significantly higher performance for the bite-sized design on review questions, suggesting that segmentation together with immediate practice can improve learning outcomes compared to longer lecture-only formats. This study supports lecture design of short instruction followed by activity. Relatedly, Sankaranarayanan et al. [10] investigate a microlearning instructional approach in an introductory database programming course and report statistically significant improvement in quiz performance after the microlearning intervention.

C. Learner Satisfaction and Contextual Constraints in Microlearning

Microlearning adoption also depends on learner experience and contextual fit. Rof et al. [11] examine microlearning effectiveness and learner satisfaction through an in-depth single-case study of MicroMaster, an EdTech provider delivering business education via sequenced microlearning units aggregated into macro-learning programs. Their programs consist of large numbers of short microlearning organized into modules, typically assessed through brief tests. Using primarily in-depth, semi-structured interviews with multiple stakeholders (including students, experts, and learning managers) and triangulated secondary data, they argue that microlearning outcomes and satisfaction are not guaranteed and that effectiveness depends strongly on learners' motives for enrolling and the applicability of content to their work context. Consistent with case-study methodology, they emphasize transferability rather than generalization and acknowledge limitations stemming from the single-case, sector-specific design. Collectively, implementation studies suggest that microlearning is most effective when short instructional units are paired with structured practice and feedback [9]. However, the literature primarily emphasizes outcome measures (mainly, performance and satisfaction) [8, 11] and offers limited explanation of how students experience microlearning as a semester long instructional method involving brief content, immediate activity, and reflection in software engineering [10, 15].

D. Active Learning and Interactive Pedagogy in Computing Education

Across computing education, "active" and student-centered instruction is consistently positioned as a response to limitations of passive, teacher-centered lecture formats. In their systematic review, Cordova-Esparza et al. [12] report that these approaches strengthen students' commitment, participation, and motivation, alongside broader cognitive and socio-emotional skill development. Within computer science education, research has also examined how instructional design and classroom structure shape the effectiveness of active learning. Hao et al. [13] argue that peer interaction is foundational to many active learning strategies, and they connect this to the characteristics of active-learning classrooms that are intended to promote collaboration and visibility among students. They found that active learning methods resulted in significantly positive effects on learning outcomes. Software engineering education research likewise emphasizes learner-centered environments but often frames the challenge through the constraints of semester time and the need to support higher-order thinking and application. Lin [15] argues that while learner-centered learning environments are desirable in software engineering, instructors frequently default to teacher-centered approaches due to limited course duration, which can leave students less able to reach high-order thinking and practical problem-solving after instruction. To address this, Lin demonstrates that a flipped-classroom pedagogy significantly improves learning achievement. However, it concentrates explanatory attention on performance and perception metrics tied to the flipped format rather than on how students experience repeated, in-class micro-activities as engagement mechanisms over time. While active learning is often evaluated through the lens of engagement metrics, recent studies emphasize its role in professional identity formation. The Situated Learning Theory suggests that learning is a function of activity, context, and culture, where students move from being novices to members of a community of practice [18]. In this view, interactive pedagogies (i.e., debates or role-playing) serve as simulated “practice fields” where students can safely enact the social norms and communication styles of the software industry [1]. However, few studies have examined how these high-friction social simulations interact with high-frequency microlearning structures to shape students’ perceptions of professional role development.

E. *Generative AI as Educational Scaffolding vs. Academic Threat*

The integration of GenAI in engineering education remains a polarized subject. While traditional discourse often frames GenAI primarily as a risk to academic integrity, recent systematic reviews highlight its growing role in influencing students’ self-regulated learning strategies [16]. Emerging research views these tools through the lens of Vygotsky’s Zone of Proximal Development (ZPD) that suggests GenAI can function as a ‘more knowledgeable other’ or a digital scaffold [17]. In a setting of self-paced learning or microlearning, where instructors may not have continuous access, the capability of GenAI for describing intricate syntax or for debugging his or her own code may theoretically address the issue of autonomy for the learners. However, little research exists on how learners naturally incorporate such solutions into a systematic microlearning curriculum.

F. *Course Syllabi as an Instructional Lever: Learner Centeredness, Autonomy, and Equity Signals*

Eslami et al. [19] conceptualize the syllabus as a consequential course artifact and assess “learner-centeredness” using a rubric organized around three factors: Community (signals of collaboration and instructor–student interaction), Power and Control (policies and structures that share authority by giving students choice, autonomy, and responsibility), and Evaluation/Assessment (mechanisms for ongoing feedback and opportunities for self-evaluation). Using this framework, they report that syllabi from courses with smaller opportunity gaps are, on average, more learner-centered, with statistically significant differences in overall rubric scores between small and large-gap course groups. Their modeling further indicates that Power and Control is a significant predictor of whether a syllabus belongs to the small opportunity-gap group, with a large reported odds ratio associated with increases in this factor. This syllabus-focused evidence provides a direct conceptual bridge to the present study. If syllabi can meaningfully signal autonomy, feedback norms, and the expected structure of learning participation, then “microlearning loops” can be treated not merely as in-class tactics but as a syllabus encoded instructional rhythm, comprising a recurring pattern of short content exposure followed by activity and feedback. At the same time, the syllabus literature does not examine microlearning-specific rhythms, such as repeated five-minute segments paired with rapid collaborative engagement and offers limited insight into how students experience these syllabus signals during day-to-day learning. Our qualitative design addresses this gap by eliciting students’ interpretations of how a syllabus-embedded microlearning-loop redesign relates to their attention, motivation, autonomy, and emerging professional identity in a software engineering course context.

