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Browsing to learn: How computer and software engineering students use online platforms in learning activities

Andrés Araos[1] | Crina Damşa[1] | Dragan Gašević[2]

[1]Department of Education, University of Oslo, Oslo, Norway

[2]Department of Human Centred Computing, Monash University, Melbourne, Victoria, Australia

Correspondence
Andrés Araos, Department of Education, University of Oslo, Postbox 1092, Blindern, 0317 Oslo, Norway.
Email: a.a.a.moya@iped.uio.no

Abstract

Background: The surge of online platforms has generated interest in how specialized platforms support formal and informal learning in various disciplinary domains. Knowledge is still limited regarding how undergraduate students navigate and use platforms to learn.

Objectives: This study explores computer and software engineering students' learning practices, wherein online platforms are used as resources for both curricular learning activities and students' interest-driven learning.

Methods: The learning practices of 73 students were examined using a mixed-methods design and a conceptualization of practices accounting for the context and purpose of their enactment. The dataset includes students' self-reports on domain-specific learning activities, three-month-long web-browsing history of multiple platforms and stimulated-recall interviews. The data were analysed through latent class and thematic analyses.

Results and Conclusion: Five distinct patterns were found in the use of online platforms. These patterns show that different types of platforms were used purposely and in combination during curricular and interest-driven activities aimed at learning software development. Moreover, students' purposes were driven by both the need to progress in their learning activities and the development of their interest in software development. The findings highlight the complexity of students' learning with online platforms, which develop quite extensively beyond curricular boundaries.

Implications: The findings stress the need to recognize that undergraduate students' learning practices involve multiple online platforms and activities beyond the formal curriculum and that these play a key role in developing students' interests in learning software development. Moreover, our findings indicate the importance of taking into account the way students' learning practices unfold within platforms and how these relate to domain-specific practices.

KEYWORDS

ecological perspectives, higher education, learning practices, online platforms, online resources, software development

1 | INTRODUCTION

The advent of digital technologies over the last two decades has revolutionized several aspects of our lives. Online platforms, such as Google, Discord, Stack Exchange or Udemy, where users can easily find, share or create content, have become an integral part of our daily practices, including those related to work and learning. Online platforms are architectures of web technologies that offer access to a wide variety of resources that can connect students to different types of information, relevant people, communities and organizations (Casilli & Posada, 2019; Bruce & Levin, 1997). This plethora of resources provided by online platforms allows several opportunities for learning that can be tailored to students' needs and their regular ways of engaging with online platforms (Peters & Romero, 2019).

Concurrently, the rapid development of online platforms challenges institutions and students, as new technologies allow for new practices that shape students' motivations for studying and learning. Yet, while students' use of online platforms is documented and while higher education is in the process of shifting towards platform-enhanced work and learning, research studies tend to focus strictly on online resources selected by teaching staff. Recent research examining social networking (SN) platforms, such as Twitter or Facebook, demonstrates the use of these platforms during formal teaching activities. These platforms are used to support students' collaboration and communication as well as the way they share and access information (Luo et al., 2020; Zlatkin-Troitschanskaia et al., 2021). While it provides valuable insights, such research disregards resources that are openly available on other online platforms that are not included in or referred to by the formal curriculum. Students access and use these resources informally (Dowling-Hetherington et al., 2020; Henderson et al., 2017), and the evidence available suggests that such resources play an important role in orienting students into various disciplinary domains and stimulating their interests towards learning (Peters & Romero, 2019; Watted & Barak, 2018). While research suggests that platforms can play an important role in both curriculum-based and interest-driven activities, little attention is given to how students explore and use resources (from) outside the course curricula.

Furthermore, despite arguments that students' use of online platforms during both types of activities relates to domain-specific practices (Azevedo, 2011; Peters & Romero, 2019), relevant research is rather limited (Zlatkin-Troitschanskaia et al., 2021). Understanding the way in which students use online platforms is particularly relevant in the domain of computer and software engineering (CSE). The CSE domain has changed radically in the last decade, becoming rich in practices that involve the use of highly distributed online platform ecosystems, especially in central activities such as software development (Storey et al., 2017). Some studies suggest that CSE students make use of those same ecosystems, and that their learning practices are influenced by the ways in which professionals use platforms for their work. This includes, for example, following methods of experienced developers (Damşa & Nerland, 2016; Tushev et al., 2020) or resources placed online by professionals (Chatterjee et al., 2020). Thus, CSE students' use of platforms and engagement with domain-specific practices that involve the use of platforms are important aspects of students' learning.

The existing research on informal and interest-driven use of online platforms that examines students' use of these platforms for academic purposes is primarily based on self-reports and tends to overlook how and why platforms are used in specific contexts (e.g., learning to code) (Zlatkin-Troitschanskaia et al., 2021). In addition, despite awareness of the dynamic and complex nature of processes related to the use of platforms (Josefsson et al., 2016), the focus in empirical research is on outcomes rather than the processes through which outcomes are generated. There is thus a limited understanding of how online platforms are used by students and how engaging with platforms beyond the boundaries of the curriculum contributes to their learning.

The study we report in this article aims to address this knowledge gap by exploring the learning practices of CSE students as they use online platforms as resources for learning activities. Activities exist beyond an individual level and can involve multiple actions and unfold under specific social and material circumstances (Zheng & Yano, 2007). The learning activities in focus may concern those that are defined by the course curricula as well as those initiated by students based on their own learning needs and interests. Specifically, in this study, we seek answers to the following research questions:

> **RQ1.** *How do CSE students use online platforms as resources for their learning activities?*

> **RQ2.** *What purposes drive students' use of online platforms during these learning activities?*

To answer these research questions, the study employs a conceptualization of learning practices following an ecological perspective (Barron, 2006; Damşa & Jornet, 2017) that expands the notion of 'social practice' (i.e., the way people do things by interacting with their environment) (Kemmis et al., 2014; Schatzki, 2001). We use a mixed methods design that combines digital traces, survey and interview data, as well as quantitative and qualitative analytical methods.

In the remainder of the article, we review literature on the use of platforms during learning activities, explain the theoretical notions employed in our interpretations, present the research design, data and analyses and discuss the patterns of use of online resources while emphasizing their relevance for research and practice.

2 | USE OF PLATFORMS FOR LEARNING ACTIVITIES—A REVIEW

2.1 | Use of platforms for curriculum-based learning activities

The literature addressing students' use of online platforms during curriculum-based activities has focused mostly on the formal use of online platforms (i.e., when these are officially recognized and included in these activities by teaching staff) (Portelli, 1993). The majority of those studies focuses on SN platforms, specifically Facebook, Twitter and Pinterest, showing they have been used to facilitate student communication, sharing and accessing course-related information, discussions and the asking of questions (Luo et al., 2020). Other studies show SN platforms being used to connect students with field experts (Kassens-Noor, 2012), simulate connections with customers or manage online portfolios during course assignments (Baker & Hitchcock, 2017; Lapolla, 2014). Domain-specific platforms in contrast have received less attention. In CSE education, some studies have examined the formal use of GitHub, a source code repository (SCR) platform, and Stack Overflow, a software development-centred question and answer (Q&A) platform. These platforms were introduced during software development tasks and used to support collaboration (Tushev et al., 2020) and problem-solving using selected posts from the platforms (Chatterjee et al., 2020). Although this literature suggests that the formal use of platforms can support students during curriculum-based activities, its scope is limited to single platforms and mainly SN platforms.

The available research on students' informal use of online platforms, which 'arises out of their own reactions and attitudes towards' curriculum-based activities (Portelli, 1993, p. 346), suggests that students use a wide variety of platforms (Dowling-Hetherington et al., 2020; Henderson et al., 2017; Yot-Domínguez & Marcelo, 2017). This includes SN platforms and others, such as Google, YouTube, Khan Academy and WhatsApp, which students use to search, find, share and organize information, discuss, communicate and collaborate with others and watch course-related videos. Studies in CSE education specifically suggest that students use platforms such as Facebook to communicate (Charlton et al., 2009) and also domain-specific platforms, such as W3Schools, a tutorial platform, to learn methods used by experienced developers (Damşa & Nerland, 2016). Nevertheless, these studies rely mostly on self-reported data, focusing mainly students' perceptions rather than on how platforms are being used during curriculum-based activities. In addition, these studies disregard the use of platforms during learning activities that take place outside curricular contexts.

