Integrating Digital Tools in Education: An Analysis Using Engeström's Activity Theory

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Abstract. This study examines the teaching of software design and development using an active learning approach centered around a practical IT project. Students were organized into groups and tasked with developing a functional software product based on specific requirements. Throughout the project, teams encountered various challenges, particularly during the coding phase. A qualitative approach, combining interviews and observations, revealed that students frequently turned to external resources, such as the Internet, to support their learning and problem-solving. Educational platforms like MOOCs and YouTube provided structured learning paths and video tutorials that facilitated visual and practical learning. Collaborative coding platforms, including GitHub and Stack Overflow, enabled effective code sharing and teamwork, while interactive tools like ChatGPT offered personalized, on-demand assistance. This diverse ecosystem of digital platforms and online communities supported various learning styles and highlighted a shift towards increased reliance on digital and collaborative resources. The study's findings suggest a deviation from Engestro¨m's model of Activity Theory, indicating that the growing use of digital and collaborative tools is reshaping traditional learning and teaching practices.

Keywords: Engestro¨m's Theory, Learning Styles, Digital Platforms, Online Communities, AI Asssiatance, Software Design and Development

1 Introduction

Historically, educational practices have centered around structured interactions between students and teachers, relying primarily on internal resources. However, the rise of digital technologies has introduced new dimensions to these interactions, reshaping the traditional boundaries of educational systems. Today, students frequently turn to online platforms for problem-solving, raising questions about how these external tools align with or diverge from established educational goals and practices. In software development education, this integration of technology and diverse resources has transformed the learning process. Students often face complex challenges that require a multifaceted approach to problem-solving. This study investigates how the reliance on external resources,

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such as the Internet, impacts students' problem-solving strategies and knowledge construction within a project-based software development context. The theoretical framework guiding this investigation is Engeström's Activity Theory, which offers a comprehensive lens for examining the dynamics of educational activities. In this model, an activity system comprises several interrelated components : the subject (students), the object (project goals), tools (resources and instruments), the community (teachers and peers), rules (norms and guidelines), and division of labor (task distribution). This research aims to explore how the shift from traditional educational resources to external resources affects the learning process. Specifically, it examines the role of the Internet, online coding communities, and AI assistance as tools within the activity system, and how these deviations impact cognitive, social, and affective dimensions of learning. The study seeks to answer the following questions: How do students use digital resources and online communities to overcome challenges and construct new knowledge in a project-based learning environment? How does the integration of these external resources influence the dynamics of collaborative classroom learning and the application of Engeström's model? This research underscores the need to understand how students navigate between formal and informal resources to solve complex problems and explores the implications for socio-constructivist learning models, such as Engeström's. The remainder of this paper is structured as follows. In Section 2, we review the relevant literature and theoretical framework. Section 3 details the methodology employed in this study. The results are presented and analyzed in Section 4, followed by a discussion of the findings in Section 5. Finally, Section 6 concludes the paper and suggests directions for future research.

2 Literature Review

2.1 Activity theory

Activity Theory is a theoretical framework in the humanities and social sciences focused on studying human practices as developmental processes, integrating both individual and social dimensions. Rooted in the work of Russian psychologist Lev Vygotsky, the theory emphasizes mediation, where human behavior is shaped by material or symbolic artifacts [1]. Leontiev, Vygotsky's disciple, expanded this concept to highlight the collective nature of activity, emphasizing how shared goals lead to a division of labor and the establishment of rules within a community [2]. Engeström further developed this framework, introducing the concept of an activity system centered on object-oriented activity. In this model, subjects use artifacts and collaborate within a division of labor, guided by community rules and shared practices [2]. According to Rogalski, the theory focuses on purposeful, motivated activity, where subjects pursue action-oriented goals driven by underlying motives [3]. This perspective views the subject as a multifaceted entity, encompassing cognitive, psychological, social, and affective aspects [4]. Activity Theory also addresses how subjects use artifacts, initially raw tools, that evolve into instruments through knowledge appropriation, a process known as instrumental genesis [5]. Despite the existence of various didactic

theories, Activity Theory is particularly useful in analyzing teaching and learning processes, as it considers how different elements interact within a system of activities and adapts to the specificity of the knowledge being taught.

