Online help-seeking occurring in multiple computer-mediated conversations affects grades in an introductory programming course

ELIZABETH B. CLOUDE, Graduate School of Education, University of Pennsylvania, USA

RYAN S. BAKER, Graduate School of Education, University of Pennsylvania, USA

ERIC FOUH, Department of Computer Science, University of Pennsylvania, USA

Computing education researchers often study the impact of online help-seeking behaviors that occur across multiple online resources in isolation. Such separation fails to capture the interconnected nature of online help-seeking behaviors that occur across multiple online resources and its affect on course grades. This is particularly important for programming education, which arguably has more online resources to seek help from other people (e.g., computer-mediated conversations) than other majors. Using data from an introductory programming course (CS1) at a large US university, we found that students (n=301) sought help in multiple computer-mediated conversations, both Q&A forum and online office hours (OHQ), differently. Results showed the more prior knowledge about programming students had, the more they sought help in the Q&A compared to students with less prior knowledge. In general, higher-performing students sought help online in the Q&A more than the lower-performing groups on all the homework assignments, but not for the OHQ. By better understanding how students seek help online across multiple modalities of computer-mediated conversations and the relationship between help-seeking and grades, we can re-design online resources that best support all students in introductory programming courses at scale.

CCS Concepts: • **Social and professional topics** → **CS1**; • **Applied computing** → **E-learning**; • **Human-centered computing** → **Web-based interaction**.

Additional Key Words and Phrases: Programming, Online help-seeking, Learning analytics at scale, CS1

1 INTRODUCTION

Despite the rapid increase in the number of digital platforms removing physical barriers to programming education (e.g., Khan Academy, Codio; [18]), most students who complete these online courses cannot pass basic knowledge assessments of programming skills [24]. The demand for programming continues to grow [11] and the average failure rate in introductory programming courses hovers near 28% [5]. A possible explanation may be that most of these digital platforms fail to teach or scaffold the self-regulated learning skills required for solving open-ended programming problems. Self-regulated learning (SRL) describes students who play an active role in their learning to achieve their academic goals by monitoring and adapting cognitive, affective, metacognitive, and motivational processes [39]. One of the key ways that SRL skills manifest while learning to program is through help-seeking [14]. When students seek out help in their courses, it can indicate that they not only have the metacognitive awareness to identify a problem in their current knowledge, but they have also judged they do not have the resources to solve the problem themselves and have

therefore taken the steps to ask for help [21]. To foster help-seeking, resources are provided to students in their courses or during learning activities via humans or tools built into intelligent systems [1].

As the use of online resources continues to expand in higher education, online help-seeking becomes a core element of learning introductory topics and thus increasingly important for college students to develop effective help-seeking skills to succeed [8, 9]. The landscape of help-seeking has changed drastically compared to nearly a decade ago when students needed to seek help in face-to-face contexts. Help resources in fully in-person courses typically involve meeting with an instructor 1-on-1 or with a smaller group. Today, there are multiple help resources online that students can use to seek out answers to their questions, and different online resources vary in their accessibility. For instance, online office hours are available at specific time frames, while Q&A discussion forums are available 24/7. Different online resources also vary in the sources of help they provide to students. For example, discussion forums have multiple sources of help including peers and instructors, while online office hours have instructors or teaching assistants. Thus, questions remain about how students use multiple modalities of online resources while seeking answers to their questions. For example, do students use multiple modalities of computer-mediated conversations (e.g., discussion forum versus online office hours) in CS1 courses, and if so, are there differences in their online help-seeking behaviors between certain modalities relative to others? Or is there an interplay between the use of multiple computer-mediated conversations? Most of all, are students getting the help they need via computer-mediated conversations and succeeding in their CS1 course? Understanding if, when, and how students' online help-seeking behaviors occur in multiple modalities of computer-mediated conversations and their relation to grades in a CS1 course is the objective of this paper.