2.2 | Use of platforms for interest-driven learning activities

The use of online platforms during learning activities planned and driven by students outside the lecture or seminar hall (i.e., interest-driven activities) has received little attention. These activities reflect interests and need for information that are not included in the curriculum but that supplement it (Kim & Jung, 2019; Portelli, 1993). Josefsson et al. (2016) studied students' use of SN platforms and found a clear distinction between educational and personal (i.e., leisure) use of platforms. Moreover, they identified a third use related to career building and highlighted that these were constantly changing over time. Other studies examining students' interest-driven activities with SN and VR platforms found that students used these platforms for multiple purposes (Brown et al., 2016; Daniels et al., 2021). This includes discussing with others, searching for interest-based activities, and publishing videos created in course assignments, poetry, song writing, personal journals or information about work experience. Lastly, some studies explored students' motivations for partaking in massive open online courses (MOOCs). These studies found that students' main drivers were personal interests, their future careers and income, knowledge improvement, obtaining certifications and complementing their formal education (Milligan & Littlejohn, 2017; Watted & Barak, 2018). Romero-Frías et al. (2020) found that while a majority of MOOCs participants were driven by intrinsic motivations, such as academic success, extrinsic motivations, such as monetary rewards, also played an important role. While scarce, this literature suggests that using online platforms during interest-based activities can play a key role in student learning, as these activities can be study-related and linked to students' motivations towards learning.

2.3 | Use of platforms for CSE domain-specific learning activities

The CSE domain has changed radically in the last decade, becoming rich in online resources and practices (Storey et al., 2017). Research has shown that students' learning practices are influenced by professionals' methods and the ways in which they use platforms (Damşa & Nerland, 2016; Tushev et al., 2020) or resources placed online (Chatterjee et al., 2020). CSE professionals often engage in loops of problem-solving for their work and also in domain-specific learning activities based on long-term interests (Nerland, 2008). Empirical studies have shown that CSE professionals rely on multiple online platforms for these purposes, including tutorials and courses (T&C), Q&A and SCR platforms (Saddler et al., 2020; Xia et al., 2017). CSE professionals use these platforms to access different online resources, such as explanations, code snippets, discussions and solutions to coding problems, and to develop and submit contributions to open-source projects. Moreover, some studies also show that CSE professionals rely on these platforms and on SN platforms to follow relevant news and the progress of open-source projects, as well as to gain reputation by sharing updates to their work and answering questions from others (Aniche et al., 2018). These professionals stay up to date with trends from the software industry and manage their careers (Nerland, 2008), with these studies suggesting that platforms play a key role in the enactment of such practices.

3 | CONCEPTUAL FRAMEWORK—AN ECOLOGICAL PERSPECTIVE ON LEARNING PRACTICES

The notion of *learning practice* allows us to interpret students' use of online platforms for educational purposes, as we conceive of this use as constitutive of practices that are enacted by students in order to learn. Practices are socially constructed ways of experiencing the world by acting on it (Kemmis et al., 2014; Schatzki, 2001). Both the world and actions are complex and dynamic. An ecological perspective on learning practices accounts for such complexity, as it views practices as emergent of relations that students establish within their environment (e.g., curriculum, learning environments and platforms) and encompasses how these relations are experienced, through purposes, motivations and valuing (Barron, 2006; Damşa & Jornet, 2017).

One cannot separate practices from their specific physical space–time locations and the context in which they are enacted (Kemmis et al., 2014). While actions are performed by the learner, they take place as part of contextualized activities that exist beyond isolated actions and are bound to specific situations and circumstances (Zheng & Yano, 2007). For example, trying to solve coding problems (activity) during a software development group task part of a specific course (context). However, contexts also shape practices by influencing learners' subjectivities, since they trigger different ways of relating with the environment (Papadopoulos, 2008). When learning, learners reconsider and reconfigure their actions as they move from one context to another over time, making the enactment of practices and learners' concerns interrelated (Dreier, 1999). This enactment is determined by both the dynamic changes in the activities learners partake in (Zheng & Yano, 2007) and its continuous interplay with the context in which these activities take place. Therefore, learning practices need to be studied in terms of the relations learners establish in their environment, how these unfold and are organized and learners' activities in relation to their (contextualized) purposes (Damşa & Jornet, 2017).

Building on this conceptual underlay, two main constructs facilitate the interpretation of students' engagement with online platforms for learning. The first is the notion of *contextualized learning practices*, that is, the learning activities taking place in specific contexts and that serve specific purposes (Kemmis et al., 2014; Zheng & Yano, 2007). Online platforms represent sites for the enactment of practices, as they provide the necessary infrastructure for certain activities to take place. Analytically, we focus on the performance of actions that involve accessing and using online platforms, which have different configurations and varying intensity. *Configuration* characterizes learning practices and is a variable constituted of different combinations of platforms or functionalities that offer students different forms of support. *Intensity* is given by the frequency and duration of use contingent on the types of activities, number of participants and/or platforms involved, and so forth. The types of activities taking place as practices are enacted help explain why specific actions are performed and why particular platforms or functionalities are accessed in certain circumstances. For example, using Stack Overflow in conjunction with GitHub while developing software is different from using it while discussing a coding problem with others using a communication platform. Activities can be directed towards contributing to the conceptual and/or physical (or virtual) progress of a task—*epistemic activities*, or to supporting and managing the progress of a task— *regulative activities* (Damşa et al., 2010).

A second construct employed for interpretations is learners' *purposes* (or motives to act). Purposes are determined by the relationship between the meaning of the actions performed from the learners' perspective, the perceived value of the resources used, and by how meanings are accessed in each situation (Nolen et al., 2015). Purposes respond to the subjectivities that learners build over time as they interact with their environment. Analytically, we use a typology of purposes related to students' engagement with and use of platforms (Garrick & Solomon, 1997). Such purposes help explain why practices are enacted and/or platforms are used in the first place. This includes purposes related to promotion and/or better wages—*future reward purposes*, to valuing diverse knowledge, skills and experiences—*difference purposes*, to being part of a team or a community—*belonging purposes*, and to having a sense of ownership of the decision taken—*empowerment purposes*.

4 | METHODS

This study employed an exploratory mixed-methods research design (Greene, 2007). We used this approach to address the challenges of a limited sample size and of collecting data outside of students' formal educational setting. We combined a quantitative approach, used to find patterns in students' digital traces from online platforms, with a qualitative approach to conduct an in-depth exploration of students' purposes when engaging with platforms following particular patterns.

4.1 | Empirical context and participants

We recruited students from CSE programs from four major universities in Norway in two rounds: one during the fall 2020 semester (S1) and the other in the spring 2021 (S2) semester. S1 had the objective of exploring students' learning practices with online platforms in relation to activities specific to the CSE domain. S2 had the objective of relating those same activities that involve the use of platforms to different learning activities. We used a convenience sample to reach out to teachers in software development related courses, who became contact points for students. The topics addressed in those courses include different coding languages and approaches, web development and the construction and implementation of databases, among others. For recruiting students, we used a voluntary response sampling. The teachers sent invitations to students to participate voluntarily in the study. In addition, we also asked students who volunteered to participated in the interviews to invite their peers, thus involving a snowball sampling approach. The identities of the participants during data collection, processing, analysis and storage were protected using randomly generated ID codes and by use of a secure server, compliant to the European General Data Protection Regulations (GDPR) and the Norwegian regulations for data privacy (NSD). S1 comprised of 33 students, while S2 of another 40 students. Of the total 73 participants, 32 identified as female and 42 as male students.

4.2 | Measurements and data preparation

4.2.1 | Data type I: Self-reports on the use of online platforms for CSE domain-specific learning practices

We collected students' self-reports on the use of online platforms for CSE domain-specific learning activities using a two-stage strategy. In S1, students answered a survey about four categories of activities involving the use of online platforms linked to the practices of CSE professionals (Nerland, 2008): (1) solving problems while working on software tasks; (2) learning about software development; (3) staying up to date with trends in the software industry and (4) career management. For each one of these categories, we identified activities in studies addressing CSE professionals' use of online platforms and resources. Students answered the survey by selecting, from a predefined list, activities they carry out and which platforms they use for each category of activities. In S2, we related the identified domain-specific activities from the first survey to four categories of learning activities: (1) searching, saving and sharing resources; (2) understanding concepts or methods; (3) reusing/repurposing resources and (4) working together with others. For each one of these categories we assigned activities identified in S1, which we re-distributed and adapted. Students also selected the activities they carry out and which platforms they use for each category of activities and indicated if they use these platforms for activities unrelated to software development.