2.2 Engeström Model

Engeström's model, known as the third generation of Activity Theory, provides a framework for understanding human activities as complex, socially situated phenomena [6]. It extends Vygotsky's concept of mediated action by incorporating a broader set of elements: the subject which means individual or group engaged in the activity, the object or the goal or motive of the activity, and mediating artifacts like tools, signs, or resources used. It also includes the community which is the social context in which the activity occurs, rules which regulates governing the activity, and division of labor that leads to the distribution of roles and tasks [7]. The model emphasizes how these elements interact dynamically to shape and transform both individual and collective practices, especially in contexts of learning and innovation [8]. The following figure 1 illustrates Engeström model:

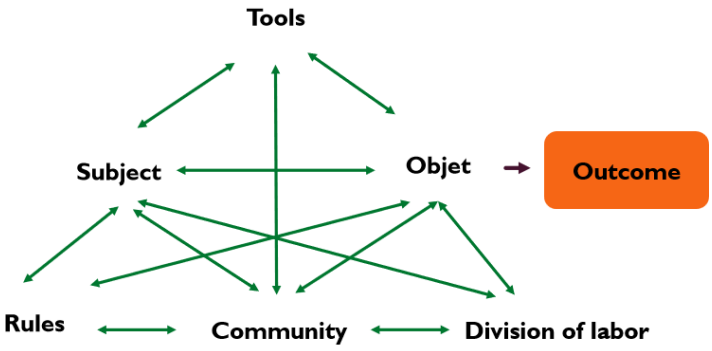

Fig. 1: Engeström model

2.3 The project-based approach

Project-based approach and groupwork refer also to Vygotsky's socioconstructivist model. In a work team, what a member cannot do alone, he will do with the support of the group. Indeed, according to this model, students and their teachers are all enrolled in a system of activities [2]. Despite their respective roles, they are called upon to interact while respecting certain rules for the production of an expected result that is the objective of the projects. The project-based approach makes it possible to engage students in a didactic instrumental genesis. It is in vogue in higher education where it constitutes a rather radical paradigm shift [9]. It is a problem-based learning method designed to stimulate

the utilization and construction of new knowledge. It is employed to illustrate the phenomena of the Zone of Proximal Development (ZPD) within a system of activities, delineating the scope of what the learner could achieve with their teammates. According to Rogalski, the ZPD lies between the current level of development, demonstrated by what the learner can independently accomplish or solve, and what the learner can achieve or solve with the assistance of others, such as adults, teachers, knowledgeable peers, etc. [10]. Thus, it seems to us that the theory of activity is very suitable to be applied in a project-oriented context since the tasks prescribed are based on the subject. They guide, encourage and characterize its practices. In addition, the student learns from what he does and his learning is consolidated in the work in alliances since he is not singular in his activity. Actor of his learning, he interacts and influences himself with others and the knowledge acquired is in perpetual evolution. Tools, subject, object, rules, community and division of labor fare part of the system of activities on which the theory of activity in its third generation is based.

2.4 Digital Tools and Resources in Learning

Technologies, platforms, and digital content support the acquisition, construction, and application of knowledge [11]. These tools and resources encompass a broad range of formats [12], including educational websites, interactive applications, online courses, multimedia content, digital libraries, collaborative platforms like forums or coding communities, and AI-based tools such as ChatGpt. They are designed to facilitate different aspects of learning, such as information access, skill development, communication, collaboration, and personalized support, ultimately aiming to enhance the learning experience and outcomes in both formal and informal educational settings [13]. This use of digital tools generates an effective learning environment and encourages self-learning, which even improves students' pedagogical performance [14]. This integration demonstrates the effectiveness of digital tools in developing critical analysis, problem-solving, and reasoning skills, as well as enhancing student motivation [15]. While these applications and automated digital environments offer many opportunities, they cannot replace the role of a supervisor or teacher. Otherwise, we would need to consider either redefining the role of teachers or facing the obsolescence of the profession [16] So, it seems to be an inevitable restructuring of higher education teaching and learning pedagogies ensuring the continuous and effective learning of students is deemed important. Despite such vitality, a prevalent disparity worldwide on the usages and gains of digital and social media integration is still noticeable [17].