RESEARCH QUESTIONS:

Literature suggests that microlearning can reduce cognitive load in some instructional contexts [20]. However, less is known about how these segmented strategies influence *professional identity formation, affective* dimensions of learning, and the *spontaneous adoption of digital tools*. To address this, this study utilizes a qualitative, exploratory case study to investigate the *how* and *why* behind student engagement in an active learning environment with multiple microlearning components in a SE course. This study is guided by Cognitive Load Theory (CLT) [4] and Self-Determination Theory (SDT) [21] with attention to three interconnected domains: the *students' perceptions* of the course structure, the role of *GenAI* as a support tool, and the function of *social interaction* in professional identity formation. The study addresses the following three research questions:

RQ1: How do students describe the ways microlearning architecture relates to cognitive load and conceptual clarity, especially in comparison with traditional lecture-based instruction?RQ2: How do students describe the extent to which this active, segmented approach supports learner autonomy and a sense of professional engineering identity?
RQ3: What role does Generative AI play as an emergent scaffold within microlearning loops, and how do students navigate the trade-off between efficiency and deep learning?

While the primary aim was to explore student experiences with the microlearning redesign (RQ1, RQ2), our inductive analysis revealed a third, critical factor: the spontaneous integration of Generative AI. Therefore, RQ3 serves as an emergent line of inquiry that explores how students utilize GenAI as a support to navigate the self-paced demands of the course.

THEORETICAL FRAMEWORK:

To investigate the intersection of cognitive processing and student volition, this study utilizes a dual-theoretical framework integrating CLT [4] and SDT [21]. CLT provides a *mechanistic* explanation for how micro-instruction manages the processing limitations of the learner and SDT provides the *motivational* lens to understand how these strategies foster engagement and professional identity.

Cognitive Load Theory, originating from Sweller [4], suggests that human working memory is limited in capacity and duration. In the context of engineering education, learners are often burdened by high *intrinsic load* (the inherent complexity of software architecture) and *extraneous load* (ineffective instructional delivery, such as long-form lectures). Within this study, we interpret microlearning intervention through the lens of the Segmentation Principle, a derivative of CLT defined by Mayer [22]. This principle suggests that people learn more deeply when a multimedia message is presented in user-paced segments rather than as a continuous unit. By segmenting complex software engineering architectures into granular *micro-loops* (e.g., short video [23], online reading [24], debate [25], think-pair-share [26], games [27], peer evaluation [28], group projects [6]), the course design aims to minimize *extraneous load*, effectively 'resetting' attention and preserving working memory for the *germane load* required for schema construction [4, 29]. Crucially, this segmentation is not merely temporal but structural; by treating these loops as iterative ‘sprints,’ the design simulates an Agile professional environment [18], transforming the classroom into a simulated practice field where technical tasks function as industry deliverables. This framework provides the analytical lens to examine how segmentation modulates attention and manages the density of technical information.

While CLT [4] explains the processing efficiency, it does not account for the learner’s willingness to engage. To address this, we employ Self-Determination Theory [21], a macro-theory of human motivation widely applied in engineering education literature [30]. SDT posits that optimal learning and well-being occur when three basic psychological needs are met: *Autonomy* **(**The need to feel in control of one’s own behaviors and goals), *Competence* **(**The need to feel capable of mastering tasks and effective in the environment) and *Relatedness* **(**The need to feel connected to others). In this study, SDT serves as the lens for analyzing the interactive and social components of the course. Crucially, structured debates and role-playing are examined as drivers of Relatedness, shifting the classroom dynamic from passive observation to Professional Identity Formation, where students simulate the social interactions of industry practitioners [1]. Simultaneously, we conceptualize GenAI not merely as a reference tool, but as a scaffold for Autonomy and Competence. It functions as a ‘dyadic support,’ allowing students to self-regulate the difficulty of technical content and maintain momentum in a self-paced environment.

Together, the integration of cognitive segmentation (CLT) and motivational scaffolding (SDT) generates the Social Friction necessary to drive Professional Identity Formation. This culminates in a Simulated Professional Practice, where the recurring pressure of public defense and collaborative execution shifts the student’s role from passive learner to active practitioner. We propose that Cognitive Load Modulation serves as the necessary prerequisite for Self-Determination; once cognitive noise is reduced, the instructional design creates the ‘space’ for Autonomy and Relatedness to emerge.

METHODS

Research Methodology: This study employs a qualitative, exploratory case study approach to investigate the lived experiences of engineering students engaging with microlearning and active engagement strategies [31]. While the sample size is small (n=5), this methodology prioritizes information richness over frequency. The goal is to understand the ‘how’ and ‘why’ behind student perceptions, achieving saturation through deep, semi-structured inquiry within a specific curricular context. The present research design affords rich within-case description of how students navigate the intersection of autonomy, technology, and social learning within one specific software engineering course context.

Course Context and Instructional Design: The study was conducted within a junior-level Software Engineering course at a large public research university. The course delivery was profoundly redesigned from a traditional lecture format into a high-frequency Microlearning Architecture (see Figure 1). To bridge the gap between academic theory and industry rhythm, the course operationalized microlearning loops not merely as instructional segments, but as simulated ‘sprints’ mirroring an Agile professional environment. Here is an example of a microlearning loop. First, students will get a short briefing where they might either watch a five-minute video or a short online reading that visualizes concepts of CI/CD pipelines. Next, the students do an activity to practice what they learned by participating in an activity of either a game, or a debate, or think-pair-share discussion where they must argue about a particular topic (e.g., why a project broke). During this activity, students can use any generative AI for help. Mainly for quick lookups, they are allowed to use it to look up definitions or analytical reasoning, like what *containers* mean or why it matters. This cyclical structure of micro-instruction and immediate active engagement was consistently replicated for every module in the syllabus.