To ensure the quality of both surveys, we implemented several measures. In the design of the questionnaires, we used only dichotomous questions, to avoid the need of validating a scale, and piloted them with CSE students and professionals, and with peers. After data collection, we calculated correlations for the aggregated responses of each category of both surveys and ran Kuder–Richardson 21 tests to assess reliability. The correlations resulted to be significant in 5 out of 6 of the tests and consistent with theory, while the reliability tests resulted in 0.93 in S1 and 0.94 in S2. Other relevant measurements include completion rate, which reached 55% in S1 and 60% in S2, and average response time, which reach 13.8 min in S1 and 14.9 min in S2.

4.2.2 | Data type II: Web browsing history

We collected web-browsing history data of the platforms selected by the students in both surveys using a custom-made Google Chrome extension (Google, 2021). This software was developed for the particular purpose of this study. It was installed by participants on their Google Chrome browsers and uninstalled after the survey was completed. The extension collected, for each student, a longitudinal dataset with information about every time each selected platform was accessed during the three-month period prior to the moment the survey was submitted. The dataset included two main variables: the name of the platform (e.g., Google) and the exact time and date when it was accessed.

4.2.3 | Data type III: Stimulated recall interviews

We carried out stimulated recall individual interviews (Dempsey, 2010). Based on volunteer participation, 16 students were interviewed in S1 and 11 in S2, using an online video conference service that had a screen sharing feature. During each interview, students were shown the platforms they selected in the survey responses as well as the monthly frequency of access to each platform, as obtained from their web-browsing history data. Students were prompted to discuss their experiences with using platforms in terms of what projects or tasks they were working on, what they were learning during the three-month period (i.e., during corresponding semesters), and which resources they accessed and what they were used for. The interviews were audio recorded and transcribed verbatim.

4.2.4 | Data preparation: Sessionization and data triangulation

We used students' *web-browsing sessions* (i.e., the *continuous use of different online platforms*), classified by time across multiple overlapping contexts, as our primary temporal-contextual unit for analysing learning practices that involve the use of online platforms.

We operationalized these sessions through a process of *sessionization*, in which the events in the browsing history data were grouped into smaller aggregated units by defining a maximum separation between events (i.e., a session threshold). For example, if two consecutive events in the browsing history of a student are separated by 120 min and the session threshold defined is smaller, these events will be assigned to different sessions. The session threshold used was 58 min, defined by fitting a zero-inflated Poisson distribution (Lambert, 1992) over the separation in minutes between all the events in the dataset. We chose a Poisson distribution because of the nature of the data (count data) and a zero-inflated version because there was a high frequency of events separated by less than a minute. The sessionization process resulted in a total of 12,799 sessions.

After the sessionization, we carried out a *descriptive mapping* of the different platforms identified in the survey responses. We performed this mapping using *platform resource categories* created for this purpose based on the taxonomy on resources proposed by Bruce and Levin (1997), adding an extra category to account for social network platforms (Boyd & Ellison, 2007). We coded the survey and interview data as well as the platforms in the 12,799 sessions based on this categorization in order to triangulate the three datasets, which were already related ex ante during the data collection process.

Finally, we selected a subgroup of sessions for the analysis based on the activities assigned to each platform in the self-reported data to increase the likelihood of the sessions being related to learning topics associated with the CSE domain. There were 3336 sessions in total; 1755 from S1 and 1575 from S2. Each session was characterized by (1) the types of platforms used, (2) the frequency of access to each platform type, (3) the duration of the session assuming a minimum duration of 1 min and (4) the number of different platforms used

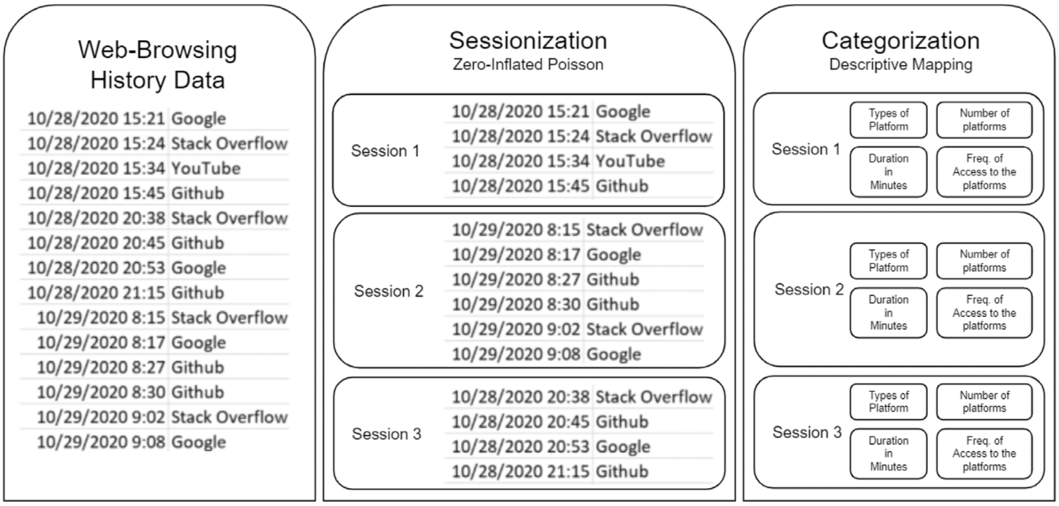

FIGURE 1 Data preparation process

during the session. Figure 1 summarizes the main steps of the data preparation process.

4.3 | Variables and analytical strategy

We analysed students' browsing sessions in terms of two main aspects. *Latent configurations of platform usage* depict emergent ways of using online platforms across web-browsing sessions in terms of the types of platforms used and the intensity of their use. *Contexts, activities and purposes of use of online platforms* refer to the sites and circumstances in which students used online platforms and the purpose of use.

We analysed latent configurations of platform usage by carrying out a latent class analysis (LCA) with distal outcomes (Muthén, 2001) employing the types of platforms used as indicators for estimating the models and four intensity distal outcome variables: (1) the duration of the session in minutes; (2) the frequency of access per minute to search engine (SE) platforms; (3) the frequency of access per minute to the rest of the platforms; and (4) the number of different platforms used. We separated the frequency of access of SE platforms from the other variables because SE platforms were used widely across the sessions, and the rest were scattered across sessions. We used Mplus 8.6 for statistical analysis and maximum likelihood estimation with robust standard errors (Muthén & Muthén, 2018). We estimated a two-class LCA model separately and added latent classes until we found the best model. We followed the lowest Bayesian information criteria (BIC), used likelihood ratio tests (Nylund et al., 2007) and examined the entropy of the models. We included distal outcome variables using the BCH procedure recommended by Asparouhov and Muthén (2014), which can handle non-normal distributions.

To examine in-depth the nature of the use of online platforms in terms of contexts, activities and purposes, we conducted a deductive thematic analysis of the interview transcripts (Braun & Clarke, 2012). This analysis involved three stages. Firstly, we used an approach resembling a thick description (Hammersley, 2008) of the contexts in which online platforms were used, differentiating between curricular (formal) and interest-based (informal learning) contexts. Secondly, we developed a coding template based on the theoretical framework and performed a qualitative content analysis of the interview transcripts (van Aalst et al., 2022). We identified and coded (1) main activities involved in the use of online platforms and (2) purposes related to the contexts and activities involved. To improve reliability, we used an approach that combines negotiated agreement with interrater reliability (Campbell et al., 2013). This approach involves first having two researchers coding a sample of the transcripts to later compare results, discuss disagreements and negotiate a final version of the codes. Second, it involves calculating interrater reliability using a Cohen's kappa statistic, in this case based on whether agreement was reached in terms of activities, purposes or both, which reached 0.8. Finally, we allowed for identifying theory-based themes and comparing these to the patterns identified in through the survey data. The interpretation helped understanding how patterns of platform use (i.e., actions/activities) relate to the purposes for which students used these platforms, and what this use supported.

We answered RQ1 by contrasting the latent configurations of platform usage to the contexts and activities identified, to determine the way in which online platforms were used as resources across different contexts to support different learning activities. To answer RQ2, we interrogated the activities and purposes behind the web-browsing sessions found in the qualitative analysis and related them to how platforms were combined across latent configurations.

5 | FINDINGS

5.1 | Latent configurations of platforms usage

The 3336 web-browsing sessions were characterized by combinations of eight different types of platforms identified from the descriptive mapping of 48 different platforms (See Appendix, Table A1). The most common types of platforms were SE and VR platforms, which were present in more than half of the sessions (See Table 1). T&C, Q&A, SCR and communication (COMM) platforms were used in about 30–40% of the sessions. The least used types of platforms were text library (TL) and SN platforms (less than 30% of sessions).

