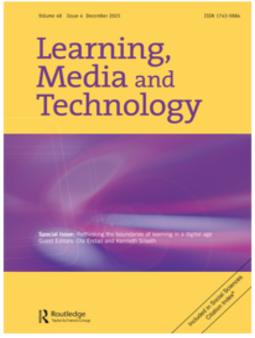

Learning, Media and Technology

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/cjem20

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To cite this article: Andrés Araos Moya & Crina Damşa (2023) Affordances and agency in students' use of online platforms and resources beyond curricular boundaries, Learning, Media and Technology, 48:4, 685-700, DOI: 10.1080/17439884.2023.2230124

To link to this article: https://doi.org/10.1080/17439884.2023.2230124

Published online: 30 Jun 2023.

LEARNING, MEDIA AND TECHNOLOGY
2023, VOL. 48, NO. 4, 685–700
https://doi.org/10.1080/17439884.2023.2230124

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Affordances and agency in students' use of online platforms and resources beyond curricular boundaries

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ABSTRACT

This study explored how agency is expressed when undergraduate students cross curricular boundaries to learn software development by realising affordances enabled by resources on online platforms. The study employed a qualitative research design based on individual stimulated recall interviews with 27 computer and software engineering students. The hybrid thematic analysis employed an ecological framework in which the actions the students performed during software development tasks were interpreted in relational terms. The results reveal multiple interrelated affordances that were realised as the students learnt by using various resources on different online platforms. Agency was expressed primarily through students pursuing specific objectives related to their learning across platforms and curricular boundaries and was shared and distributed across people and the environment. The findings highlight the idea that boundaries are formed and crossed based on how people experience the environment, which, in turn, is enabled or constrained by the resources used.

ARTICLE HISTORY
Received 1 June 2022
Accepted 22 June 2023

KEYWORDS
Boundary crossing; online platforms; learning practices; agency; affordances

Introduction

Online platforms are here to stay. Their use has transformed schools, education and learning, specifically with the rise of platforms as the dominant web model. Platforms are architectures of web-technologies, each one with the potential of enabling (and constraining) learning in different ways (Casilli and Posada 2019). Web-technologies, e.g., forums or wikis, are generic, functional web-based interfaces that can be integrated into any platform (Bower 2016). They are the building blocks of online platforms. Through their use, platforms can become powerful resources for learning by connecting learners to different types of information, people and communities (Bruce and Levin 1997; Casilli and Posada 2019). As part of a process coined 'platformisation', platforms not only open up possibilities for learning, they also steer these in particular ways through the technologies they offer access to (van Dijck, Poell, and de Waal 2018). Online platforms are by no means neutral; people and organisations serving various stakeholders and interests own them. Therefore, while playing an increasing role in learning, platforms represent both opportunities and reasons for concern.

Various studies have examined undergraduate students' use of web-technologies on different platforms. Text-messaging technologies on WhatsApp or WeChat can enable students' communication and collaboration during curriculum-based activities (Tang and Hew 2017). Blogging and

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videoconferencing technologies allow students to connect course content with their life experiences and collaborate in small groups (Hsu, Ching, and Grabowski 2014; Lawson et al. 2010). Nonetheless, attention has mostly been given to how students use platforms educational institutions provide in teacher-led activities. Meanwhile, more and more platforms not necessarily integrated or connected to formal curricula are openly available to students on the internet. Students often rely on these platforms (Henderson, Selwyn, and Aston 2017), even replicating professional practices or developing their own ways of capitalising on online resources (Araos, Damşa, and Gašević 2023; Damşa and Nerland 2016). Still, few studies have investigated students' use of online platforms and the resources available on these platforms in domain-specific contexts (Zlatkin-Troitschanskaia et al. 2021).

As learning in higher education is guided by curricula, learning opportunities enabled through online platforms have emerged at the boundaries of these two worlds. Formal curricula, the officially recognised educational offerings (e.g., goals or tasks) (Portelli 1993), seemingly do not always keep pace with rapid technology developments in, for example, computer and software engineering (CSE). CSE students can easily cross curricular boundaries into the realm of online platforms to access multiple resources relevant to their learning. The process through which students access and use such resources and learning takes place may appear similar to learning in formal education contexts. However, using such resources means diverging from practices predefined by formal curricula. Engaging with platforms generates specific practices other than those facilitated by curricular guidelines (Araos, Damşa, and Gašević 2023), and such boundary crossing requires certain agency on the side of the learners (Akkerman and Bakker 2011; Edwards 2005). We propose that while openly available and curriculum-based platforms might resemble, students' realisation of affordances for learning is not a straightforward process. We argue that it is essential to understand how such processes enabled by online platforms unfold and how such boundary crossing relates to how students learn in relation to curricular demands. So far, educational research has given insufficient attention to this issue, and the agency implied in students' actions when they access or publish information using online platforms has largely been overlooked.