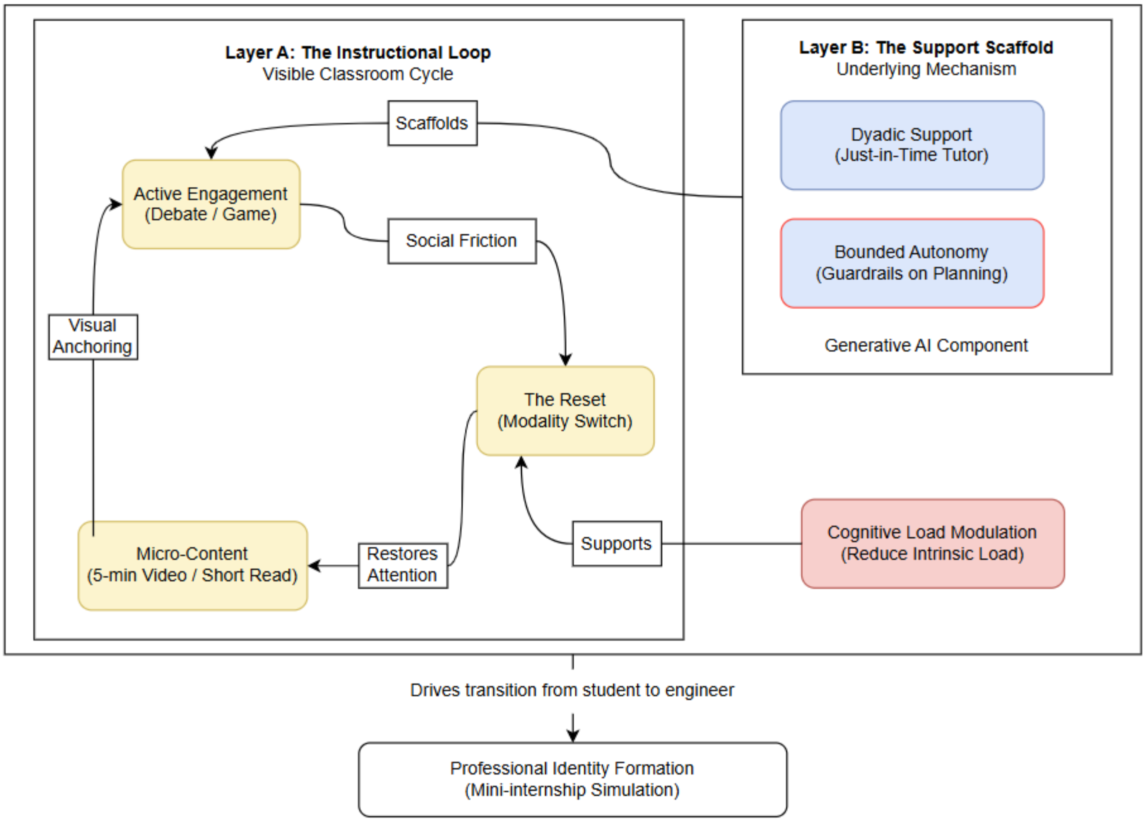

Figure 1: Microlearning Architecture

The course operates on a dual-layer process designed to balance efficiency with deep processing: Layer A (The Instructional Loop): This layer replaces hour-long lectures with a cycle of Briefing and Execution. Asynchronous Micro-Content (e.g., short videos, short readings) minimizes initial cognitive load, freeing class time for Active Engagement. These sessions focus on 'Social Friction' activities (e.g., debates, games) that act as a simulated practice field for professional defense. Layer B (The Support Scaffold): To sustain this self-paced rhythm, Generative AI serves as a Dyadic Support tool. However, this autonomy is 'bounded'; specific guardrails prohibit AI use during critical planning phases (e.g., Scrum estimation) to ensure students engage in the productive struggle of engineering management.

Participants: Participants were selected via purposeful sampling strategies within a junior-level Software Engineering course at a large public research university during the Fall of 2025 [32]. The sample consisted of five male junior-level undergraduate students. We assigned pseudonyms - Alpha, Beta, Gamma, Delta, and Epsilon. The participant pool was predominantly Black or

African American (80%, $n = 4$), with one participant identifying as White (20%, $n = 1$). Sixty percent ($n = 3$) of this participant pool is comprised of international individuals, and two individuals did not self-identify English as their native/first language. Although not generalizable, this creates an interesting demographic nuance for the findings of this study on visual scaffolding and micro-instruction, specifically situating this population within the context of learners using complex technical jargon in a second language. Lastly, one participant was a first-generation college student.

Table 1. Participant Demographics

Pseudonym	Year	Gender	Race/Ethnicity	International	English Primary	First Gen	Helpfulness Rating
Alpha (P1)	Junior	Male	Black or African American	Yes	No	No	Very Helpful
Beta (P2)	Junior	Male	White	No	Yes	No	Very Helpful
Gamma (P3)	Junior	Male	Black or African American	Yes	No	No	Very Helpful
Delta (P4)	Junior	Male	Black or African American	No	Yes	No	Moderately Helpful
Epsilon (P5)	Junior	Male	Black or African American	Yes	Yes	Yes	Moderately Helpful

Data Collection: We use a qualitative approach to capture students' experiences and perceptions. Semi-structured interviews were conducted online with five undergraduate SE students during Fall 2025. Each interview lasted 45–60 minutes and focused on three broad areas: (1) the experience with the traditional method of education (see Appendix A for the full interview protocol), (2) the experience with the microlearning activities, (3) the use of the Generative AI tool. All the interviews were recorded and transcribed.

Data Analysis: The transcripts obtained from the interviews were analyzed through a systematic multi-cycle coding procedure to ensure rigor and depth in interpretation [33]. Coding was conducted manually using structured spreadsheets to allow for close, iterative engagement with the text (see Figure 2). This manual approach facilitated a granular analysis of the participants' experiences without the interpretive layering, sometimes introduced by automated software. The first cycle of open coding was conducted to identify initial concepts and *in vivo* codes directly from the participant narratives, focusing on moments of engagement, frustration, and adaptation. In the second cycle, thematic analysis was used to synthesize these discrete codes into broader categories [34]. The analysis employed a hybrid approach. While Cognitive Load and Self-Determination served as deductive lenses for RQ1 and RQ2, the role of GenAI (RQ3) emerged inductively during the second cycle, prompting a retrospective mapping of AI usage to the *Autonomy* construct of SDT. Finally, a cross-case analysis was conducted to identify key patterns across the participant profile range (e.g., the 'skeptical' learner vs. the 'enthusiastic' adopter), explicitly searching for negative cases (e.g., distraction, AI over-reliance) to ensure the findings reflected the complexity of the learning environment. This synthesis formed the basis of the Findings section, resulting in the three primary themes summarized in Table 2.