3 Methods

This study adopts a qualitative research approach, specifically utilizing a case study design to explore the experiences and challenges faced by students in a project-based learning environment for software design and development. The

objective is to understand how students navigate through their tasks, interact with resources, and develop problem-solving skills while working on an active IT project. The study was conducted with 160 third-year students specializing in Information Systems Development, all of whom were enrolled in a "Mini-Project Workshop" module. The participants were divided into several working groups, each tasked with developing a software product based on specific project requirements provided by the instructor. Each team consisted of 4–6 students, which allowed for a range of collaboration dynamics and learning experiences.

3.1 Data Collection

Data were collected through two qualitative methods to capture a comprehensive understanding of the students' experiences:

- Direct observations were made during the project development phases : The researcher observed group interactions, tool usage, and team dynamics. The goal was to identify points of difficulty and the strategies adopted to overcome them. These observations were documented in the form of field notes.
- Interviews were conducted after the project phases to provide deeper insights into their experiences, challenges, and perspectives on problem-solving.

3.2 Data Analysis

A qualitative content analysis was performed on the collected data. After coding process, we have identified key themes related to the following aspects:

- Difficulties Encountered: Challenges faced by students at different stages of the software development process, such as issues with coding, debugging, or conceptual understanding.
- Use of digital tools and Resources: How students utilized external resources (e.g., online communities, coding forums) to support their learning and problem-solving efforts.
- Classification of the external tools used to overcome challenges in a software development context. A codebook was developed to support the transparency of the coding process.

The table 1 presents how codes were structured within broader themes.

4 Findings

We conducted a comparison of engineering activities that involve a greater reliance on digital tools to solve difficulties. I discovered that students tend to utilize digital tools predominantly during the implementation phase of the project, and to a lesser extent during testing. However, the modeling phase is relatively less involved in the use of digital tools. Figure 2 presents the results. Focusing on the implementation activity, we conducted an examination of the use of environments and tools in students' projects. We observed that the use of online tools and resources compensates for the environments and languages not included in

Table 1: CodeBook

Theme	Code	Description
Difficulties Encountered	Modeling issues	Challenges related to understanding and applying UML
	Implementation difficulties	Problems encountered during the coding phase such as syntax or logic flow errors
	Testing obstacles	Issues during testing phase including debbuging or verifing functionality
Use of digital tools	Overcome challenges	Use of digital platform to solve modeling, coding and testing issues
	Learn by oneself	Self-directed learning via digital platforms to explore new technical domains.
Classification of External tools	Tool classification	Categorization of tools used by students
	Percentage of use	The percentage breakdown of the different external tools used by students

their curriculum. Indeed, access to various sources of information has enabled them to engage in autonomous learning of new frameworks. This reliance is further motivated by their courage to explore new environments and their openness to the technologies currently used in the market. Additionally, the limited hours allocated in the curriculum for teaching various programming languages and environments inevitably restrict their exposure and learning opportunities.They maintain proactive engagement with digital tools. Figure 3 clarifies the results.

Focus on External Tools used, we conduct this classification which helps to understand the different roles and benefits each type of tool can offer in the learning and problem-solving process :

- Online Learning Platform such as OpenClassrooms which provides structured courses, tutorials, and projects related to various subjects, including software development. They appears as courses, certifications, interactive projects, mentorship
- Video Sharing Platform such as Youtube which offers a wide range of video tutorials, lectures, and demonstrations on various topics, including coding and software development. Their features are Video tutorials, user-generated content, visual explanations, practical demonstrations.
- Collaborative Coding Platforms like GitHub and Stack Overflow that facilitates version control, collaboration, and sharing of code with features for issue tracking and code reviews. It offers code repositories, version control, collaboration tools, open-source projects.