2 HELP-SEEKING IN ONLINE LEARNING ENVIRONMENTS

Research shows that students can struggle to implement effective help-seeking strategies in online learning environments (OLEs) due to several reasons (e.g., avoiding asking for help due to social factors like embarrassment [23] or failure to recognize their need for help [30]). To deal with this, a great deal of work has designed help resources into OLEs (e.g., intelligent tutoring systems; ITSs) to scaffold students' online help-seeking during learning activities [1]. Students using OLEs often have access to a range of resources. Some OLE help-seeking resources leverage tools that estimate students' level of knowledge in the domain at every moment by tracing their behaviors during learning activities [31]. These traces identify opportunities to scaffold effective help-seeking behaviors, often via on-demand, step-by-step contextual hints that explain how to solve a current problem [37], or pedagogical agents designed to mimic human tutoring [2]. Other resources include computer-mediated conversations include Q&A discussion forums or online office hours. These resources require students to self-initiate effort in seeking the help they need to find answers to their questions via social interaction (e.g., peers, instructors, and/or adults). Generally, research shows that students' online use of help-seeking resources with OLEs is beneficial for learning and academic success [1, 2, 31], but the findings are less clear for computer-mediated conversations where the student initiates help from another human.

This study focuses on the use of computer-mediated conversations during an introductory programming course, as their social component is more complex. Because computer-mediated conversations involve social interaction and self-initiation, metacognitive awareness, and self-regulation from the student [14, 23], students must consider the cost-benefit trade-off associated with help-seeking, such as the potential cost of embarrassment from peers or instructors compared to other OLE resources without humans [20]. A study by Tseng et al. [36] found that the more frequently students' demonstrated online help-seeking in a Q&A discussion forum was associated with better performance in the course. Similarly, Corrin et al. [7] collected the quantity of online help-seeking behaviors in discussion forums across several MOOCs. Using dimension reduction to identify student profiles on the basis of online help-seeking, five profiles

emerged, and the profiles indicating online help-seeking in a discussion forum were related to better performance across all MOOCs [7].

Other studies have examined the quality of students' online help-seeking behaviors in discussion forums by classifying the types of questions posted in a CS2 (traditionally, the second programming course for undergraduate computer science education) course using Piazza [38]. They classified questions into different types and assessed whether question type was associated with course grades. The question types were described as constructive (i.e., request for help that does not display reasoning or indicate that the student has tried to solve the problem themselves), active (i.e., questions reflecting students' reasoning or attempts to find a solution), logistical (i.e., questions on course policies, schedules, etc. not necessarily related to course content), and content-clarification (i.e., requests additional information on project assignments, software, or other design documentation that does not involve questions on students' problem-solving work). They found that most students asked logistical and shallow questions in the discussion forum. However, the questions reflecting at least some degree of constructive problem-solving were associated with better grades [38]. Their results also suggested that questions neither describing logic nor indicating an attempt to find a solution were related to students' prior knowledge about programming. This finding suggests that prior knowledge may play a role in the type of questions that students use while seeking help online in discussion forums.

However, sometimes more online help-seeking in discussion forums is not associated with better performance. A study found that less online help-seeking in discussion forums was related to better course grades [34]. For example, a study [34] examined multiple types of online help-seeking behaviors for both students and instructors, capturing a more holistic representation of the help-seeking process. Help-seeking types were classified into four categories based on students 1) asking questions, 2) answering questions, and 3) viewing questions/answers, and instructors 4) answering questions/providing clarifications. Their results showed that high-performing students did not necessarily ask or answer more questions in the discussion forum, but they viewed significantly more questions and answers. The results also suggested negative relationships between interactions with instructors in the discussion forum and students' grades [34]. A possible explanation for these mixed findings could be due to capturing a more holistic representation of the help-seeking process. For example, did the student receive an answer that addressed their question appropriately, and who was the source of help (e.g., peer or instructor)? Another study found that the source of help played a role in online help-seeking [16]. The paper examined three types of help-seeking: 1) online searching, 2) asking teachers online for help, and 3) asking peers online for help. The results showed that the strongest predictor of online help-seeking regardless of the source of help was assignment difficulty. Yet, gaps remain because [34] did not examine whether performance varied based on where and how students sought help.