In terms of the four intensity distal outcome indicators (see Table 2), the browsing sessions involved, on average, the use of 3.4 different platforms (Median = 3.0, Q1 = 2.0, Q3 = 4.0), and the average duration of the sessions was approximately 115 min (Median = 81.0, Q1 = 28.0, Q4 = 165.0). On average, the frequency of access of the platforms per minute was 0.32 for SE platforms (Median = 0.14, Q1 = 0.037, Q4 = 0.303) and 0.64 (Median = 0.24, Q1 = 0.104, Q4 = 0.602) for the other platforms. A Kolmogorov–Smirnov test corroborated the non-normality of all four intensity distal outcome variables.

We fitted five different latent class models using Mplus and decided on a five-class model for the LCA. Table 3 shows the BIC index, entropies and likelihood ratio tests for the five models we ran. We chose the five-class model because it had the lowest BIC score compared to the other models, and both Vuong-Lo–Mendell–Rubin (VLMR) and parametric bootstrap likelihood ratio tests (LMR and BLRT) suggested a five-class model over a four-class one. Moreover, the entropy of the five-class model was 0.906 and its latent class probabilities were high for all five latent classes (See Table 4), suggesting a good class assignment.

Figure 2 shows a graphic representation of the chosen five-class model; the *x-axis* lists the eight types of platforms involved, and the *y-axis* represents the conditional probability of class membership. Each of the latent classes of the selected model resulted in at least one distinctive type of platform. Such distinctiveness facilitates the interpretation of the latent classes as ways in which various platforms were combined as resources.

Latent class 1 (LC1), labelled as *learning software development methods*, accounted for 19% of browsing sessions after assigning the most likely class to the sessions (see Table 4). This latent class had a high conditional probability of having T&C and SE platforms (See Figure 2). The sessions associated with *latent class 2* (LC2), labelled as *solving coding errors or problems*, accounted for 33.3% of the browsing sessions. This latent class had a high conditional probability of having Q&A and SE platforms. *Latent class 3* (LC3), labelled as *learning theoretical or conceptual knowledge*, accounted for 21.7% of the browsing sessions. LC3 had a high conditional probability of having TL and SE platforms in the configuration of the sessions associated with it. *Latent class 4* (LC4), *working together with others*, accounted for 6.4% of the browsing sessions once the most likely latent class was assigned. This latent class had a high conditional probability of having COMM, SN and SE platforms. In addition, Q&A, VR and SCR platforms also had a moderately high conditional probability of being present. Finally, *latent class 5* (LC5) accounted for 19.7% of the browsing sessions and was labelled as *revising and managing source code*. It had a high conditional probability of having SCR platforms present and moderately high probability of having SE platforms present in the configuration of the sessions associated with it.

In terms of intensity, the BCH procedure demonstrated that the five latent-class model was a statistically significant predictor of all four intensity distal outcomes ($p < 0.000$). Table 5 shows the results

TABLE 1 Types of platforms used across web-browsing sessions

Platform type	Total
Tutorials and courses platforms (T&C)	1195 (35.8%)
Questions and answers platforms (Q&A)	1274 (38.2%)
Source code repository platforms (SCR)	1273 (38.2%)
Text library platforms (TL)	919 (27.5%)
Communication platforms (COMM)	1086 (32.6%)
Social networking platforms (SN)	597 (18%)
Video repository platforms (VR)	1.604 (48.1%)
Search engine platforms (SE)	2702 (81%)
TOTAL	3336

TABLE 2 Descriptives of the intensity distal outcome indicators across web-browsing sessions

Intensity outcome	Mean	Median	Percentile 25	Percentile 75	K-S sig.
Duration in minutes	115.02	81.0	28.0	165.0	0.000
Number of different platforms used	3.4	3.0	2.0	4.0	0.000
Freq. per minute: SE platforms	0.32	0.14	0.037	0.303	0.000
Freq. per minute: rest of the platforms	0.64	0.24	0.104	0.602	0.000

TABLE 3 Information criteria indexes for the latent-class models

Latent classes	AIC	BIC	aBIC	Entropy	VLMR	LMR	BLRT
2	31263.34	31367.25	31313.23	0.888	0.000	0.000	0.000
3	30243.09	30402.02	30319.4	0.871	0.000	0.000	0.000
4	29448.46	29662.4	29551.19	0.979	0.000	0.000	0.000
5	**29222.77**	**29491.72**	**29351.91**	**0.906**	**0.000**	**0.000**	**0.000**
6	29180.72	29504.68	29336.28	0.845	0.089	0.0919	0.000

Note: Bold values represent the Model (5-classes) that was chosen for analysis.

TABLE 4 Latent class probabilities for the five-classes model

	LC1	LC2	LC3	LC4	LC5	Class count	Proportion
LC1	0.945	0.000	0.007	0.04	0.008	633	19.0
LC2	0.000	0.934	0.016	0.05	0.000	1111	33.3
LC3	0.012	0.003	0.965	0.02	0.000	723	21.7
LC4	0.023	0.095	0.058	0.792	0.032	212	6.4
LC5	0.000	0.000	0.000	0.022	0.978	657	19.7

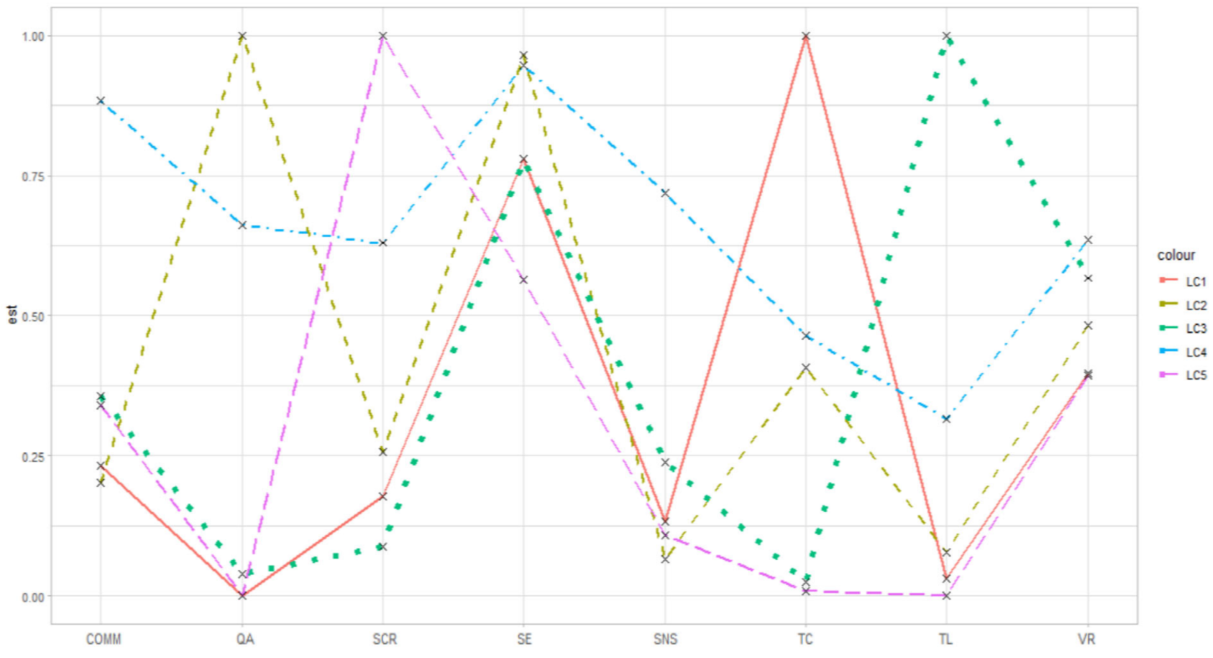

FIGURE 2 Five-classes model—Conditional probabilities for each latent class

of the BCH procedure comparing each of the latent classes in terms of the four intensity distal outcome variables. Although not all the latent classes were significantly different across all these outcomes, the model enables a meaningful comparison of the intensity with which platforms were used as resources.