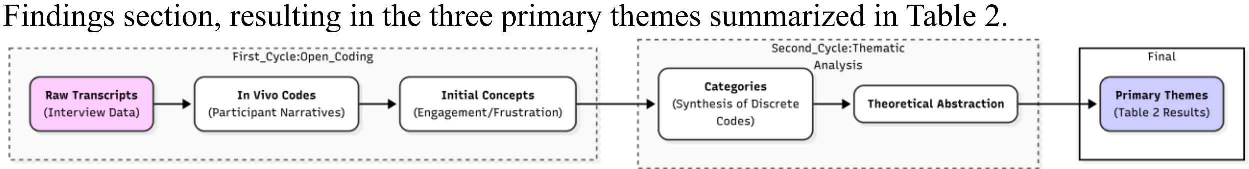

Figure 2: Systematic multi-cycle coding spreadsheet: from in-vivo codes to theoretical themes.

Quality and Trustworthiness: Given the researchers' interest in the pedagogical method, strategies of validity were employed to ensure trustworthiness and mitigate potential bias. The primary researcher engaged in analytical memoing throughout the data collection process to bracket personal assumptions. Furthermore, findings were triangulated [35] by comparing perspectives across the participant pool to ensure the analysis reflected the complexity of the data rather than a single positive narrative.

Researcher's Positionality: The primary researcher is a doctoral student in Engineering. This insider [36] perspective facilitated rapport and technical vocabulary navigation. The researcher held a mixed view, remaining theoretically optimistic about active learning but skeptical of its practical implementation. There was no prior relation with participants and crucially, the researcher did not serve as a teaching assistant.

FINDINGS

Results from the analysis of the recorded interviews identified three key themes. Table 2 below is a roadmap to the evidence supporting each theme identified through coding.

Table 2. Summary of Themes and Associated Codes

Theme	Description	Associated Codes
Theme 1: Cognitive Load Modulation	This theme explores how micro-instructional units' function not merely as shorter content, but as a mechanism for 'resetting' attention, reducing extraneous load, and allowing for immediate cognitive recovery between complex technical tasks.	- Resetting Attention - Instructional Conciseness - Visual Anchoring
Theme 2: Professional Identity Formation	This theme describes the transition from 'student' to 'engineer' through social simulation. It captures how high-friction activities like debates and role-playing serve as a 'safe practice field' for the communication and leadership skills required in the software industry.	- Mini-Internship Simulation - Adversarial Defense - Distributed Leadership
Theme 3: Assisted Autonomy and AI Scaffolding	This theme illustrates the shift from instructor-dependence to learner-regulated pacing. It highlights how students utilize Generative AI as a 'dyadic support' to personalize the difficulty of content, while simultaneously navigating the tension between efficiency and deep learning.	- Dyadic Support Tool - Personalized Simplification - Bounded Autonomy

Theme 1 - Cognitive Load Modulation and the *Reset* of Attention: Participants consistently juxtaposed the redesigned microlearning format against a backdrop of traditional lecture fatigue. The participants perceived that the course structure did not merely shorten content but actively modulated cognitive load, providing a *reset* mechanism that allowed students to sustain attention across the 50-minute period of the class time.

The first sub-theme was *Inefficiency of Mass Delivery*. Participants described traditional engineering lectures as cognitively taxing, often leading to a *tuning out* phenomenon. Alpha (P1) noted the difficulty of retaining information in standard formats, stating, *"Instructors go through slides, sometimes 40 pages... reading and explaining page by page... It's hard to focus, so it doesn't feel very efficient."* This sentiment was echoed by Delta (P4), who admitted that during long lectures, *"Sometimes they'll talk about a certain thing and I'll kind of tune out... I won't hear anything."* In contrast, Alpha found the micro-loop approach allowed for immediate cognitive engagement: *"When you are doing something, that is when you learn, rather than listening for an hour and a half."*

Another sub-theme that emerged was *Instructional Conciseness and Resetting*. The segmentation of content into five-minute videos and short readings appeared to reduce extraneous load. Delta (P4) emphasized the value of this instructional conciseness, noting, *"I feel like the duration was good... it's condensed, which is really good for what we were doing."*

Gamma (P3) utilized this mechanism of *task switching* that helped maintain attention. Gamma explained that *"Switching topics or activities, like a short video followed by an activity, helped me refocus"*. This suggests that for these participants, the *transition* between media types functioned as a cognitive reset button, effectively mitigating the accrual of extraneous cognitive load that is common in continuous lectures.

The final sub-theme was *Visual Anchoring vs. Fragmentation*. While the visual embedding of videos helped retention with Epsilon (P5) noting that *"the photo of the video stays in your head"*, the high frequency of transitions introduced a risk of cognitive fragmentation. Epsilon described moments where the pacing felt overwhelming: *"Sometimes there was too much going on... the next thing there is a poll, the next thing there's a video... To some extent, it distracted me from the main topic."* This contrasting example emphasizes a key boundary condition: while load is reduced through segmentation, the *rapid-fire* switching approach can re-impose extraneous load if not choreographed well.

Theme 2 - Professional Identity through Social Simulation: The second theme identifies an essential change in the participants' perception of themselves as agents in the classroom: from being passive *students* to active *engineers* tackling their profession's friction. This data shows that the loops of interactivity, especially role plays in debates and team-discussions, served as a kind of *safe practice field* for participants' simulation of their professional identity.