This study explored which affordances CSE students realise as they use web-technologies (as resources) within platforms not included in the formal curriculum to learn software development and how agency is expressed as these technologies are used. We employed an ecological perspective on boundary crossing, implying that it is practices, and not objects, which emerge as boundaries that are crossed by being reconsidered and reconfigured (Akkerman and Bakker 2011; Damşa and Jornet 2017; Dreier 1999; Reed 1992). We conducted stimulated recall interviews (Dempsey 2010) with 27 CSE students, in which we prompted the reconstruction of their use of multiple platforms over a three-month period with survey and web-browsing history data. These interviews were analysed through hybrid thematic analysis (Fereday and Muir-Cochrane 2006) to address the following research questions:

RQ1: Which affordances are realised by students as they cross curricular boundaries to use online platforms to learn software development?

RQ2: How is agency expressed as these affordances are realised?

Learning through using online platforms within and outside formal curriculum boundaries

Several authors have studied how online platforms can be used to support student learning guided by formal curricula. Social networking and text-messaging technologies on different online platforms, for instance, enable synchronous and asynchronous communication, finding, publishing and sharing information, and making connections between users (Xue and Churchill 2019). Videoconferencing technologies enable students' remote participation in lectures and small-group meetings (Lawson et al. 2010). Research has also shown social networking and text-messaging technologies being used to enable discussions with peers (Manca 2020) and engage in dialogic activities (Tang and Hew 2017; Xue and Churchill 2019). Some studies have shown how text-messaging technologies facilitate understanding of course content and self-reflection (Tang and Hew 2017), how blogging technologies enable the integration of theory and practice, and how wiki technologies facilitate students' critical thinking (Hsu, Ching, and Grabowski 2014).

Other research has addressed students' use of online platforms not included in formal curricula, evidencing boundary crossing. Some studies showed students report using platforms such as Facebook, Google Docs, WhatsApp and Wikipedia (Henderson, Selwyn, and Aston 2017; Yot-Domínguez and Marcelo 2017). Other authors investigated students' use of massive open online courses (MOOCs), which provide access to e.g., video lectures, articles and assignments. They showed that students were strongly driven by their education advancement, but also their personal interests, future careers and income (Watted and Barak 2018). Other studies have focused on domain-specific settings. In a study by Damşa and Nerland (2016), students in a web development course reported informally using examples in specialised online tutorials and forums. Araos, Damşa, and Gašević (2023) showed that CSE students use and combine different types of platforms to learn, many of which are domain-specific.

These studies suggest that students use a much larger ecology of online platforms than in formal learning environments. Nonetheless, most studies investigating students' use of platforms beyond curricular boundaries do not examine which web-technologies within them are used or how these enable learning.

Theoretical framework – Learning across boundaries from an ecological perspective

To examine how students learn across curricular boundaries using online platforms, we employed a perspective on learning underpinned by ecological realism (Reed 1992). From this ecological perspective, learning is conceptualised as a process of constant becoming, in which knowledge is continuously (re)constructed based on information available in the environment (Packer and Goicoechea 2000). This perspective differs slightly from traditional socioconstructivist and sociocultural views, which either embrace dualist ontologies or see people as social and historical products and not as natural entities. Ecological realism sees both the mind and body as inseparable from the environment people inhabit (Reed 1992). How people come to know about their environment is seen as primarily rooted in people's tacit awareness, which can be (at least partially) shared by different observers, as the environment they inhabit is also shared. Knowledge is also considered to have 'history', since past experiences yield justified beliefs that permeate how people experience their environment (Grene 1987). Ontologically, what is considered relevant is not the mind or specific objects but the available information in the environment found in patterns of change that are ambient to and explored by the observer(s) (Reed 1992). Such an ontology is relational in nature because people always perceive and act relative to themselves and the sources of information they explore.

Within this framework, practices play a crucial role in how people explore their environment, act and therefore learn. *Practices* are socially constructed ways of experiencing one's environment by acting on it, a process entailing the use of social, material and symbolic resources (Kemmis et al. 2014). Using resources does 'not and cannot replace the tacit sharing of the world based on environmental information', but it enables more than just situations and shared awareness (Reed 1992, 14). *Resources* are environmental sources of information whose use enables exploring the environment by accessing, sharing, transforming and manipulating information (Bruce and Levin 1997; Reed 1992). Resources can help specify situations, make claims about the environment and *act upon it*.

Practices constitute boundaries because their enactment both enables and limits how we experience our interaction with the environment. The use of resources can never fully specify the information in the environment and, thus, can lead to incorrect and partially correct discoveries or claims, as well as conflicting views (Reed 1992). However, such boundaries can be (and are) crossed by people as they can decide to reconsider and reconfigure their practices (Dreier 1999). We conceive *boundary crossing* as a divergence from specific practices (Akkerman and Bakker 2011). Suchman's (1993) and Engeström, Engeström, and Kärkkäinen's (1995) original notions considered boundary crossing to be experiential in nature. However, this ecological perspective also emphasises the ontological nature of boundaries, differing in that neither objects are seen as boundaries nor is meaning gained or assigned to objects through 'a process of collective concept formation' (Engeström, Engeström, and Kärkkäinen 1995, 321). Rather, 'it is the information (in the environment) and what that information specifies that counts' (Reed 1992, 16). Hence, meaning exists implicitly within the environment; it can be accessed and manipulated because people are also an integral part of that same environment (Reed 1992). Thus, meaning is also relational, as it reflects how people interact with their environment based on their observations, feelings, thoughts, history, etc.