While online discussion forums host multiple sources of help that encompass both peers and instructors and are also accessible 24/7 to students (though responses are not always available 24/7), other computer-mediated conversations vary in their accessibility and source of help. Another common computer-mediated conversation resource is online office hours. This resource is different than discussion forums because, again, they are not accessible all of the time and they provide one source of help: instructors. A study by [15] found that students attending online office hours often coincided with periods of actively working on programming assignments. The results suggested that online office hour attendance was positively related to course grades. They hypothesized that since office hours were provided throughout the week, students choose to attend and work actively on their assignments at those times since they might have questions and they can ask for the instructor's help they needed. In contrast, a study found no relationship between students' attendance during online office hours and course grades [12].

Overall, we suspect that a possible explanation for the mixed findings in the literature on online help-seeking in computer-mediated conversations could be due to a lack of differentiation as to if, when, and how students seek help between multiple modalities of computer-mediated conversations in OLEs. Critical information is missed when we only consider whether a student is seeking help, not how. We question whether quantifying online help-seeking in one modality of a computer-mediated conversation holistically represents students' online help-seeking when they have access to multiple modalities of computer-mediated conversations. For example, did the student attend online office hours in addition to using the discussion forum, or did they only engage in one type of help-seeking which had little influence on course grades [12]? Was one modality of the computer-mediated conversation more or less helpful for students succeeding in the course? How might students' differ in their online help-seeking between different modalities with varying accessibility and sources of help (e.g., peers or instructors, or both)? Advancing our understanding of if, when, and how students select between multiple modalities of computer-mediated conversations to seek help is important for holistically examining the role of online help-seeking in multiple computer-mediated conversations on course grades. Furthermore, developing a more in-depth understanding of *how* students are selecting between multiple modalities of computer-mediated conversations in large OLEs could provide information that augments both teaching and learning practices at scale.

2.1 Key Challenges

Common computer-mediated conversational resources students use to seek help include discussion forums and online office hours. There are mixed findings regarding the role of online help-seeking across multiple modalities of computer-mediated conversations (e.g., discussion forums and online office hours) on course performance. Some studies find positive relations between the quantity and quality of online help-seeking in discussion forums and course grades [7, 34, 36, 38], while other studies find none or sometimes negative relations between online help-seeking in discussion forums and course grades [34]. Similarly, some studies find that attending online office hours to seek help is beneficial to course grades [15], while others find no relations between attending online office hours and course grades [12]. Perhaps the inconsistent results stem from challenges associated with considering online help-seeking behaviors in isolation. If students are attending online office hours, can we assume they are not seeking help in other computer-mediated conversations? Are students utilizing different types of online help-seeking behaviors between multiple modalities of computer-mediated conversations, and if so, are different approaches differentially beneficial for course grades? Studying online help-seeking in computer-mediated conversations separately misses the complementary and interconnected nature that might occur when students have access to multiple modalities of computer-mediated conversations during online help-seeking with OLEs.

Other gaps in literature stem from little understanding regarding the role of assignment difficulty [16] and prior knowledge [38] on online help-seeking behaviors between multiple modalities of computer-mediated conversations. While most studies find consistent results that task difficulty and prior knowledge impact online help-seeking behaviors, few studies examined the role of task difficulty and prior knowledge in online help-seeking that occurs between more than one computer-mediated conversation. In this paper, we address the key challenges discussed above by examining online help-seeking behaviors that occur between multiple computer-mediated conversations: Q&A discussion forum and online office hours. We account for the role of assignment difficulty and prior knowledge on online help-seeking behaviors across multiple modalities of computer-mediated conversations and assess its relation to course grades. To guide our research questions, hypotheses, and interpretation, we anchor our work in a theory on help-seeking by

Nelson-Le Gall [28]. In the following section, we present a model of help-seeking [28] and highlight how it deals with key challenges identified in the literature on online help-seeking.