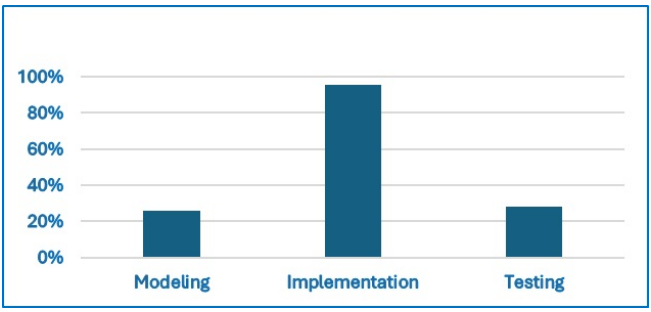

Fig. 2: Comparison between activities involving online ressources

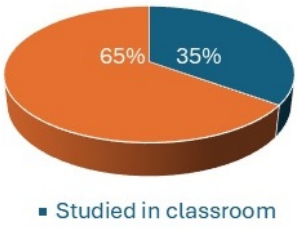

Fig. 3: Environements and tools used

– Interactive Learning Assistance represented by ChatGPT (AI) which provides real-time assistance, explanations, and guidance on various topics, including coding problems and theoretical concepts. Ils allows real-time conversation, personalized responses, problem-solving assistance, explanatory content.

The rate of external tool use is shown by the following figure 4:

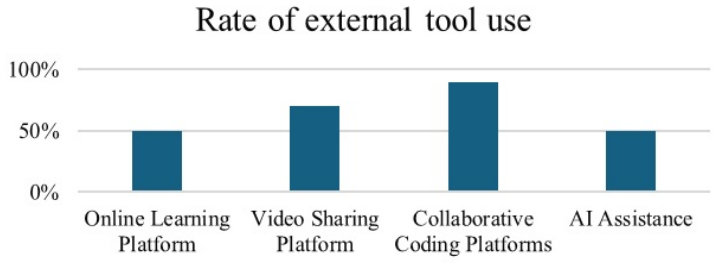

Fig. 4: Rate of external tool use

5 Discussion

Our investigation revealed that Generation Z students, who are highly accustomed to using the Internet, have developed a reflex of searching online for information to address the challenges they face, particularly in coding their software. Their search behavior tends to focus on four main sources: MOOCs, tutorials, forums, and Git repositories, as well as artificial intelligence assistants. Access to these online information sources and AI assistance has also empowered students to explore frameworks and programming languages not covered in the classroom. This demonstrates a growing sense of courage and willingness to learn independently at this level. We deduce that these online sources significantly influence students' knowledge construction and skill development, providing diverse tools and perspectives beyond traditional classroom learning. Moreover, the growing reliance on these digital resources also impacts teaching methods and practices, pushing educators to adapt their approaches to integrate these tools, foster digital literacy, and support self-directed learning among students. this requires teachers to modify their teaching strategies, embrace new technologies, and encourage independent learning skills. The results may suggest a divergence from traditional classroom-based learning models and the potential need for curriculum adjustments.

Our findings reveal that students frequently rely on digital tools and external communities to overcome challenges encountered in their software development projects. Using Engeström's Activity Theory as a lens, this reliance can be understood as a dynamic interaction within the activity system, where traditional educational tools and resources are increasingly supplemented or replaced by online platforms, forums, and AI assistance. This reflects a deviation from the traditional model at different stages :

- Tools and Mediating Artifacts : According to Engeström's model, tools are mediating artifacts that influence how subjects (students) interact with the object (learning goal). In this case, digital tools such as MOOCs, online tutorials, forums like Stack Overflow, and AI assistants like ChatGPT serve as mediating instruments. These tools extend the students' capacity to solve problems by providing immediate access to vast repositories of knowledge, peer support, and expert guidance, which is not always available within the classroom environment.
- Division of Labor: The division of labor in traditional classroom settings often assigns roles such as teacher as the primary knowledge source and students as passive recipients. However, the reliance on digital tools shifts this dynamic, encouraging students to become active participants in their learning process. This shift reflects a deviation from the conventional distribution of tasks, where students take on roles traditionally held by teachers, such as seeking out information, evaluating its relevance, and applying it to their projects.
- Community: The digital learning environment expands the "community" component of the activity system. Instead of being limited to peers and teachers within the classroom, the community now includes online platforms,