The formal CSE education curriculum, from this perspective, entails practices students can enact to learn using various predefined resources (Portelli 1993), such as structured goals, reading material and tasks. Therefore, using web-technologies from online platforms not accounted for in formal curricula translates into a divergence from its practices, i.e., a boundary crossing process.

Affordances and agency at the crossing of curricular boundaries and online platforms

We employed two theoretical notions to explore students' process of boundary crossing: affordances and agency. *Affordances* are activity-specific meanings that characterise how interacting with information in the environment can enable specific people to perform specific actions (Chemero and Turvey 2007; Gibson 1977; Reed 1992). In other words, realising an affordance is experiencing a relation of oneself relative to a resource in the environment (Reed 1992). For example, two students, a beginner and one experienced in programming, can cross curricular boundaries to use an online tutorial during a course task. While the beginner might need to follow every step in the tutorial, the experienced student might only reuse specific code components. Similar situations lead to different students realising different affordances because they experience them differently. Affordances constitute the 'basic objects of knowledge' because, although they relate to specific resources, they always exist relative to the user(s) and the user(s)'s past experiences (Reed 1992, 18).

Agency is a temporally embedded process in which one or more agents directly or indirectly influence the orientation of people's actions (Edwards 2005; Virkkunen 2006). *Actions* are changes in the environment oriented towards achieving specific objectives, which are future circumstances envisioned by the people who perform them (Davidson 1963). An orientation, however, is viewed not as 'determining but [as] facilitating; not [as] a foundation, but [as] a guideline' (Reed 1992, 13). As a process, agency is ontologically linked to events with an intelligible sequential relation with one another (Vayda, McCay, and Eghenter 1991). Thus, examining how agency is expressed as a process involves exploring the conditions under which linkages between events emerge. These conditions depend not only on the extent to which people can directly influence the orientation of specific actions. Awareness of a situation can be shared, and the actions performed using specific resources can, in turn, facilitate and guide the performance of consequent actions. In the example above, the company that created the tutorial can be considered an agent that influences students' actions to different extents, depending on their past experiences and objectives. In another situation, where students collaborate using videoconferencing, the agents can include individual students, the group and the students with the platform. An agent can thus influence the orientation of an action in multiple ways, but what is considered an agent is not necessarily limited to individuals. Agents can overlap if they act as a group or use of specific resources that connect them to people and/or information (Schiermer 2021b; Virkkunen 2006).

Analytically, we focused on how performing different actions using resources from online platforms that diverge from curricular practices (i.e., boundary crossing) became the basis for realising affordances. For example, a student solving coding problems during a course task (objective) might check a video tutorial to come up with solutions (actions). Solving coding problems becomes not only the objective of the actions performed but also of crossing boundaries, as the student diverges from the task's guidelines. To characterise how events connect when students use platforms (Schiermer 2021b), we propose three interrelated types of actions, which are defined based on the idea that actions can address objectives directly and indirectly. *Objective-oriented* actions directly support the main objective of enacting a practice; *collective* actions gather and keep people together as a group; and *mediational* actions do not address the objective of a practice directly, but enable both objective-oriented and collective actions. The latter, however, are mediational not in the sense of objects becoming a connection between the mind and an external world (Wertsch 1994), but through referring to the performance of one action facilitating or guiding another.

Methods

We employed a qualitative analysis approach, as part of a larger mixed-methods design. The participants were students from different CSE programmes in four major universities in Norway. They were invited to participate voluntarily in consecutive semesters (autumn 2020 and spring 2021) through calls their course instructors sent. We protected the participants' identities during the data collection, processing, analysis and storage using randomly generated ID codes and a secure server, compliant with the European General Data Protection Regulations (GDPR) and the Norwegian Centre for Research Data (NSD). In total, 27 students participated in this study, 16 in autumn 2020 and 11 in spring 2021.

We collected baseline, in-depth data on the students' practices through stimulated-recall interviews (Dempsey 2010) and survey and web-browsing history data collected using a custom-made Google Chrome extension (Google 2021). The survey asked about the platforms students used for learning software development and/or working in software projects/tasks from a predefined list and the courses they enrolled in. The web-browsing history data comprised three months' log data for each platform selected in the survey back-dated from when the students submitted their answers. We visited the websites of the courses students reported being enrolled in and collected information on the expected learning outcomes, the teaching and assessment methods, the learning materials and the schedules.

The interviews explored specific situations in which the students used specific online platforms to learn about software development and/or work in software projects/tasks to gain insights into why they decided to act in the way they did. During each interview we presented screenshares of those experiences as prompts. The screenshares comprised a list of platforms each student accessed during a three-month period and the monthly frequencies of access to each platform, obtained from the survey and web-browsing history data. Each interview was audio recorded and transcribed verbatim.