All five latent classes were significantly different in terms of the *number of different platforms used* (see Table 5). These differences are observable in Figure 3, which shows histograms of this intensity distal outcome for each one of the latent classes, enabling a comparison of their distributions. The results show that LC4 (M = 7.56. SE = 0.17) predicted the use of a significantly larger number of platforms compared to the other latent classes, and LC5 (M = 2.4, SE = 0.046) and LC1 (M = 2.7, SE = 0.06) predicted significantly less platforms. LC2 (M = 3.5, SE = 0.045) and LC3 (M = 3.1, SE = 0.05) resulted in a moderate number of platforms; however, on average, less than half compared to LC4. This suggests that depending on the types of platforms involved, students moved across platforms, revealing important differences related to the complexity of the platform infrastructure used.

With respect to the *duration in minutes* of the sessions, there were statistically significant differences across latent classes, except LC2 and LC3 (see Table 5). Figure 4 presents histograms of this distal outcome for each latent class, and these differences and similarities are visible when comparing their distributions. The sessions related to LC4 (*M* = 298.1, SE = 16.08) were significantly longer than those related to other classes, and those related to LC1 (*M* = 80, SE = 3.9) and LC5 (*M* = 69.3, SE = 3.7) were significantly shorter. The sessions related to LC2 (*M* = 113.4, SE = 3.94) and LC3 (*M* = 118.1, SE = 4.4) had moderate duration. These results suggest that there are important differences across latent classes in terms of the time spent on the platform infrastructure and, therefore, in the complexity of the tasks for which platforms are used for.

In terms of the *frequency of access per minute to SE platforms* across sessions, although not homogeneous across all classes, we found statistically significant differences when comparing the latent classes. The sessions related to LC4 (*M* = 0.217, SE = 0.023) and LC5 (*M* = 0.161, SE = 0.023) resulted in significantly lower values for this distal outcome compared to the other latent classes, although they were not significantly different from one another. Similarly, LC1 (*M* = 0.303, SE = 0.03) and LC3 (*M* = 0.350, SE = 0.025), although not significantly different from each other, resulted in moderate values for this distal outcome when compared to the rest of latent

TABLE 5 BCH procedure. Comparison of intensity distal outcome variables across the five-classes model

Latent class	Number of different platforms used		Duration in minutes		Freq. per minute: SE platforms		Freq. per minute: Rest of the platforms	
	Chi-square	*p*-value	Chi-square	*p*-value	Chi-square	*p*-value	Chi-square	*p*-value
LC1 (*reference*)								
LC2	130.465	0.000	38.075	0.000	12.538	0.000	32.403	0.000
LC3	27.064	0.000	41.786	0.000	1.594	0.207	7.292	0.007
LC4	735.875	0.000	163.423	0.000	5.442	0.02	22.209	0.000
LC5	19.989	0.000	3.99	0.046	15.561	0.000	37.741	0.000
LC2 (*reference*)								
LC3	34.081	0.000	0.666	0.415	5.933	0.015	4.939	0.026
LC4	527.296	0.000	114.402	0.000	32.936	0.000	0.346	0.556
LC5	312.75	0.000	69.471	0.000	60.347	0.000	102.684	0.000
LC3 (*reference*)								
LC4	622.67	0.000	112.187	0.000	14.427	0.000	2.477	0.116
LC5	109.339	0.000	73.735	0.000	31.55	0.000	64.771	0.000
LC4 (*reference*)								
LC5	860.049	0.000	185.909	0.000	2.85	0.091	85.603	0.000

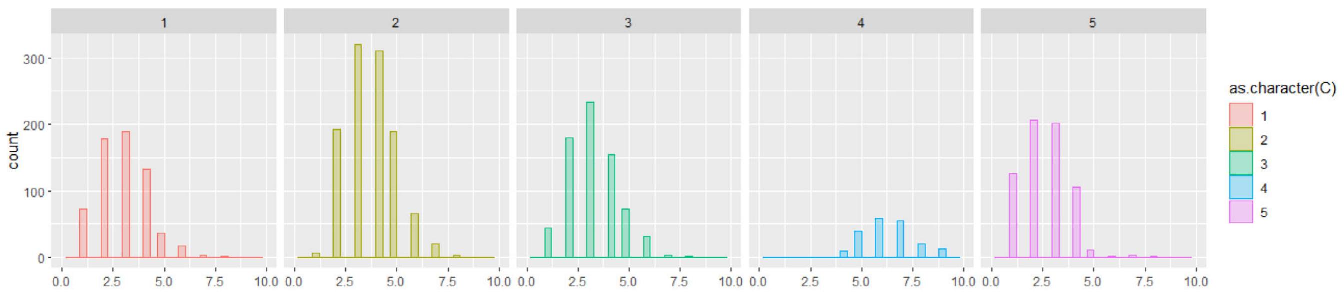

FIGURE 3 Histogram for intensity distal outcome variable: Number of different platforms used in each latent class

classes. LC2 ($M = 0.443$, $SE = 0.028$) resulted in significantly higher values compared to all the other latent classes. Figure 5 shows how the distributions of the frequency of access per minute to SE platforms vary across latent classes by presenting histograms with the counts for each latent class. These results suggest that although SE platforms were present in most of the web browsing sessions, there are significant differences in how these platforms are used depending on what other types of platforms are involved. Moreover, our results suggest that the use of QA platforms, related to LC2, translates into a higher use of SE platforms.

Finally, we found significant differences between the latent classes in terms of the *frequency of access per minute to the rest of the platforms*, but not across all of them. The sessions related to LC2 ($M = 0.368$, $SE = 0.021$), LC3 ($M = 0.488$, $SE = 0.049$) and LC4 ($M = 0.392$, $SE = 0.031$), although not significantly different from each other, resulted in significantly lower values for this distal outcome compared to the other two latent classes. LC1 ($M = 0.68$, $SE = 0.05$) resulted in moderate values for this distal outcome, while LC5 ($M = 1.3$, $SE = 0.094$) predicted significantly higher values. Figure 6 presents histograms of this intensity distal outcome for each latent class, showing how these differences are observable in their distributions. Our analysis suggests that LC5 as well as LC1, to a lesser extent, are predictors of significantly higher levels of interaction with the platform infrastructure involved than other classes, as this indicator reflects how much students navigated within the platforms they used.

5.2 | Contexts, activities and purposes in the use of online platforms

Our analysis of the web-browsing sessions revealed that the use of online platforms took place mainly in curricular contexts. These contexts mainly involved recurrent software development activities and, to a lesser extent, other curriculum-based activities such as online lectures. While most students reported using online platforms

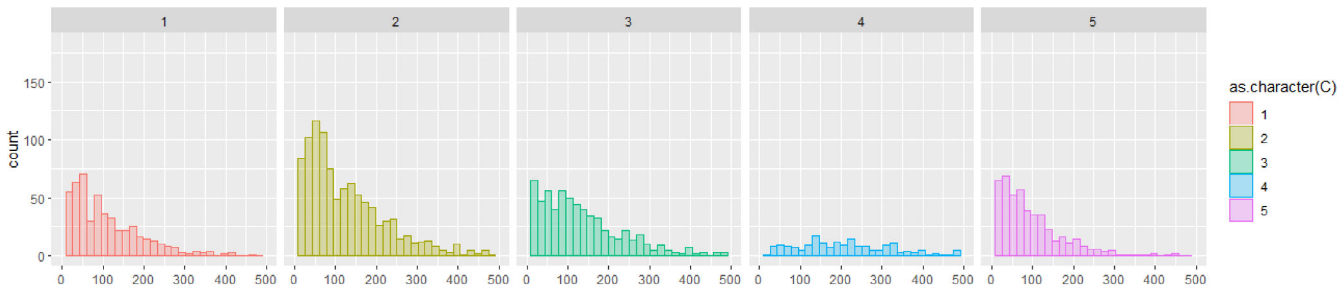

FIGURE 4 Histogram for intensity distal outcome variable: Duration of the sessions in minutes in each latent class

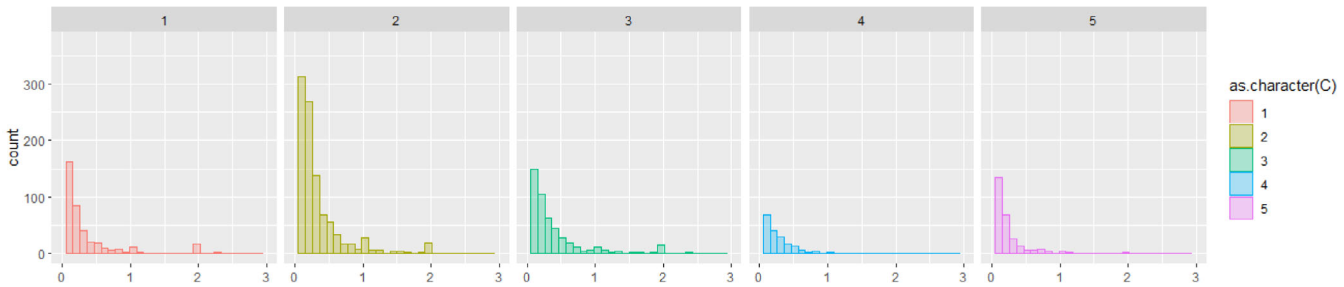

FIGURE 5 Histogram for intensity distal outcome variable: Frequency of access per minute to search engine platforms in each latent class