coding communities, and open-source contributors. This expansion allows students to engage with a broader network, facilitating collaborative learning and the sharing of diverse perspectives and expertise.
- Rules: Engeström's theory also emphasizes the influence of rules or norms governing the activity. In a traditional classroom, the norms are often teacher-centered, with a fixed curriculum and standardized assessment. However, the use of digital resources introduces new norms, such as self-directed learning, peer validation, and collaborative problem-solving. These evolving norms may cause tension within the activity system as students navigate between formal classroom expectations and the informal practices of online communities.
- Outcomes and Learning Goals: The outcome of the educational activity, initially centered around the creation of a software product, is now also influenced by the knowledge and skills acquired through external digital tools. This reliance on external resources suggests a transformation in how learning goals are achieved, emphasizing adaptability, self-regulation, and collaborative skills alongside technical proficiency.

6 Conclusion and outlook

The didactic subject, often regarded as a sociological entity, is increasingly familiar with the use of ICT, making web-based research a natural, reflexive activity. This shift suggests that today's students, influenced by technology, display cognitive styles and learning modes distinct from previous generations. This research aims to explore further the role of out-of-classroom learning in shaping knowledge construction and evolving teaching practices. This reflects a deviation from the traditional model, as the community expands beyond the classroom and the division of labor shifts, with students taking a more autonomous role in their learning process. By applying Engeström's Activity Theory, we can interpret the reliance on digital tools and external communities as a response to the evolving educational ecosystem, where traditional classroom resources and methods alone may not suffice to meet the complex and dynamic needs of contemporary learners. When exploring the impact of digital tools and external communities on learning—especially through the lens of Engeström's Activity Theory—several potential limitations may arise. Firstly, one limitation is the absence of a comparative study between two subsets of students: those using digital tools exclusively versus those relying solely on traditional learning methods. This comparative analysis could provide valuable insights into the effectiveness of different learning strategies in addressing challenges encountered during software development tasks. By not including this perspective, we miss an opportunity to evaluate how each approach influences student engagement, problem-solving skills, and overall learning outcomes. Future research could benefit from exploring this comparison to enrich our understanding of effective educational practices in the context of digital tool usage. Secondly, data collection challenges may introduce biases in the results, despite the presentation of the codebook. By integrating quantitative

methods alongside qualitative approaches, we can triangulate the data and obtain a more comprehensive view of how digital tools impact student engagement and learning outcomes. This mixed-methods approach will not only improve the reliability of our findings but also allow for clearer comparisons and conclusions regarding the use of digital tools in educational settings. Lastly, we acknowledge that the results may vary in different contexts, as the specific focus on third-year Information Systems students at a Tunisian university limits the generalizability of our findings.

However, several research questions warrant further exploration. We propose :

- Does relying on online resources lead to greater problem-solving skills and project success compared to students who depend solely on internal, classroom-based resources?
- What are the risks associated with over-reliance on digital tools? Does it hinder the development of critical thinking, creativity, or non-technical skills such as teamwork and communication?
- What about the effectiveness of external resources? Do they contribute to the depth and quality of students' understanding? Is there real knowledge construction?
- Does reliance on external resources increase or decrease cognitive load, and how does this impact overall learning outcomes and knowledge retention?
- What didactic approaches should be adopted to effectively integrate digital tools and external communities into the learning process? How can educators design their teaching strategies to align with these new dynamics?
- How can teachers address the challenges of integrating digital tools into their classrooms? What support, training, or resources do educators need to effectively use these technologies while balancing traditional teaching methods?
- How well do external resources and tools align with the curriculum goals set by educational institutions? Are there conflicts or gaps that need to be addressed?
- How should assessment practices evolve to accommodate the shift towards using external resources and digital tools? Are traditional assessment methods still valid, or do new forms of evaluation need to be developed?
- What would the findings be if we investigated different educational environments, student demographics, or academic disciplines?

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