We analysed the transcripts using identified practices related to learning software development or working in software projects that involve using different types of platforms as a baseline (Araos, Damşa, and Gašević 2023) (see Table 1), characterised by the objectives students have for enacting them. We used a two-stage analytical strategy based on a hybrid thematic analysis approach (Fereday and Muir-Cochrane 2006) to examine the students' reconstruction of the realised affordances and expression(s) of agency in relation to the selected practices. We first used a theory-driven coding scheme to identify the web-technologies used, using a taxonomy of online resources (Bower 2016; Bruce and Levin 1997) (see Table 2), and the types of actions performed (mediational, collective or objective-driven). We also performed a content analysis (van Aalst et al. 2022) of the course data to define the formal curriculum as a boundary based on objectives and resources and contrast it with the analysis of the interviews. The second stage involved interpreting the data units with respect to the resources used, the types of actions performed and the agents involved. This strategy enabled us to examine the process of boundary crossing in terms of how and which affordances were realised as relational phenomena (RQ1) and how agency was expressed (RQ2).

Table 1. Learning practices and platform types.

Main Objective	Platform Types
1. Learn and remember software development methods	Tutorials and courses* (e.g., W3Schools) Search engine* (e.g., Google)
2. Solve coding errors or problems	Q&A* (e.g., Stack Overflow) Search engine*
3. Learn theoretical or conceptual knowledge	Text library* (e.g., Wikipedia) Search engine*
4. Work or connect with others to learn software development or work in software projects	Communication* (e.g., Discord) Social networking* (e.g., Twitter) Video repository* (e.g., YouTube) Q&A** Source code repository** (e.g., GitHub)
5. Revise and manage source code	Source code repository* Search engine**

*High probability. **Moderately high probability.
Note. Based on Araos, Damşa, and Gašević (2023).

Table 2. Taxonomy of online resources.

Resource Category	Resource	Description
Analysis and thought	Visualisation software	Functionality for generating graphic representations of specific data.
	Procedural models	Procedures presented in a sequence of steps.
	Knowledge representation	Illustrative representations of information.
	Summaries	Synthesis of relevant information from several or a particular field.
	Problem-solving	Problems and their solutions.
Data access	Web-search	Functionality that searches web domains on the internet.
	Digital libraries	Structured collection of organised digital objects.
	Discussion threads	Structured collection of conversations around a specific topic.
Communication and collaboration	Publishing	Functionality that makes content available to a specific public.
	Text-messaging	Functionality that exchanges text between specific persons synchronously and/or asynchronously.
	Synchronous videoconferencing	Real-time video streaming functionality between specific persons.
	Synchronous voice-messaging	Synchronous and/or asynchronous audio exchange functionality between specific persons.
	Screen-sharing	Real-time streaming functionality of content visible on a computer screen between specific persons.
	Shared document preparation	Document editing functionality that allows specific persons to modify the same document remotely.
	Shared data environments	Data accessibility functionality for specific persons.
Social networking	Public/semi-public profiling	Functionality that makes personal information publicly available.
	Connecting	Functionality that establishes a connection between users in a platform.
	See others' connections	Functionality that makes others' connections visible.
Construction	Construction of source code	Functionality to store and edit source code.
	Construction of text	Functionality to store and edit text.
	Construction of video	Functionality to store and edit video.
	Construction of audio	Functionality to store and edit audio.
	Construction of code components	Functionality to store and edit code components.

Note. Based on Bower (2016) and Bruce and Levin (1997).

Findings

The findings comprise five themes that emerged through the two-stage analysis. We describe, explain and illustrate each theme through relevant data excerpts identified during the coding and interpretative stages following a description of the curricular context.

Formal curriculum boundaries

The courses students reported enrolment covered various topics, including object-oriented programming, databases, the internet of things, web development, and web security, among others. The learning outcomes described the knowledge and actions students should acquire, including how to use specific programming languages, data structures, software development methods, frameworks and concepts, web and computer architectures, ethical issues and how to work with others. These outcomes made the curriculum objectives explicit.

The course resources included lectures, group sessions, books, articles, assignments and exams. Most courses required the students to pass a minimum number of obligatory individual- or group-based assignments to take the exam. The exams were individual tasks answered in a limited timeframe, group or individual home assignments or projects or a combination of both. Very few resources and objectives explicitly mentioned the use of web-technologies or platforms, with the exception of learning management systems and some online resources provided by the university library. The Zoom and GitHub platforms were mentioned in some cases. These findings provide a baseline for understanding the formal curriculum as a boundary that students cross by using online platforms. The results of the thematic analysis of the interview transcripts are presented in the following sections.

Accessing information within and across platforms

The first theme relates to accessing information. The students recalled that using web-search technology from search engine platforms enabled them to access information across different platforms, which involved the performance of several actions, as illustrated by excerpt 1:

Excerpt 1. *Student Recollection of Using Web-Search on the Google Platform.*

I was googling and searching through. It's not like I'm always choosing one website. If the answer is not satisfying, because maybe they didn't have a relevant example or maybe the question I found on that website or the article wasn't really related to my problem, I would search on another website, but first I'm just googling and just looking through alternatives.

The action of googling in the excerpt involved selecting and introducing keywords (e.g., a concept or an error message) into the platform as input. In response, web-search provided alternatives (i.e., links to other platforms) by activating an algorithm. The students could then browse through the alternatives returned by the algorithm to search for information across multiple platforms.