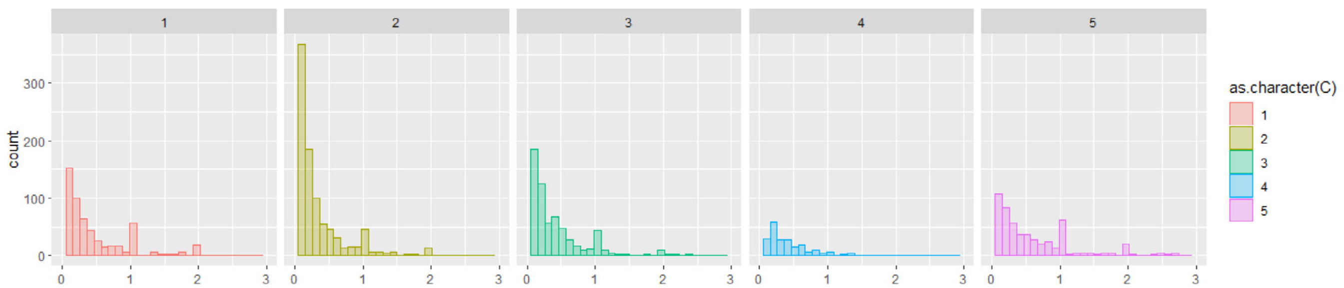

FIGURE 6 Histogram for intensity distal outcome variable: Frequency of access per minute to the rest of the platforms in each latent class

during, some students used platforms also prior to partaking in these activities. We also found that some students used platforms while engaging in study-related interest-based activities not included in the curriculum. In these contexts, students reported engaging in learning activities such as employing and implementing new software development methods, and entrepreneurial activities, which at times involved working with other people.

In both curricular and non-curricular contexts, students' engagement in learning activities was driven mainly by their personal interests and self-development, denoting a sense of empowerment in their decisions (see (a) and (d) in Table 6). Some students also expressed being driven by the prospect of better economic opportunities, for example, the promise of future rewards (see (b) in Table 6), diversifying their skillset, for example, valuing diverse knowledge and skills, and adopting practices from professional communities, for example, belong to a specific group (see (c) in Table 6). More importantly, these purposes were not exclusive to one another, as students were sometimes driven by more than one of them. Furthermore, we noted that activities from both curricular and non-curricular contexts influenced students' interests and became interrelated over time. For example, in statement (d) in Table 6, the use of online platforms outside curricular activities was driven by empowerment but influenced by experiences that took place during curriculum-based activities. In curricular contexts, similarly, students linked their interest in software development to past experiences outside of their courses, like recommendations from friends or family, video gaming, entrepreneurship or previous studies and work.

In terms of activities, we found that students used online platforms for epistemic or regulative activities, or both. However, the qualitative analysis revealed that, although they served similar activities, the differences observed across platforms draw important distinctions across the latent configurations obtained from the LCA. These differences were related to the type of knowledge involved

TABLE 6 Purposes across contexts of learning in the web-browsing sessions

Type of context	Student statement	Indicators of purposes
Curricular	(a) 'Yeah, I used [an online] introduction course. I started it like a little before the first semester started so I had like a head start which I found really helpful, and it made me [feel] like I was a bit ahead of everyone else and it was a really great feeling, and it really helped me during the semester. But I used it the second semester also because then I had another course at school that also was on Codecademy, so then I tried to use them simultaneously so I could like stay a little bit ahead in that class too'.	*Empowerment purposes* • Engagement in context/activity to be better at or feeling better about performing a specific task.
	(b) 'It's a discussion forum, with what I believe is a lot of other enthusiastic coders that wants to help with solving problems, and I have not contributed there myself, but I think when I get better at coding and I know more about what the code should be, I will probably help other people with their problems there as well'.	*Belonging purposes* • Engagement in context/activity because of the values and norms of a group one is part of or wants to be part of.
Interest-based	(c) 'I check sometimes to see like what jobs are available right now for when I'm done, like what employers look for in their employees. And I see what's relevant for like coding, there are a lot of coding programs, like coding languages, and I only know a few and there is so many. And I try to just see what do they want me to know, what should I learn from them'.	*Future rewards purposes* • Engagement in context/activity in order to improve the social or pecuniary conditions of (future) work.
	(d) 'Sometimes it's courses I have. When I have like obligatory assignments that I have to do I get like "Oh, this was really fun, I want to learn more" and then I go studying on my own [on the tutorial platform] because I found it really fun'.	*Empowerment purposes* • Engagement in context in order to know more about a task or topic.

TABLE 7 Activities across web-browsing sessions—Survey data

Platform type	CSE activities	Learning activities
Tutorials and Courses Platforms (T&C)	• Solve coding problems (82%) • Learn something new about software development (99%)	• Search and share resources (88%) • Understand concepts or methods (90%) • Repurpose resources (58%)
Question and Answer Platforms (Q&A)	• Solve coding problems (80%) • Learn something new about software development (89%)	• Search and share resources (81%) • Understand concepts or methods (86%) • Repurpose resources (60%)
Source Code Repository Platforms (SCR)	• Solve coding problems (80%) • Learn something new about software development (57%)	• Search and share resources (87%) • Work with others (69%)
Text Library Platforms (TL)	• Solve coding problems (56%) • Stay up to date with the software industry (22%) • Learn something new about software development (78%)	• Search and share resources (64%) • Understand concepts or methods (86%)
Communication Platforms (COMM)	• Solve coding problems (80%)	• Search and share resources (64%) • Work with others (77%)
Social Networking Platforms (SN)	• Stay up to date with the software industry (71%)	• Search and share resources (72%)
Video Repository Platforms (VR)	• Solve coding problems (91%) • Stay up to date with the software industry (66%) • Learn something new about software development (91%)	• Search and share resources (86%) • Understand concepts or methods (86%) • Repurpose resources (59%)
Search Engine platforms (SE)	• Solve coding problems (97%) • Stay up to date with the software industry (69%) • Learn something new about software development (94%)	• Search and share resources (91%) • Understand concepts or methods (89%) • Repurpose resources (80%)

and to the way in which students interacted with other people as they used online platforms. Tables 7 and 8 illustrate the identified activities related to the use of each type of platform in the survey data and qualitative analysis, respectively.

LC1, LC2 and LC3 were characterized by the use of T&C, Q&A and TL platforms, respectively. These platforms served epistemic activities and were used to solve coding problems or learn software development concepts or methods, both before and during software