The first sub-theme that emerged was *the "Mini-Internship" and Process-Oriented Assessment.* Participants explicitly described the course environment as simulating professional reality. Beta (P2) articulated this distinction by comparing the assessment style to a culinary metaphor: *"It's like being asked how you cook an omelet rather than listing the ingredients."* Beta emphasized that the game-based modules taught *"industry-level thinking, decision-making, risk, and impact,"* rather than rote memorization. Participants explicitly identified the microlearning structure as a driver of professional realism. This sentiment was strongly echoed by Alpha (P1), who stated, *"The class feels like a 'mini-internship'. You learn how to document and write code that others can understand"*. This suggests that the microlearning activities were effective not just because they were short, but because they possessed high ecological validity relative to the software industry.

Second subtheme was *Adversarial Defense as a Learning Mechanism.* A key mechanism for this identity formation was *Adversarial Defense*, the requirement to defend a technical viewpoint against peer critique. Gamma (P3) noted that being assigned a viewpoint to defend *"forces you to think deeply about it... It can be uncomfortable or stressful, but that exposure is valuable"*. Gamma explicitly connected this stress to professional preparation: *"In real jobs, you need to explain and defend your work to others... These activities helped build those communication skills"*. Delta (P4) distinguished this dynamic from traditional quizzing, noting that in a debate, *"someone could ask you a question... you have to try and find a compromise or refute that point"*. This indicates that the *social friction* of the debate format was a driver of deeper cognitive processing.

Final sub-theme was *Distributed Leadership and Psychological Safety*. The small team project structure provided a scaffold for distributed leadership. Alpha (P1) highlighted the rotating roles (e.g., group leader) as a critical developmental arc: *"This creates a stepping-stone: leading a small group... then eventually leading in larger contexts"*. Importantly, Alpha noted that this structure provided Psychological Safety for quieter students: *"Speaking up in front of 100 students is difficult,"* but the small group format *"helps students with anxiety who may not* *approach strangers easily"*. This suggests the course structure allows students to *try on* leadership roles in a low-stakes environment before scaling up to whole-class interactions.

Theme 3: Assisted Autonomy and the Generative AI Dilemma: The final theme illustrates a shift from instructor-dependence to learner-regulated pacing, a transition that was significantly accelerated by the spontaneous use of Generative AI (GenAI). Participants perceived the micro-tasks not just as assignments, but as scaffolds for autonomy, utilizing GenAI as a "dyadic support" tool to bridge gaps in understanding. However, this autonomy was accompanied by a distinct tension regarding the depth of technical competency.

The first sub-theme that emerged was *GenAI as a Dyadic Support Tool*. Participants described GenAI acting less as a "cheat sheet" and more as a private, on-demand tutor that reduced the friction of information retrieval. Alpha (P1) utilized AI for personalized simplification, explaining that while finding a specific video tutorial is difficult, *"ChatGPT can explain it in a personalized way. For example, explaining something 'like I'm five'"*. This allowed Alpha to customize the complexity of the content to their immediate readiness level. Similarly, Gamma (P3) viewed AI as a *friction-reducer* that maintained the flow of the micro-loops: *"With short readings or videos, it's easier to look something up on Google or ask ChatGPT for clarification"*. Gamma explicitly noted that AI functioned as *"an advanced search tool... reducing barriers to learning and helping students move forward faster"*.

The second sub-theme was *Exploratory Freedom*. This support structure fostered a sense of Exploratory Freedom. Beta (P2) noted that unlike traditional exams that demand "right and wrong answers," the course's game-based modules encouraged *"experimentation, trying different approaches, failing, and learning from outcomes"*. Beta emphasized that *"That sense of control made learning more meaningful"*, suggesting that the combination of micro-tasks and AI support empowered students to take ownership of their learning trajectory.

Despite these benefits, a strong sub-theme of *Bounded Autonomy* emerged regarding the ethics and long-term efficacy of AI. Delta (P4) warned that AI should be restricted for tasks requiring human judgment, such as Scrum planning. Delta argued, *"You should figure out times and put that to paper instead of using AI to be lazy,"* noting that in testing scenarios, AI *"missed at least half of the things I had to fix"*. Epsilon (P5) offered the most critical reflection on this Competency Trade-off. While admitting that GenAI fast-tracked project tasks, Epsilon conceded that *"it crippled learning to some extent... You will have a working app, but you don't know what it does."*. This insight highlights a critical pedagogical tension: while GenAI fosters the *feeling* of autonomy and efficiency, it risks undermining the *productive struggle* necessary for deep technical mastery if not bounded by instructional guardrails [37].

DISCUSSION:

The data suggests that the integration of microlearning does more than simply shorten content delivery. It restructures the cognitive economy of the classroom, moving the focus from content coverage (how much can be taught) to attention management (how effectively focus can be sustained). Furthermore, the synergy between micro-autonomy and GenAI suggests a new model for scaffolding, where GenAI acts as a dyadic support that enables, rather than inhibits, self-regulated learning. Our findings corroborate Cognitive Load Theory, specifically the value of segmenting complex technical information to manage *intrinsic load* [4]. Participants described traditional lectures as cognitively taxing, leading to a 'tuning out' phenomenon. However, our data extends established research on segmentation by highlighting a distinct *reset* mechanism. As noted by Gamma (P3), the switching modalities (e.g., from video → game → debate) allowed learners to 'refocus' their attention resources. This suggests that the *variety* of the micro-loop is just as critical as the *brevity* in maintaining engagement. However, Epsilon's experience shows that moving too fast between activities can cause distraction. This highlights the need for careful design to ensure that constant task-switching [38] does not hurt learning more than it helps.