The students also recalled using text-messaging technologies on communication platforms, discussion threads on Q&A platforms and digital libraries on tutorials and courses platforms to access information within platforms. Excerpt 2 exemplifies how using text-messaging realised these affordances:

Excerpt 2. Student Recollection of Using Text-Messaging on the Discord Platform.

I just wrote in the subject chat, 'Here's the SQL task, here's my sentence, it doesn't work exactly right. What's wrong? The comma or parenthesis? Must be some small mistake, obviously'. [T]hen another student answered me. [Another time, I had a problem with] the 'for' loop, 'while' loop or 'foreach' […], and I copied a screenshot of my code [in the platform] […]. Then, somebody corrected it […]. I tried it and it worked, and it was perfect […].

The excerpt illustrates three main actions using text-messaging. The student first shared a coding problem with peers or teaching staff, who respond with information relevant to solving the problem, and text-messaging transmitted information back and forth. Another example, using discussion threads, is shown below:

Excerpt 3. *Student Recollection of Using Discussion Threads on the Stack Overflow Platform.*

I would go to a link after searching about the problem […]. [On Stack Overflow, people] write their problem, and then, [others] answer how they would have solved [that] problem […]. I normally look at which [solution]

> is getting a high rating because that would indicate that the way of solving the problem is probably a better one. […][A]nd, if not, I'll go to the next one that has been highly voted upon.

In the excerpt, the student recalled using discussion threads to read problems and browsing through solutions posted by professionals to assess their relevance, as organised by this technology. Digital libraries also organise information within platforms, with the main difference being its nature and the way information is organised. Discussion threads organise posts from professional developers through e.g., rankings based on professionals' votes. Digital libraries in a tutorials and courses platform (e.g., W3Schools) organise information through a predefined structure that redirect to specific content (e.g., lists of links).

The actions the students recalled reflect affordances related to accessing information realised with resources not considered in the formal curriculum, which we interpreted as divergences from curricular practices. The students showed in their reflections that they knew that using a web-search enables access to links to other platforms selected by its algorithm. They knew that using text-messaging enables sharing information with specific people and accessing information shared by them. They also knew that using discussion threads from Q&A platforms enables accessing information about coding problems shared by professionals and that clicking items listed by digital libraries offers access to specific information. Thus, the students showed knowledge about the use of specific resources from specific platforms across curricular boundaries relative to their own possibilities.

We interpreted the actions described both across and within platforms as mediational, because they did not directly address the objectives of learning or remembering coding methods or solving coding problems. Instead, their performance enabled consequent objective-oriented actions. Moreover, without these resources, mediational actions could not have been performed, or at least not in the same way. Therefore, while individual students were relevant agents that oriented the actions performed by deciding to use platforms and which information to ultimately use, they were not the only agents involved. The students also acted as co-constitutive overlapping agents with the web-technologies used. The agent that accessed information across platforms was the student with web-search technologies, as their algorithms limited the possible paths to follow. The agent who communicated with their peers to ask for help was the student together with text-messaging technologies, as without them sharing information in different space–time locations would not be possible. Agency, therefore, was expressed as distributed, as their experiences and actions could not be separated from the resources used.

Understanding, remembering and repurposing information

The second theme relates to crossing curricular boundaries to understand and remember concepts or methods and to repurpose information. To do so, the students recalled using several web-technologies from tutorials and courses and Q&A, text library, video repository and source code repository platforms.

Some students recalled using summaries from tutorials and courses, and text library platforms. Summaries provided written explanations and, in some cases, code examples. Moreover, on these platforms and video repository platforms, the students recalled using procedural models, both written and video, that offered information for implementing specific methods and graphic representations of such methods. Excerpt 4 illustrates how summaries from tutorials and course platforms were used to remember and understand coding functions and methods:

Excerpt 4. *Student Recollection of Using Summaries on the W3Schools Platform.*

> [Using] W3schools is mainly [about] syntax that I'm looking for […]. For instance, how do I set up that syntax, where do my parameters go, where do I need apostrophes and where not. [I do it by] looking at their examples […]. [T]hey explain basically what is the name of this function or [what] this element is and what it does, and they [also] set up the code [of that function] in a way that the arguments and parameters are very clear. That way is easy to see step by step what's the thinking, how do you do this and how does it function on a very basic level.

Excerpt 4 shows several actions performed using summaries across curricular boundaries. The student read information about coding functions, made sense of it and directly implemented those functions in a course task's source code. Such information includes written explanations and examples (i.e., code components). Similarly, the students used problem-solving resources from Q&A and communication platforms, to access written explanations and code components related to specific coding problems or errors, as excerpt 5 exemplifies:

Excerpt 5. *Student Recollection of Using Problem-solving on the Stack Overflow Platform.*

A person had posted their code, and they had a similar problem […]. I remember a person commenting, 'You used the wrong variable to make the list'. It kind of clicked for me. I was like, 'Oh yeah, that makes sense'. So then […], I changed the 'self.underscore' word with a variable that referred to a string of the same variable […] [but it did not work, because] I had to make it a string to make it correct.