3 NELSON-LE GALL'S MODEL OF HELP-SEEKING

Computer science courses in higher education are a relevant context to study help-seeking from multiple computer-mediated conversational resources, as computer science courses typically have more ways to seek help from other people (tutorials, help forums, etc.) than other majors [10]. In studying this, we leverage a classic theory developed by Nelson-Le Gall [28] to describe help-seeking, which states that help-seeking occurs in a series of steps that is both cyclical and nonlinear. Students must 1) identify whether an impasse or problem exists by monitoring their knowledge base which encompasses their prior knowledge, and then 2) judge if help is needed. Information gathered from 1-2 influences whether students 3) decide to seek out help, and upon making the decision to seek help, students need to 4) select which type of help-seeking is best. These steps, in turn, inform 5) the selection of a source of help they seek out (e.g., peer or instructor or both). Following this step, the student must then 6) ask for help, 7) obtain help, and 8) process the help received (see Fig. 1).
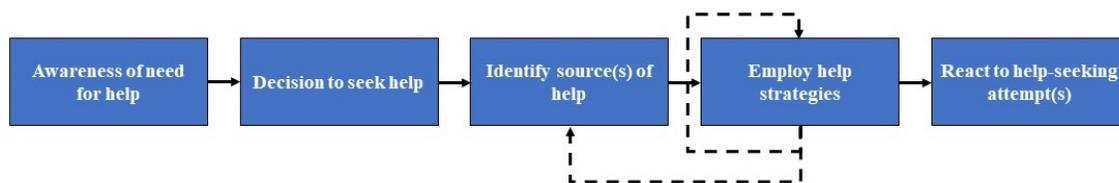

Fig. 1. Model of help-seeking by Nelson-Le Gall [28]

In deciding whether to seek help, the student must make a cost-benefit trade-off [22, 23, 28], weighing the cost of feeling inadequate or less competent than surrounding peers or instructors [27], against the benefit of acquiring new knowledge and possibly increasing the likelihood of success [28]. Karabenick and Berger [20] extended Nelson-Le Gall [28]'s model of help-seeking by emphasizing that students need to possess cognitive, metacognitive, emotional, and social competencies within each step of help-seeking. Yet, computer-mediated conversations do not require the same social interactions (or cost) as in traditional face-to-face settings. For example, students can post anonymous questions to discussion forums, reducing the cost associated with help-seeking altogether. However, this may potentially increase the rate of unproductive help-seeking behaviors, where students may make no attempt at solving the problem themselves (called "executive help-seeking" [25, 28]), especially if there is an influx of posts and responses for students to access at any time. Thus, we address these gaps by guiding our study using the model of help-seeking [20, 28], and go beyond previous studies by differentiating online help-seeking behaviors that occur in 1) online office hours (instructors) and 2) a Q&A discussion forum (peers and instructors). We investigate how students seek help online when they have access to multiple modalities of computer-mediated conversations. For example, do students demonstrate more executive help-seeking, or are their behaviors more adaptive, where they switch from one computer-mediated conversation to another depending on their current learning needs?

4 CURRENT STUDY

Because of the role that computer-mediated conversations play in supporting students' online help-seeking behaviors and overall course grades, it is important to understand the ways in which students seek help online with multiple

computer-mediated conversations. The overall objective of this paper was to investigate students' online help-seeking occurring in both a Q&A discussion forum and online office hours. We assessed the role of programming assignment difficulty and prior knowledge on students' online help-seeking behaviors across both computer-mediated conversations. Further, we examined the degree to which online help-seeking behaviors across both computer-mediated conversations were related to course grades.