This study reframes active learning from generic engagement to specific identity construction. *Situated Learning* argues that learning is a function of activity, context, and culture [18]. Participants described the course as a *mini-internship* (Beta, P2). The debates and peer discussions were not viewed as participation points, but as simulations of the high-stakes communication required in the software industry. This challenges the view that *soft-skills* are secondary to technical proficiency. Our findings suggest that defending a technical viewpoint may be one important way students perceived their understanding as becoming more concrete. In other words, the microlearning format appeared to provide low-stakes opportunities for students to rehearse professional roles and communication practices. Finally, the integration of GenAI offers a counter-narrative to the anxiety viewing it as a threat to academic integrity. Participants described using AI in ways that can be interpreted, through Self-Determination Theory lens, as supporting feelings of competence and autonomy [21]. By utilizing AI as a 'dyadic support' (e.g., Alpha's use of "explain like I'm five" prompts), some students felt ownership over their learning trajectory. Notably, this function appeared especially valuable for international participants, who utilized GenAI for linguistic simplification and 'cultural translation' of complex metaphors. However, the data reveals a critical competency trade-off. While AI fostered autonomy, participants like Delta (P4) and Epsilon (P5) acknowledged it could 'cripple learning' if used to bypass the *productive struggle* of coding. This suggests that bounded autonomy may be a useful design principle when integrating AI into microlearning environments. Mainly, instructional guardrails that define *when* AI assists and *when* the student must struggle alone to build deep technical schemas.

LIMITATIONS AND FUTURE RESEARCH:

Although this study offers qualitative insight into how a small group of SE students experienced microlearning, some limitations exist. First, the sample size (n=5) excludes statistical generalization to the broader engineering student population. Furthermore, as this was a qualitative exploratory study, findings regarding 'improved learning' are based on student self-reports rather than quantitative performance metrics. Consequently, causality between the microlearning format and academic performance cannot be established from this data alone. While the study prioritizes qualitative insight over frequency, the sample was predominantly international (60%) and of Black or African descent (80%). This demographic profile offers specific insights into microlearning for non-native speakers (Theme 3), yet it would be important for future studies to determine whether these results apply with native English-speaking participants. Second, the study is subject to self-selection bias. The participants were volunteers who were generally career-conscious and engaged. For instance, Epsilon (P5) is already working as a software developer, and Beta (P2) is actively seeking internships. Consequently, our findings may tip the scale in favor of intrinsically motivated individuals while obscuring the experience of the *silent majority*. This absence is notable given Delta's (P4) description of teammates who were *"just there to be there"* and contributed minimally to group discussions. Future research should recruit *disengaged* students to understand if microlearning loops mitigate passivity or merely amplify existing motivation gaps. Third, the findings are contextually bound to an SE course, which inherently balances theory with social application. Participants explicitly questioned the transferability to other domains. Gamma (P3) noted that while this structure worked for SE, it might be less effective for theory-heavy courses like *"Theory of Computation"*. Similarly, Delta (P4) argued that the interactive overhead might be unnecessary for *"purely implementation-based classes like Data Structures"*. Future work should examine whether similar patterns of perceived attentional support and conceptual clarity appear in highly mathematical or theoretical disciplines where social simulation may be less central.. Also, future work should employ a mixed-methods design that evaluates instructional materials alongside quantitative performance metrics to triangulate these qualitative findings. Finally, the *Competency Trade-off* suggests an urgent need for research into bounded autonomy. Future studies should explore how to formalize the integration of Generative AI by designing *AI-free* zones within the syllabus, as suggested by Delta regarding Scrum planning. Additionally, there is a need for longitudinal studies to examine whether the *Professional Identity* perceptions reported in these micro-loops persists once students transition into the workforce.

CONCLUSION:

This study demonstrates that microlearning serves as more than a concession to shrinking attention spans. It functions as a mechanism for Cognitive Load Modulation, allowing students to reset attentional resources and engage in deep technical processing without the fatigue inherent in traditional lectures. By replacing passive endurance with active segmentation, the course transformed the classroom into a simulated professional environment where identity formation takes precedence over rote memorization. Findings reveal a dual-layered success model. First, the Microlearning Architecture satisfies psychological needs: it enables *Autonomy* by offering flexible entry points, supports *Competence* through gamified experimentation, and inspires *Relatedness* by turning isolated study into social defense [21]. Second, our results counter the fear that Generative AI inevitably leads to passive learning. Participants were not lazy learners; rather, they were architects of their own cognition. They utilized AI as a dyadic support or a personalized tutor to bridge gaps and navigate complex jargon, sustaining autonomy required for a self-paced environment. As engineering education evolves, institutional focus will have to shift from content transmission to the architecture of attention. It is on educators to move from static models of delivery to dynamic ecosystems that focus on students and involve technological scaffolding instead of forbidding it. In doing so, we ensure that students master not only technical syntax but also the professional adaptability required for the software workplace.

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Appendix A

Q1: Could you please describe your typical experience in standard and traditional lecture-based engineering courses?
Q2: How did the strict time limit on these short five-minute video modules affect your willingness to watch them?
Q3: How did the course’s short online reading segments change your reading habits?
Q4: When you participate in online games and quick quizzes in the course, did they feel like tests or did they feel like part of the learning process?
Q5: Did the prospect of a game or quiz at the end of a module help you pay closer attention to the content?
Q6: How did explaining concepts to your classmates in active peer discussion and think-pair-share activities affect your own understanding?
Q7: How did having to defend a technical viewpoint in structured debates differ from simply answering a quiz question?
Q8: In terms of autonomy/independence, with so many different activity types (reading, watching, playing, debating), did you feel more in control of how you learned?
Q9: Can you give me an example of a concept you learned through a debate or game that stuck with you longer than something you learned in a lecture?
Q10: Did the variety of these activities make you look forward to class more than usual?
Q11: How do you see the skills of teamwork and adaptability that you used in the debates and peer discussions translating to a real software engineering job?
Q12: If you designed the next version of this course, would you change the balance of these activities? (e.g., More games? Fewer videos? More debates?)
Q13: Is there any other aspect of your experience with this course whether it’s about the microlearning format, the interactions with your peers, or your own motivation that we haven’t discussed yet but you feel is important for us to understand?”