The excerpt illustrates how the students repurposed code components in a course project or task. These actions involved students reading the questions and answers found within Q&A platforms, making sense of them, tailoring code components to their needs by modifying them (e.g., changing 'self.-underscore'), and integrating them into their projects or tasks. Something similar took place when the students accessed and used open-source code from source repository platforms and problem-solving resources mediated by the use of text-messaging and videoconferencing resources. The last cases differed in that the students formulated explanations of their own problems, and their peers or teaching staff instead of professional developers formulated the answers and shared them with the students.

These actions illustrate multiple interrelated affordances realised across curricular boundaries using several resources. The students knew how to read and make sense of the information accessed and how to manipulate and transform such information by customising it and integrating it into their own work. Moreover, the students needed to use not only resources from online platforms but also the languages enabling communication with others and manipulation of code components.

We interpreted these actions as objective-oriented because they directly addressed the objectives of solving coding problems or errors, or learning about software development concepts or methods. Moreover, these actions were mediated by the actions described in the previous section, which enabled accessing information. Agency, thus, is expressed as a process that began with the students accessing information together with resources such as web-search, discussion threads or text-messaging. Mediated by these web-technologies, the students used information shared by professional developers, peers and/or teaching staff or summaries and procedural models created by private companies. These people and organisations, existing outside the formal curriculum boundaries, created the information used, making them relevant agents for understanding the students' divergence from curricular practices. Individual students were also relevant agents, as they decided to cross curricular boundaries, although the objectives were ultimately addressed by acting together with resources as agents to orient the actions performed.

Synchronous and asynchronous joint work

The third theme relates to using online platforms to work with others synchronously and asynchronously. The students recalled synchronous joint work through the combined use of screen-sharing, voice-messaging, text-messaging and/or videoconferencing from communication platforms, as excerpt 6 shows:

Excerpt 6. *Student Recollection of Using Screen-Sharing and Voice-Messaging on the Discord Platform.*

[W]e were all struggling to meet, do our tasks during corona times, so we said 'we have to be up at 10:00 and we have to meet on Discord and talk together and start working'. [T]hen we used a lot of screen-sharing to see what the other person was writing, see if it was correct. And then, if it was wrong and had a lot of errors we can all look through the code [together] and say like 'Oh no, there is a mistake there because you forgot a punctuation mark or like you forgot this or you didn't think of that', like work together at the code.

Using the aforementioned technologies, the students performed several actions. Voice-messaging enabled the students to meet remotely to 'talk together' regardless of their location, and screen-sharing enabled sharing information with each other (i.e., source code or text), allowing the group to work together towards a common goal. In the excerpt, for instance, the student recalled using voice-messaging and screen-sharing to 'work together on the code' to solve problems. Other students recalled using these resources to discuss, plan and reach agreements on steps to follow in a project. It is noteworthy that, while most platforms many students relied on were not in the curriculum, the Zoom platform was included.

The students also recalled asynchronous joint work involving shared document preparation technologies on source code repository platforms. Using these web-technologies, the students worked in different space–time locations but still as a group by contributing individually to the source code of shared software projects and managing the contributions made by each group member, as excerpt 7 illustrates:

Excerpt 7. Student Recollection of Using Shared Document Preparation on the GitHub Platform.

> When you use GitHub with several people, you have to make a project together that everyone shares. But then, you have to learn how to properly send what you have worked on to GitHub so that others can 'merge' it with. If you were working in the same lines, you will say, 'Oh my God, there is a crash', because you both edited in the same space, and then, you have to learn how to get both of your codes working together in the file […]. [It was] a learning curve to see what we should keep and what we shouldn't keep when we edit in the same space.

The excerpt illustrates different actions performed using shared document preparation. The students worked on a shared document (i.e., source code) linked to a specific project, meaning the group first had to create the document and provide access to all group members. Each student worked individually on the project and 'sent' their contributions using shared document preparation. These contributions could 'crash' or 'collide' with one another, meaning they could create inconsistencies or errors, requiring corrections to make them coherent. In some courses, the students were provided with a source code repository platform. However, most students used openly available alternatives.

The actions described show that the students were able to realise affordances related to synchronous and asynchronous joint work by crossing curricular boundaries. In the case of synchronous joint work, the students showed that they knew how to log into a specific communication platform to meet as a group, communicate with each other and make sense of the information shared during the meeting. In synchronous joint work, the students demonstrated knowledge about creating projects on the platform, referred to as a 'learning curve' in the excerpt, and how to create and add their contributions to the project, visualise the changes made by others and make sense of and solve conflicts between these and their own. In both cases, the students' shared awareness of the projects enabled working together. This shared awareness, in turn, was enabled by the different web-technologies used. Shared document preparation, for instance, enabled the students to share their awareness of a project's source code by enabling accessing, sharing and manipulating the same information regardless of their space–time locations. Videoconferencing, voice-messaging and text-messaging enabled shared awareness relative to the virtual space they occupied synchronously.

We interpreted these actions as mediational, collective and objective-oriented. Mediational and collective because some actions oriented the flow of information and brought the group together, respectively, enabling the performance of consecutive objective-oriented actions where they worked together as a group on a project. Meeting remotely and sharing information enabled discussing and explaining problems and tasks and reaching agreements on the steps to follow. Meanwhile, managing the contributions of all group members in a project enabled solving conflicts between these contributions.