We defined the following research questions (RQs) and hypotheses to guide our study:

- **RQ1: Do students seek help in online office hours and Q&A discussion forums when both are available in a CS1 programming course, and to what extent does help-seeking change across homework assignments?** RQ1 will allow us to quantify and compare online help-seeking behaviors in both a Q&A discussion forum and online office hours on programming assignments over time. Our findings will provide insight into how students seek help online and select between multiple modalities of computer-mediated conversations across homework assignments that vary in topics and difficulty.

- **RQ2: Does online help-seeking in both online office hours and Q&A forums vary depending on the topic difficulty, and to what extent are online help-seeking behaviors associated with prior knowledge of programming?** RQ2 will help uncover relations between topic difficulty and online help-seeking within each computer-mediated conversation. Item Response Theory was used to calculate topic difficulty across homework assignments [40]. Further, we will assess the degree of prior knowledge about programming on students' online help-seeking behaviors across computer-mediated conversations.

- **RQ3: Does online help-seeking in both online office hours and Q&A forums affect grades in a CS1 programming course?** Finally, RQ3 will tell us if there are relationships between online help-seeking behaviors across multiple computer-mediated conversations and course grades.

5 METHODS

5.1 Participants

Participants in this study were 301 first semester students enrolled in a CS1 course using Java offered at a large and highly-selective private university in the USA. The majority of participants did not have a declared major, and they did not have previous experience in computing. For most participants, this was their first semester at a higher education institution. Throughout the course, students were required to complete a total of 9 homework assignments and two timed examinations. Students were also required to complete 11 online quizzes. For purposes of this study, we only examined students' final grades on the homework assignment submissions because these data most directly reflected students' performance in each topic being studied, and were most closely linked to the online help-seeking behaviors being studied.

5.2 Homework Assignments and Course Design

Students enrolled in the course had to complete nine programming homework assignments, and they had the option of dropping one homework. All students were assigned homework assignments for 7-14 days. To complete the programming assignments, students used Codio[1], an online platform. In addition to programming support, Codio provided resources such as lecture notes that included an interactive electronic textbook and other learning activities for several of the

---

[1]https://www.codio.com/

topics covered in the course (e.g., recursion, abstract data types). Students were also provided with PDF slides on other topics in the course.

Students had an unlimited number of submissions for each homework and received immediate feedback on their submission (e.g., errors). They had one week to work on most assignments (two of the assignments could be worked on for two weeks). The next assignment was released on the due date of the previous one. Although there might be an overlap between two homeworks if a student submitted late, the number of students submitting late was relatively small (less than ten students on average for each homework) despite the fact that students were allowed to use four late days throughout the semester.

5.3 Data Coding and Scoring

The course used Piazza[2] as an online Q&A platform, and an online office hours queue (OHQ) to record office hours attendance. Piazza and the OHQ recorded all the students' interactions within the platform and a timestamp. We used that data to identify and quantify the help-seeking behaviors of the participants.

The course also used Gradescope [3], an online grading platform to collect and automatically grade students' code. We used the results from Gradescope to compute the students' performance in the course. In this analysis, we excluded the first (HW0) and the last (HW9) homeworks. We excluded HW0 because it was implemented in the lecture by the instructor and consisted of writing "hello world" to the standard output. HW9 was excluded because it was a self-designed homework, with each participant working on a different problem. In order to compare students, we ranked them based on their grades and conducted our analysis based on students' ranks instead of their raw grades alone. We did this because a large portion of students scored highly on the homework assignments (i.e., achieving a score of 90 or more), causing our homework grades to be left-skewed.

5.4 Statistical Analysis

5.4.1 RQ1. In our first RQ, we examined the percentage of participants who used the Q&A forum and online office hours across each of the eight homework assignments to quantify how they used both of the digital platforms. We analyzed these data in terms of percentages because the total number of students submitting their homework differed slightly across the eight homework assignments. This was due to some students dropping the class or simply not submitting a particular homework assignment. In addition, for each homework, we calculated the days students used each platform during the week (seven days) before the assignment submission date by that student. Then, we compared the average days students use each platform across the homeworks.