Appendix B

Code	Description	Excerpt
Theme 1: Cognitive Load Modulation		
Sub-Theme 1: Inefficiency of Mass Delivery		
Slide Fatigue / Monotony	The cognitive exhaustion and boredom caused by instructors reading verbatim from large slide decks over long periods.	Alpha (P1): "In other classes, instructors go through slides… sometimes 40 pages… over two class sessions, reading and explaining page by page. As a student, I find it hard to focus, so it doesn't feel very efficient."
		Delta (P4): "Essentially, for courses like Intro to Operating Systems, they just give us a presentation. They read off the slide and might do one or two questions on the board."
		Epsilon (P5): "The professor would just open up their slides. From there on, they'll just be talking through what's happening in the slides."
Passive Learning / Observation	A state where the student is merely a recipient of information with no opportunity to process it, leading to low comprehension.	Alpha (P1): "When you are doing something, that is when you learn, rather than listening for an hour and a half while someone goes through slides."
		Beta (P2): "Most of the talking and work is done by the professor."
		Epsilon (P5): "There hasn't been a day where I've gone to that sort of lecture and came out saying that I actually fully understood what was happening, just because the person was talking and talking to the end."
Attention Drift / Tuning Out	A defensive mechanism where the student involuntarily stops paying attention because the cognitive load is too high or the delivery is unengaging.	Alpha (P1): "But it is hard to focus for an hour and a half, so you miss content."
		Delta (P4): "Sometimes they'll talk about a certain thing. I'll kind of tune out because it's not too important to me. I won't hear anything and I'll have to go back into my notes later."
		Epsilon (P5): "It's really hard for me to stay focused throughout the whole lecture."
Cognitive Mismatch	The disconnect between how the brain naturally retains information and the "binge-learning" required by traditional lectures.	Gamma (P3): "I might not get much out of weeks of lectures, but then right before the exam I would learn almost everything... I don't think that's how the brain is supposed to retain information."
		Beta (P2): "Most of the time, the information is not processed immediately."
Sub-Theme 2: Instructional Conciseness and Resetting		
Cognitive Reset / Refocusing	The phenomenon where switching modalities (e.g., video to activity) acts as a reset button, allowing attention to be refreshed.	Gamma (P3): "Switching topics or activities, like a short video followed by an activity helped me refocus."
		Beta (P2): "Because the videos were short and sometimes split across classes, they stayed engaging. I didn't feel bored."
Conciseness / Manageable Volume	The value derived from content stripped of "fluff," providing a high signal-to-noise ratio that reduces anxiety.	Alpha (P1): "Sometimes we read half a page or less... It's not overwhelming."
		Beta (P2): "Instead of being overwhelmed by long chapters, the readings were concise, clear, and straight to the point."
		Gamma (P3): "Shorter readings helped focus on the main topics and made learning more manageable."
		Delta (P4): "I feel like the duration was good... it's condensed, which is really good for what we were doing… I have most definitely felt less overwhelmed by the volume of text."
Segmented Focus	The ability to tackle one discrete concept at a time without the burden of mastering a massive unit all at once.	Alpha (P1): "With this approach, you focus on one concept at a time, discuss it, and then return later to another concept... it works better than reading 50 pages at once."
		Beta (P2): "The readings created "aha" moments instead of confusion."
		Gamma (P3): "A five-minute video is much easier to watch than a 50-minute one."
Sub-Theme 3: Visual Anchoring vs. Fragmentation		
Visual Anchoring	Using embedded visuals to create a spatial memory hook, helping the student recall the concept later.	Alpha (P1): "CI/CD pipelines. The video explained it visually, showing how things used to be done and how automation works now."
		Epsilon (P5): "Those videos stuck out because when you open [LMS] and are reading the text, the video is embedded there, so the photo of the video stays in your head."
Cognitive Fragmentation (Distraction)	The negative effect of switching tasks too frequently,	Epsilon (P5): "That kind of reduces your focus because now you're talking about this, the next thing there is a poll, the next thing there's a video... Sometimes there was too much going on. To some extent, it distracted me

Code	Description	Excerpt
	leading to scattered attention and re-imposed load.	from the main topic we were going through that day. Sometimes it was pretty dynamic. I'm more of a structured person, so that dynamism didn't help much."
Theme 2: Professional Identity Formation		
Sub-Theme 4: Mini-Internship and Process-Oriented Assessment		
Mini-Internship / Industry Simulation	The perception that the course mirrored the professional workplace (deadlines, teams, deliverables) rather than a classroom.	Alpha (P1): "The class feels like a 'mini-internship'. At the end, you present your project, which is similar to presenting work at the end of an internship."
		Alpha (P1): "You learn how to document and write code that others can understand. Similar to code review and approval processes in internships."
		Epsilon (P5): "It made me very prepared because we treated the class like teams working different sprints."
Process-Oriented Assessment	Assessing the *method* of thinking rather than just the final answer, emphasizing reasoning over memorization.	Beta (P2): "It's like being asked how you cook an omelet rather than listing the ingredients. You explain your process and reasoning."
		Beta (P2): "The games helped me understand industry-level thinking, decision-making, risk, and impact, rather than just academic knowledge."
Professional / Industry Mindset	Shifting focus from academic theory to professional concerns like stakeholders, cost, and sustainability.	Gamma (P3): "In real jobs, you need to explain and defend your work to others, including non-technical stakeholders."
		Delta (P4): "I really think discussions are necessary to understand what a software engineer actually does... not just the knowledge required."
		Beta (P2): "It taught me to balance usability, security, sustainability, and cost. That kind of thinking goes far beyond what you typically get from lectures."
Sub-Theme 5: Adversarial Defense as a Learning Mechanism		
Productive Friction / Deep Processing	The necessary stress or discomfort experienced when defending a viewpoint, which forces deeper engagement.	Gamma (P3): "Defending a viewpoint forces you to think deeply about it... It can be uncomfortable or stressful, but that exposure is valuable… That requires deeper understanding."
		Beta (P2): "That forces you to understand the strengths of that position... It requires deeper analysis than simply choosing a correct answer."
Defense as Verification	The idea that you only truly know a concept if you can successfully argue for it against criticism.	Alpha (P1): "This class gives you practice explaining and defending ideas."
		Gamma (P3): "If someone challenges your argument, you need to explain why the system works the way it does."
		Epsilon (P5): "Sometimes it's easy to say you know a particular thing until you are in a position where you have to defend why it is better than the other."
Dynamic / Real-Time Analysis	The skill of synthesizing responses on the fly during a debate, requiring rapid access to technical knowledge.	Delta (P4): "But in defending a standpoint, someone could ask you a question... and then they bring up another aspect that you have to acknowledge. You have to try and find a compromise or refute that point. It was more that I was able to speak better and think more before I said something."
		Epsilon (P5): "If someone asks you a question and you have to defend a particular idea, it's easier for your brain to formulate ideas in that scenario."
Sub-Theme 6: Distributed Leadership and Psychological Safety		
Psychological Safety	Creating a low-stakes environment (small groups) where anxious students feel safe to speak up without pressure.	Alpha (P1): "Speaking up in front of 100 students is difficult... In the software engineering class, we work in groups of about seven students... so you become comfortable with them… It also helps students with anxiety who may not approach strangers easily."
		Beta (P2): "Many of us are reserved, including myself, but these activities pushed us to interact. Over time, those interactions turned into genuine connections."
Distributed Leadership	The structural requirement for different students to rotate into leadership roles, ensuring everyone leads.	Alpha (P1): "Everyone gets a chance to take responsibility. Every two weeks, someone becomes the group leader... This creates a stepping-stone."
		Beta (P2): "Everyone had opportunities to lead and represent their group. Even quieter students had to stand up and speak."
		Gamma (P3): "Someone from the group often had to stand up and share, which kept the conversation focused."