Agency, therefore, was expressed as a process in which several different overlapping agents oriented the different actions performed. The students acted as individuals when they offered their own ideas and contributions, but also as a group when they had to reach agreement in pursuit of collective goals (i.e., the project). Moreover, the students, individually and collectively, acted jointly with the web-technologies they used. This joint engagement resulted in the students and the group becoming co-constitutive agents with these technologies. Using web-technologies enabled and constrained the information flow and manipulation, limiting how and what information could be shared. Thus, the individual students' and the group's actions, or at least part of these actions, could hardly be separated from the use of such technologies in the situations recalled.

Students' interest development

The fourth theme concerns students' development of their interests in software development, for which some students used digital libraries on video repository platforms and public/semi-public profiling and publishing technologies on communication, source code repository and social networking platforms. Digital libraries on video repository platforms, in particular, besides organising content and using algorithms to search for information within the platform, also recommend content automatically (i.e., videos), as shown in excerpt 10:

Excerpt 8. *Student Recollection of Using Digital Libraries on the YouTube Platform.*

> [Y]ou start on YouTube and you're wondering about something specific [for a task], and then, [the platform] suggests you [watch] 15 different videos that are all equally interesting, and then, you just click them and you're in a spiral, and that's your whole day on YouTube, learning about things you had no idea you were curious about.

The excerpt shows that crossing curricular boundaries to use digital libraries enabled accessing videos during a curricular task, activating that technology's algorithm. This algorithm provided recommendations to the student automatically without these being requested, in contrast to the algorithm in web-search, which reacted to inputs the students provided.

The students also recalled using public/semi-public profiling and publishing technologies on social networking, communication and source code repository platforms to connect to specific professionals and companies, and to access information they created and published. This information related to these professionals' and companies' profile, as well as events attended, topics learnt, things they worked on or specific software projects with their source code.

In contrast to the other themes, the students accessed this information because they considered it helpful for developing their topical interests geared towards future learning. Therefore, the objectives addressed differed from those discussed above in that they were still undefined. The students performed the actions described precisely so that they could decide on future objectives. We interpreted these actions as mediational because they were oriented toward the future students envisioned for themselves. Agency was expressed as a process primarily oriented by the individual students, as they decided what their interests are, but also by the students with the web-technologies that enabled reaching the information used to develop such interests. The networks of professional developers and private companies were also relevant agents, as they created the content the students accessed.

Discussion

This study investigated the boundary crossing as undergraduate CSE students used online platforms not included in the formal curriculum to learn software development and explored realised affordances and agency expressions. The students experienced their learning in ways that exceeded the possibilities offered by the curriculum by constantly moving between curricular and online contexts. This boundary crossing, however, did not result in complete divergences from curricular practices. Rather, the students moved across boundaries to address course objectives and requirements (i.e., the expected learning outcomes) by reconfiguring them and aligning them with their own needs. To do so, the students used various resources from multiple platforms not included in curricular design, such as web-search, problem-solving, text-messaging and/or videoconferencing, to mention a few (see Table 2).

RQ1 was: *Which affordances are realised by students as they cross curricular boundaries to use online platforms to learn software development?* The findings showed that the students recalled the realisation of several different affordances involving the use of online resources: (1) accessing relevant information across and within platforms; (2) understanding and remembering software development concepts or methods and repurposing information; (3) synchronous and asynchronous joint work; and (4) developing interests in software development. These affordances align with those found in previous studies related to providing material infrastructure, exploring and constructing knowledge, reusing information, collaborating (Nicolini, Mengis, and Swan 2012) and transmitting and collecting emotional meaning (Vallverdú and Trovato 2016). We add to this literature by showing that the actions performed fed into realising affordances complementarily, configuring activities that mediated, brought people together and directly addressed specific objectives. The findings also reveal that realising affordances enabled activities across space–time locations, reflected both in the students' joint work enabled by their shared awareness and in the information that they used. This information was published at different times and places, connecting past events to situations in which the students learnt through traces left behind. Moreover, while the identified affordances might resemble those in the literature, they are not necessarily equivalent to those realised within curricular boundaries using similar resources. The information students accessed, while at times originating from peers or teaching staff, was created and shared by companies and professional developers, reflecting practices that exist beyond curricular boundaries and that influence those enacted by the students (see also Damşa and Nerland 2016).

RQ2 was: *How is agency expressed as these affordances are realised?* The findings showed that the students decided to (partially) diverge from the curriculum practices primarily in three scenarios: (1) the students as individuals; (2) the students with the resources they used; and (3) the students with their peers as a group. The curriculum framed most of the events that took place when the students used platforms, becoming their initial trigger; however, it did not translate into direct control over and/or completely limiting the students' actions. The students experienced curricular tasks as adaptable, finding ways of engaging in them based on their own choices, instead of following fixed pathways (Dreier 1999). Furthermore, other relations the students established played a significant role in how they performed actions. Agency, therefore, was expressed as relational (Edwards 2005) in two main ways. First, as shared (Schiermer 2021b; Virkkunen 2006), since the students' actions could hardly be understood without them acting as overlapping agents with resources and with peers, becoming co-constitutive of one another. Second, as distributed (Damşa and Jornet 2017), because the multiple relationships the students established as they moved across platforms (i.e., with peers, teaching staff, companies and professionals) influenced their actions through the information they capitalised on.