Further, we used a series of seven McNemar tests to investigate whether there were changes in the proportion of online help-seeking behaviors across the homeworks. The McNemar test was used because we have two subgroups, participants who used a platform and those who did not use it, and membership in these subgroups partially changes between homeworks, thus we are comparing correlated proportions [26]. As we moved from one homework to the next, we wanted to examine if the proportion of each subgroup changed. Specifically, for each consecutive set of homeworks, we conducted one McNemar test to assess the degree to which the proportion of students who sought help in OHQ changed between homeworks, and another McNemar test to assess whether the proportion of students who sought help in Q&A changed between homeworks. Due to multiple testing, we used Benjamini & Hochberg (B&H) False

---

[2]https://piazza.com/
[3]https://www.gradescope.com/

Discovery Rate approach to control for type II errors [4]. Specifically, we ran a series of 7 tests per computer-mediated conversation at an alpha level of 0.05 which was adjusted using B&H approach (α=0.05*k/7; see [4] for details).

5.4.2 RQ2. In our second RQ, assignment difficulty was computed using a 2-parameter (2 PL) Item Response Theory (IRT) model. The IRT model expects the grades to be dichotomized. Since students had unlimited submissions with immediate feedback, the class average on all homeworks was in the A-letter grade range. We assigned a score of 1 to a student if their grade on a homework was greater or equal to 93 (the letter A grade cutoff) and 0 otherwise. We used the R statistical software [4] (LTM package [29]) to calculate the IRT analysis. The IRT analysis ranked the homework from the most difficult to the least difficult as follows: HW8, HW1, HW6, HW2, HW7, HW3, HW4, HW5. To explore the relationship between platforms and programming topics, we first looked at the percentages of students using each platform across programming topics. Second, we calculated a Spearman correlation between homework difficulty and OHQ proportion, and the Spearman correlation between homework difficulty and Q&A proportion.

To explore the correlation between students' prior performance and help-seeking behavior, we calculated students' performance ranks on previous homework assignments and assessed their proportion of help-seeking behaviors across two computer-mediated conversations. For instance, we divided students into 4 quartiles based on their ranks in HW1. Then we looked at the difference in the proportion of OHQ and Q&A online help-seeking among groups when students were completing HW2. Specifically, we divided students into four groups based on the quartiles of their ranks on the initial homework and compared the average usage time of groups on the following homework. Therefore, the students with the top 25% ranks were assigned to Q1 (highest-performance group) and the students with the lowest 25% ranks were assigned to Q4 (lowest-performance group). Next, we calculated the average usage days of OHQ and Q&A for the next homework by rank group. A series of analyses of variance (ANOVA) were calculated to assess whether there were difference in OHQ and Q&A usage among the prior knowledge ranked groups on HWs 2-8 for each platform. A B&H post-hoc correction was utilized to control for Type II errors [4].

5.4.3 RQ3. For this RQ, we divided students into quartiles based on their grades on each homework assignment, similar to RQ2. Students' grades were ranked from high to low to increase variability, as there was little variation in the raw homework grades, since most students scored within an A-letter grade range.

Next, we calculated a series of eight ANOVA tests to examine whether there were significant differences in online help-seeking in both OHQ and Q&A forum between the quartile groups. We used a B&H post-hoc correction [4] to control for Type II errors. We calculated separate series of ANOVA tests for each computer-mediated conversation.

6 RESULTS

6.1 RQ1: Do students seek help in online office hours and Q&A forums when both are available in a CS1 programming course, and to what extent does help-seeking change across homework assignments?