TABLE 8 Activities across web-browsing sessions—Qualitative analysis

Platform type	Student excerpt example	Indicators of learning activities
Tutorials and Courses Platforms (T&C)	(a) '[I used a T&C platform] when I was working on websites, mostly JavaScript related and stuff, so I've been checking [it] when I didn't know what to write or how to write something, or when I forgot the syntax'.	*Epistemic activity*: • Learn knowledge necessary to start or advance in a software development task. • Remember software development concepts or methods previously learned.
Question and Answer platforms (Q&A)	(b) '[With the T&C platform] it's more like they have these articles that show you what and how you can implement a specific function, or element, or keyword or such. But with [the Q&A platform] it's more like you look for your specific problem, and then you see if someone else has faced the exact same thing'.	*Epistemic activity*: • Solve coding problems encountered while working on a task.
	(c) 'I think that [the QA platform] is not that good to learn new things, I think that one is better when you already know a lot and then you meet a problem […]'.	• Understand how other people solve problems.
Source code repository platforms (SCR)	(c) 'I was checking out some issues that [came up] when I was downloading some public packages […], there were certain issues, so sometimes I was finding them on [the SCR platform] […]'.	*Regulative activity*: • Managing infrastructure for coding.
	(d) '[W]e were thinking [with our group], "ok, how are we going to work together?" […]. [O]ne group member suggested [the SCR platform], we set it up and started using it, and that has helped a lot, it's way more practical, in that kind of sense'.	• Managing infrastructure for working with others in software development tasks.
Text library platforms (TL)	(e) 'In [the platform] they explain how stuff work and what they are, and for me, to [code] something, I have to understand how it works, or else I'll never be able to [code] it, so I'm using it mostly just to understand how the algorithm works and not necessarily how to code it'.	*Epistemic activity*: • Understand theoretical or conceptual knowledge related to software development methods.
Communication platforms (COMM)	(f) '[We used a communication platform] a lot in school to be able to answer our tasks efficiently and, also, I used it in the other project that I worked with a lot, to be able to have meetings regarding different problems, [and for] weekly meetings to have updates'.	*Epistemic activity*: • Solve problems with other students (a) (b). *Regulative activity*: • Coordinate work with other students (a).
Social networking platforms (SN)	(g) '[In those platforms] I follow some professional [developers], I see what they're doing, the kinds of projects that they are working on, or aspiring [developers] and what are the problems they are facing, and, you know, possibilities for networking, and conferences that are happening, well not conferences but events and stuff that I can follow online […]'.	*Regulative activity*: • Staying up to date with relevant events across contexts.
Video repository platforms (VR)	(h) '[I use the video repository platform when] I'm curious about how this works, or, you know, what's this concept like. You know, you start [on the platform] and you're wondering about something specific, and then it suggests to you 15 different videos that are all equally interesting, and then you just click them and then you're in a spiral and that's your whole day'.	*Epistemic activity*: • Learn any kind of topic related to software development. *Regulative activity*: • Searching for new interesting topics.
Search engine platforms (SE)	(i) 'I usually [search] my problem [in the search engine platform] and I usually look for sites that I've seen before, like it's known to me, like [a T&C platform] and [a QA platform] I've used several times, so if I see those, I usually click those, because I know they are great help'.	*Regulative activity*: • Searching for knowledge sources in order to solve a problem or learn a topic.

development tasks (see Table 7). However, the qualitative analysis revealed that these activities differed for each type of platform in terms of the problems or topics addressed (see Table 8). T&C platforms, used for solving problems, contributed to understanding knowledge related to software development methods needed for advancing tasks. In contrast, Q&A platforms were mostly used to solve specific errors encountered while coding. TL platforms were used strictly to understand conceptual or theoretical knowledge. This suggests that learning new methods translates to a higher level of interaction with the platform infrastructure involved, based on the results of the LCA presented above. Meanwhile, solving technical problems and learning theory or concepts translates into longer browsing sessions. All three latent classes involved the use of SE platforms with relatively high intensity. SE platforms were used mostly for regulative activities and directed at many different types of activities. The qualitative analysis revealed that these platforms were mostly used to access the other platforms, consequently used to advance in tasks, playing thus a supportive role. Therefore, differences in the intensity of use of SE platforms can be explained by, for example, differences in the activities involved, for example, using a platform to learn new methods versus doing so to solve coding error.

LC4 was characterized by the use of COMM, SN and VR platforms. COMM platforms served both epistemic and regulative activities oriented towards solving coding problems and working together with others, respectively (see Table 7). However, it was precisely when students worked with others that they used COMM platforms either to solve problems or to coordinate their work (see Table 8). Similarly, SN platforms, which served mostly regulative activities, were used by students to stay connected with different people (e.g., teachers, student, software developers), and with events and information shared by these people. The use of SN platforms was driven not by the need to address specific problems but by the need to manage these relationships. VR platforms were linked to many different types of activities, and their use served both epistemic and regulative activities. The main difference with the rest of the platforms was that their use was invariant to the type of problem or topic, and rather directed at managing students' interest development. Therefore, VR platforms, as well as the moderately used Q&A and SCR platforms, could be reached through COMM and SN platforms.

Finally, LC5 was characterized by the use of SCR platforms, which were related to activities directed at solving coding problems, searching and sharing resources and working with others (see Table 7). However, the qualitative analysis revealed that these platforms mainly served regulative activities (see Table 8). The problems addressed and the information sought using SCR platforms were related to the technical infrastructure used for software development, rather than to what the students coded themselves or the methods they used. Similarly, in the context of group assignments, the students used SCR platforms driven by the need of managing collaborative software development projects by sharing their source code, instead of conceptually advance in a task. The high intensity of the interaction with the platform infrastructure observed in LC4 suggests a high complexity of the activities that took place within platforms compared to the rest of the latent classes.

6 | DISCUSSION

This study explored how CSE students enact learning practices using online platforms. We examined students' use of a variety of online platforms for the purpose of learning within and beyond the course curriculum context. Students' learning activities involving the use of online platforms were followed for 3 months and were examined empirically by combining latent class analyses of web-browsing sessions with qualitative analyses. In this section, we discuss our findings in relation to previous research and highlight this study's contribution to the research field.

6.1 | How do CSE students use online platforms as resources for their learning activities?

We answered the first question by applying latent class analysis on sessionized platform use. Students used online platforms in the context of both curricular and interest-based activities related to software development. In both contexts, these activities were primarily software development tasks but, in some cases, other curriculum-based activities, such as lectures. During these learning activities, different types of online platforms were used simultaneously as resources in different latent configurations of platform usage, becoming complementary to one another. The latent class analysis revealed platform-browsing patterns, which fed into the professional practices identified by Nerland (2008). One pattern was related to practices of *learning and remembering software development methods* needed for software development tasks, through combining specific types of platforms. Other patterns was aligned with *solving coding errors or problems*, while a third to practices of *learning theoretical or conceptual knowledge*. Another pattern of combining platforms contributed the practice of *revising and managing source code*, and a final one to *working with others*. These patterns of platform-browsing and use of online resources differed not only in terms of the platform infrastructure involved (i.e., types of platforms used) but also in terms of complexity (i.e., number of different platforms used), the level of interaction with this infrastructure (i.e., frequency of access to the platforms) and duration. The analysis of the contexts suggests that these differences could very well be explained by differences in the types of learning activities involved.

This study shows how online platforms are used as resources for learning and are indicative of students' patterns of boundary crossing between curricular and non-curricular contexts for learning. This is an important finding because, as students engage in learning activities, they cross curricular boundaries to access different platforms not considered as formal course materials (Dowling-Hetherington et al., 2020; Henderson et al., 2017). The findings add to previous studies by showing empirical evidence that students not only cross these boundaries but also deploy their own boundary/learning space by combining the online platforms necessary to support the type of learning activities they consider relevant (Damşa & Jornet, 2017). Moreover, this space seemed to vary depending on the complexity of the learning activity, as it resulted in the use of different platform infrastructures and ways of using them. Depending on the types of topics or problems addressed (e.g., learning software development methods or conceptual knowledge) or if the task was individual or collaborative, students combined specific online platforms during their sessions and used them differently. This challenges the approach of previous studies on the implementation of digital technologies and online platforms in higher education, which have focused mainly on the study of single platforms (Baker & Hitchcock, 2017; Lapolla, 2014; Luo et al., 2020). Our findings are consistent with these studies as they show how online platforms can be used to support relevant aspects of students' learning both individual and collaborative. However, our findings suggest that learning is supported by multiple types of platforms rather than on a single platform.

Our findings about boundary crossing are important because, as students develop their interests while using online platforms, the boundaries between curricular and interest-based contexts become blurred (Brown et al., 2016). The current study complements previous research by showing that this process unfolds over time (Josefsson et al., 2016), involving seemingly unrelated or circumstantial contexts that go beyond, for instance, the topic being addressed (a software development method) or the situation in which it unfolds (navigating a VR platform). Our findings stress the importance of interest-based activities and other (previous) experiences that influence their interest and determine how they configure their learning practices. This interrelatedness is an example of how one practice can unfold and be adopted when conducted in conjunction with another practice. Not just in the same situation, but also as students' interests develop over time (Kemmis et al., 2014; Schatzki, 2001). Video gaming, taking university-level courses or working on an entrepreneurship project can equally allow students to develop interests in other topics or even learn software development methods.