Code	Description	Excerpt
Failure of Connection (Negative Case)	Instances where the structure failed to create safety due to disengaged peers.	Delta (P4): “These discussions (team/group) did not make me feel more connected to classmates… But whenever the group is just ‘attending in body,’... I can use the time to find the information outside since they aren’t being helpful.”
Theme 3: Assisted Autonomy		
Sub-Theme 7: GenAI as a Dyadic Support Tool		
Personalized Simplification	Using AI to lower the complexity of a topic to the student’s current level (e.g., “Explain like I’m five”).	Alpha (P1): “ChatGPT can explain it in a personalized way, for example, explaining something ‘like I’m five’ or as a beginner. You can prompt it to simplify jargon and explain step-by-step.”
		Delta (P4): “Unlimited access means whenever you don’t understand something... you can input your thoughts into the AI, and it gives you something close to what you’re looking for.”
Dyadic Mentorship / Helper	Treating the GenAI not as a search engine, but as a conversational partner or “mentor” that guides the student.	Gamma (P3): “GenAI acts like a mentor or research assistant, reducing barriers to learning and helping students move forward faster.”
		Beta (P2): “In this class, students are encouraged to think, discuss, and engage first. AI becomes a helper, not a replacement.”
		Gamma (P3): “AI was more like an advanced search tool, similar to Google, but more interactive.”
Just-in-Time Support / Friction Reduction	Using AI to get immediate answers when the instructor is busy, reducing learning latency.	Delta (P4): “ChatGPT provides 5 or 6 bullet points faster than the professor can walk over. For immediate responses, AI is more efficient.”
		Gamma (P3): “With short readings or videos, it’s easier to look something up on Google or ask ChatGPT for clarification.”
		Epsilon (P5): “Whenever we were at a topic I didn’t grasp, the first thing I would do is ask a generative AI... It helped me quickly grasp ideas.”
Sub-Theme 8: Exploratory Freedom		
Safe Failure / Experimentation	The freedom to experiment in simulations where “losing” leads to learning without penalty.	Beta (P2): “The games... allowed experimentation—trying different approaches, failing, and learning from outcomes. That sense of control made learning more meaningful.”
		Beta (P2): “The short readings encouraged curiosity... motivated me to do additional research.”
Creative License / Ownership	The autonomy to choose *how* to solve a problem or format a deliverable.	Delta (P4): “You could format it however you wanted as long as it was within guidelines... I feel like that one gave me the most control.”
		Epsilon (P5): “The professor would say, ‘If you need to research something, just check on Google.’ That gave me ownership of what I needed or wanted to learn.”
Selective Focus	The agency decides which learning resources to prioritize based on personal interest.	Epsilon (P5): “The feeling of being in control was based on what I could choose to focus on... If I saw a video or debate was really interesting, I would try to focus more on that.”
		Delta (P4): “I felt more in control in the sense that I could choose how I’m looking at it.”
		Alpha (P1): “You have control over how you learn and apply the concepts... you still work on your own terms.”
Sub-Theme 9: Bounded Autonomy (Competency Trade-off)		
Crippled Learning / Illusion of Competence	The phenomenon where AI completes tasks so effectively that the student bypasses the struggle to learn.	Epsilon (P5): “But the downside was that… when people aren’t familiar with what they are making, it cripples the learning process… You will have a working app, but you don’t know what it does.”
		Delta (P4): “You lose the value of putting words to paper yourself and thinking through it.”
AI as Laziness	Using AI to bypass “legwork” or human negotiation simply to avoid effort.	Delta (P4): “For some assignments (Scrum)... you should figure out times... instead of using AI to be lazy and schedule it for you… Actually talking to people to figure out that schedule is definitely more effective.”
		Alpha (P1): “However, people can rely on AI too much and stop thinking for themselves.”
Manual Verification / Pre-requisites	The critical need for students to manually check code because AI hallucinates or misses edge cases.	Delta (P4): “But for things where you have to do the legwork... you should actually try to figure out the edge cases by looking at the code yourself. When I tried to use it for those things... the AI missed at least half of the things I had to fix.”
		Gamma (P3): “You need to know how to program to use AI effectively.” “AI can’t evaluate how teammates actually contributed.”