The results showed no significant differences in the proportion of students' online help-seeking behaviors between OHQ and Q&A computer-mediated conversations across any of the homeworks in either OHQ and Q&A computer-mediated conversations (see Tables 1-3 and Figure 2 for details)[5]. These findings emphasize that students used both modalities of computer-mediated conversations consistently across the homework assignments, where there were no significant changes from one homework to the other. Overall, the OHQ and Q&A forum (i.e., Piazza) seemed to be helpful for

---

[4]https://www.r-project.org/
[5]Please note the alphas are sorted according to [4].

all students based on the quantity of online help-seeking alone, but the key question is how the two types of online help-seeking are associated with course grades, a topic we return to in RQ3.

Table 1. Proportions of students' help-seeking in OHQ and Q&A platforms across HW assignments.

	HW1	HW2	HW3	HW4	HW5	HW6	HW7	HW8
n	289	290	288	284	274	271	275	278
OHQ	48%	63%	63%	41%	53%	49%	61%	42%
QA	83%	84%	87%	86%	85%	92%	93%	79%

Table 2. McNemar results for online help-seeking in OHQ between HW assignments.

	HW1-HW2	HW2-HW3	HW3-HW4	HW4-HW5	HW5-HW6	HW6-HW7	HW7-HW8
χ^2	0.01	0.068	0.002	0.003	0.000	0.009	0.001
df	1	1	1	1	1	1	1
α	0.014	0.007	0.036	0.029	0.05	0.021	0.043
p	0.918	0.795	0.964	0.954	0.984	0.925	0.973

Table 3. McNemar results for online help-seeking in Q&A between HW assignments.

	HW1-HW2	HW2-HW3	HW3-HW4	HW4-HW5	HW5-HW6	HW6-HW7	HW7-HW8
χ^2	0.445	0.489	0.538	0.509	0.554	0.715	0.603
df	1	1	1	1	1	1	1
α	0.05	0.043	0.029	0.036	0.021	0.007	0.014
p	0.505	0.484	0.463	0.476	0.457	0.398	0.438

6.2 RQ2: Do online help-seeking in both online office hours and Q&A forums vary depending on the topic difficulty, and to what extent are students' help-seeking behaviors associated with prior knowledge of programming?

To examine the extent to which help-seeking behaviors varied by assignment difficulty and prior knowledge, we leveraged difficulty estimates from IRT. First, two Spearman correlations were calculated between homework difficulty separately for the proportion of help-seeking behaviors in 1) OHQ and 2) Q&A platforms. We again used a B&H correction to account for multiple testing and control for type II errors. The results suggested there were no significant associations between homework difficulty and the proportion of help-seeking in both OHQ and Q&A computer-mediated conversations ($ps>0.05$). These findings were not consistent with our hypothesis, the model of help-seeking [28], and previous literature suggesting that assignment difficulty plays a role in help-seeking behaviors with computer-mediated conversations [16]. A possible explanation for this could be due to the limitations of IRT analyses that rely on students' final grades on homework assignments. Students could resubmit their assignments and receive immediate feedback on the errors in their scripts, which they could correct and resubmit. Since the IRT was calculated with students' final homework grades, we suspect these data may not accurately reflect students learning process but rather their learning result. Future work should look at other metrics that measure the learning process (e.g., error rate, number of compilations needed to fix errors [3, 17]) to assess if it is a better indicator of task difficulty on homework assignments
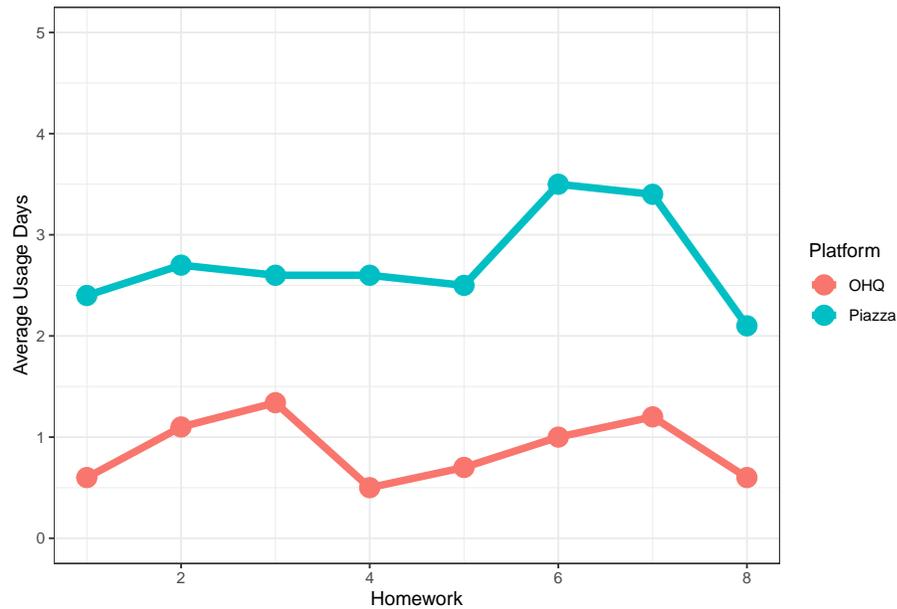
Fig. 2. Average platform usage days across homeworks.