Furthermore, the current study relates students' use of online platforms to domain-specific learning practices, in this case, in the CSE domain; up until now, addressed mostly indirectly by empirical research (Zlatkin-Troitschanskaia et al., 2021). Previous studies have already suggested that students' learning practices in both curricular and non-curricular contexts are related to domain-specific practices (Azevedo, 2011; Peters & Romero, 2019). Our findings extend this knowledge by showing how this is reflected in the way students use online platforms. Students not only access platforms typically used by CSE professionals (Damşa & Nerland, 2016) but also use them in ways similar to professionals in the CSE domain (Nerland, 2008). Furthermore, the way platforms were combined also reflect these domain-specific practices, suggesting that students' learning practices are indeed related to larger arrangements that extend beyond the context of specific learning activities (Kemmis et al., 2014). By combining platforms, students engage in loops of problem-solving, learn new software development methods based on future expectations, sometimes with their future career in mind. Moreover, by using online platforms, students stay connected with peers and professionals, and stay up to date with developments in the software development industry.

6.2 | What purposes drive students' use of online platforms during these learning activities?

The second question was answered by qualitatively analysing students' interviews. The findings revealed, first, that the learning activities for which students used online platforms were driven by purposes mainly related to students' empowerment or expectations of future rewards, or both. These purposes were influenced by previous experiences not necessarily directly related to software development, such as video gaming, recommendations from family or friends or information shared by professional developers. Second, our findings show that students used online platforms to partake in both epistemic and regulative activities. These activities were not exclusive from one another. Rather, they were complementary and, sometimes, using a given platform served both activities simultaneously. For example, the use of T&C platforms served epistemic activities, and these platforms were used in combination with SE platforms, which served regulative activities. In addition, the activities served by the use of online platforms, although similar, varied depending on the type of problem or topic addressed, which in turn translated into different combinations of platforms used.

These findings are consistent with those of previous studies on students' motivations for using online platforms, such as personal interests, career development and enrichment (Watted & Barak, 2018) and knowledge (Milligan & Littlejohn, 2017). The findings supplement the literature by showing that this is the case not only for MOOCs but also for a variety of other platforms that are used as resources by students. Similar to Romero-Frías et al. (2020), these findings show that different types of purposes and activities are neither mutually exclusive nor independent of one another. This was the case for epistemic and regulative activities, as well as for purposes. Students seem to be moved by different interests simultaneously, as they use online platforms at times deliberately to develop their interests in software development during learning activities.

Furthermore, it appears that students' learning using online platforms cannot be simply reduced to specific situations or individual processes. Students' subjectivities seem to develop over time and across multiple contexts, influenced by a variety of experiences and people, such as family, other students or professional developers (Papadopoulos, 2008). Online platforms play a key role in these processes, as students deliberately develop their interests as they use them during learning activities. It is important to note that students deliberately pursue specific situations in line with their purposes, adapting to their specific circumstances based on previous experiences (Dreier, 1999). Students involved in this study engaged in learning activities based on their interests and further developed these interests. Moreover, they combined online platforms in ways that served specific parts of the learning activities they engaged in. This raises important questions about the role that online platforms and resources play in students' subjectivation processes and how, by interacting with such platforms, their learning trajectories are shaped over time.

6.3 | Reflections on methodology

This study makes two main methodological contributions. The triangulation approach provided insights beyond what each separate data type and method could have provided. The web-browsing history data gave an empirical account of actions that take place in real situations. Meanwhile, the self-reports and the interviews complemented such data by generating insights into the relational and subjective nature of those actions. The combined analysis is what enabled a more comprehensive understanding, which addressed both the situatedness and dynamism of practices.

The focus on web-browsing sessions as the main unit of analysis, as opposed to individual persons, enabled us to address some of the limitations of our dataset. Using this approach, we generated a large and rich dataset to analyse how platforms were used in specific contexts, even if the sample used in this study was not very large.

Our methodological approach has, nevertheless, some limitations. First, the sample size was relatively small, and the sampling method was not probabilistic. The findings should, therefore, be interpreted accordingly, without ambitions for high-level generalization. We expect our findings to raise new questions about the use of online platforms and to inform future studies on the topic of platformization and learning. Second, the data collection required students to use a specific web-browser to answer the questionnaire. Students who participated in the study might have used other web-browsers for their learning activities, leading to the browsing history of some of the students to be under-represented. Third, the data was collected at the beginning of the COVID-19 pandemic, which could have created bias specific to those circumstances. During this period, teaching changed radically, becoming significantly more digital in nature, which may have translated into a more extensive use of online platforms.

6.4 | Future research and implications for practice

The findings in this study provide input for future research. First, there is a salient need to explore how learning unfolds with the use of platforms. Future research should focus on the digital and institutional infrastructure that supports students in accessing resources, and how these support and influence their learning processes and output. Such support for (almost) personalized learning requires attention within the institutional context and curriculum development. Second, the study emphasizes the relationship between students' learning practices and domain-specific practices, and about how these can be studied. Our findings suggest that learning practices can hardly be understood as circumstantial. Rather, they seem to change over time and to be a result of complex collective processes and experiences. Further research should employ suitable methodologies and frameworks that allow examining practices as emergent by-products of human relations that unfold over time, in interaction with technology and in constant flux.

Our findings also have implications for practice in CSE education. They reinforce the idea of a 'shadow curriculum' that exists beyond the formal curriculum, complementing it (Kim & Jung, 2019; Portelli, 1993). Online platforms are shown to play a significant role in how students structure this shadow curriculum. Therefore, teachers and curriculum developers in CSE education should mindful of highlighting also activities and resources typical to this shadow curriculum that can become useful in the courses they design. The current findings also can be of use for students since the recognition of a shadow curriculum could lead to (partial) inclusion in the course curricula and to support/guidance related thereto. Finally, this study provides evidence for informed decision-making by leadership in CSE education, regarding the organization of curricula and study programs in CSE, and undergraduate education in general.

7 | CONCLUSION

This study engaged in an empirical exploration of CSE students' enactment of learning practices using online platforms and resources. It advances empirical knowledge of the ways new digital landscapes influence and shape students' learning activities, and blur the boundaries between what is viewed as formal and informal learning contexts. The study sheds light on the complexity of the situation in which students live and learn, inundated with digital technologies and online resources, often falsely distinguished from their academic context. Students' learning practices seem neither guided entirely by the curriculum nor independent of it. While the formal curriculum plays a key role in how students use platforms during their learning activities, it is but one of many contexts that shape students' learning practices and outcomes. To add to this complexity, our study shows that students' use of online platforms for learning cannot be reduced to one specific context or platform. Rather, students use online platforms from one context to another, act and interact deliberately with their environments. This generates an ecology of resources and practices that are interrelated and cannot be reduced to singular activities or mere outcomes. Finally, the study has demonstrated how mixing methods with potential to trace low-level online behaviour with rich qualitative accounts of learning with online platforms can provide a comprehensive, yet detailed, understanding of complex learning landscapes students navigate in. This is a valuable departure point for research on how online platforms shape and provide affordances for learning and how undergraduate education may capitalize on such opportunities.

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No potential competing interest was reported by the authors.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study was approved by the Norwegian Center for Research Data (NSD) (Reference Number 252070) following European General Data Protection Regulations (GDPR).

INFORMED CONSENT STATEMENT

Informed consent was obtained from all individual participants included in the study.

PERMISSION TO REPRODUCE MATERIAL FROM OTHER SOURCES

No material from other sources was reproduced in this study.

CLINICAL TRIAL REGISTRATION

No clinical trials were carried out in this study.

ORCID

Andrés Araos https://orcid.org/0000-0002-6224-2668

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APPENDIX

TABLE A1 Platforms used by the students organized by platform type

Platform type	Platforms (number students)
Tutorials and courses platforms (T&C)	Coursera (1), Dev.to (1), Mozilla Developer Network (9), Microsoft Resources (2), Oracle JAVA Tutorial (5), Hackr.io (1), MIT OpenCourseWare (2), CodeCademy (11), FreeCodeCamp (7), Geeks for Geeks (27), Khan Academy (6), Medium (4), Solo Learn (2), Udemy (12), W3Schools (45)
Questions and answers platforms (Q&A)	Stack Exchange (8), Stack Overflow (56), Quora (16)
Text library platforms (TL)	Wikipedia (44)
Video repositories platforms (VR)	Twitch (8), YouTube (61)
Source code repository platforms (SCR)	BitBucket (2), Github (54), Github Education (6), GitLab (3), Source Forge (3)
Communication platforms (COMM)	Discord (28), Gmail (19), Slack (9), Facebook Messenger (42), Zoom (49), Google Hangout (1)
Social networking platforms (SN)	Twitter (7), Facebook (24), Instagram (6), Linkedin (18), Reddit Coding (1), Reddit programming (2), Reddit Learn programming (1)
Search engines platforms (SE)	DuckDuckGo (2), Google (63)