Informed by an ecological perspective, these findings also reveal important aspects of how students (re)construct knowledge across curricular boundaries and, thus, how they learn. The students knew how to use web-search or screen-sharing, for example, to access and share information precisely because they had used or seen someone using these or similar resources before. We argue that the knowledge the students (re)constructed was, above all, rooted in their awareness of their environment, as it reflected information accessed directly from it and by acting upon it (Reed 1992). The different representations, such as programming languages, the web-technologies used or even the knowledge students continuously (re)constructed, did not replace such awareness. Rather, they became resources the students capitalised on, enabling different ways of experiencing and interacting with the environment.

Moreover, since the students relied on the use of these resources (e.g., when requiring previously learnt programming languages to read posts on Q&A platforms), how such information was accessed and used depended also on the students' past experiences. Since many of these resources carry traces of others' actions in different space–time locations, such as Q&A platforms, the knowledge constructed not only reflected the students' past but also the resources' past. In other words, our findings not only illustrate the 'history' of the knowledge students (re)construct through boundary crossing (Grene 1987), its relational nature (Damşa and Jornet 2017) also becomes visible. We show that the students accessed and manipulated information in the environment depending on their own possibilities, i.e., relative to themselves and to how they could capitalise on specific resources (Chemero and Turvey 2007; Gibson 1977; Reed 1992). Additionally, we show that such information was linked to those who created and shared it, characterising more than just the knowledge that was (re)constructed. The students' practices, at least to some extent, reflected the practices of professionals, companies and peers, revealing that they also had agency in relation to students' learning. The agency expressed as the students diverged from curricular practices was thus expressed as a blend of multiple overlapping agents, involving both humans and objects together, who/which oriented the actions performed in different ways.

Overall, this study's findings are in line with the idea that resources do not constitute boundaries in themselves but that boundaries are formed in the way resources are used in the context of learning activities – how they enable (or constrain) the way the environment is experienced (Akkerman and Bakker 2011; Reed 1992). Such boundary crossing provides several possibilities for learning but also raises concerns about the quality of the information students use and the influence it may have over them. Algorithms enable accessing information efficiently, but they operate as a black box. Professionals can create and share relevant information, but its quality is not always known or safeguarded. Moreover, the interests and intentions of both private companies and professionals (most likely) differ from those of students or higher education institutions. Meanwhile, it is unclear to what extent students' practices are influenced by professionals or companies and in what ways, risking setting students on learning paths not acknowledged or supported by formal education.

Implications, limitations and further research

This study shows that using platforms beyond curricular boundaries can offer students new possibilities for learning but also present multiple challenges, possibly becoming the source of tensions. Curriculum designers and teachers should focus on finding meaningful forms of boundary crossing involving online platforms and resources that align with curricular objectives. Such an approach increases the chance of preparing students to engage critically with online platforms, raise their awareness of privacy issues and address their concerns about the relevance of specific resources in their future careers.

However, this study also had some limitations. It was exploratory in nature and did not seek to generalise its findings, as it focused on a small sample of CSE students in Norwegian higher education. The study also relied on students' recollections of past events based on their traces (web logs) rather than on data of interactions taking place during such events.

Further research on how students from other disciplinary domains learn across curricular boundaries supported and constrained by platforms is imperative. So far, the literature on learning practices involving the use of platforms in curricular contexts has seen them as separate from those of the professional domain. Exploring ways of achieving meaningful boundary crossing could help bring both worlds together and better define their boundaries with students and their learning at the centre. For this reason, more emphasis is needed on processes, the interrelatedness of affordances, and how institutional, curricular and domain-specific contexts permeate the realisation of affordances. Finally, further research is needed in relation to the increasing trade-offs that persist (and perhaps increase) between the usefulness of online resources and the protection of user privacy.

Conclusion

The main aim of this study was to better understand students' boundary crossing and agency as they learnt while using resources from openly available online platforms. The findings reveal that regardless of their (intentional or unintentional) exclusion from the formal curriculum, online platforms are becoming an integral part of students' learning practices. The resources within platforms connect students with people and organisations and the information they share. By crossing curricular boundaries to use resources available on online platforms, students (need to) act agentically in an intricate process of realising affordances that may not be possible within their curricular boundaries. This process reveals an extensive ecology of resources that cannot easily be replicated by the curriculum and that students capitalise on, but which influences their learning practices in complex ways. Essentially, the findings show that it is becoming increasingly difficult to separate the use of platforms from how and where students learn. The unstoppable 'platformisation' (van Dijck, Poell, and de Waal 2018) raises concerns and presents opportunities for students, education institutions and platform providers alike, as online platforms become increasingly embedded in our ways of working, learning and living.

Acknowledgements

We thank EngageLab, the Department of Education and the HEDWORK and LIDA research groups, all at the University of Oslo, for their support and valuable feedback and the participants for making this study possible.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability

The data used in this study is available from the corresponding author upon reasonable request.

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