and in computer science domains where students can continuously recompile their code prior to final submission. We explain in more detail in the discussion.

To examine the role of prior knowledge (i.e., performance on previous homework) on help-seeking behaviors across computer-mediated conversations, we first ranked students into quartiles based on their initial homework performance. As shown in Table 4, the average Q&A forum usage days is illustrated between the four prior knowledge groups across both computer-mediated conversations. Next, we calculated 7 one-way ANOVAs for each computer-mediated conversation across the HW assignment using a B&H post-hoc correction to assess whether there were differences in the average day usage between prior knowledge groups across OHQ and Q&A computer-mediated conversations. Results in Tables 5 and 6 suggest that online help-seeking in the OHQ platform was not significantly different between prior knowledge groups across HWs 2-8[6]. In contrast, the average days using the Q&A platform was significantly different between prior knowledge groups across HWs, with the exception of HW8.

6.3 RQ3: To what extent do online help-seeking in both online office hours and Q&A forums affect grades in a CS1 programming course?

Results indicated significant differences in online help-seeking in the OHQ between quartile groups for HW7 ($p<0.001$, adjusted $\alpha=0.006$). In general, higher-performing students (ranked top 50% of the class on HW7 grade) sought help in the OHQ computer-mediated conversation more than lower-performing groups, but only for HW7. We did not find significant differences in online help-seeking in the OH between quartile groups for HWs 1 to 6 and HW 8 (all $ps>0.03$, higher than adjusted α).

---

[6]Please note the alphas are sorted according to [4].

Table 4. Average OHQ and Q&A day usage across homework assignments between prior knowledge groups.

	PK ranks	HW2	HW3	HW4	HW5	HW6	HW7	HW8
Average OHQ Days	Q1	1.06	1.28	0.57	0.83	1.05	1.28	0.61
	Q2	1.18	1.33	0.87	0.72	1.05	1.06	1.08
	Q3	1.08	1.41	0.61	0.71	1.03	1.22	0.95
	Q4	1.16	1.17	0.67	1.03	0.97	1.23	0.66
Average Q&A Days	Q1	3.35	3.2	3.35	3.11	3.86	3.91	2.33
	Q2	2.73	2.6	2.98	2.71	3.86	3.73	2.56
	Q3	2.85	3	2.33	2.58	3.25	3.25	2.18
	Q4	2.24	2.18	2.07	1.98	2.8	2.72	1.76

Table 5. ANOVA results for online help-seeking in OHQ between prior knowledge groups.

	HW2	HW3	HW4	HW5	HW6	HW7	HW8
OHQ	0.2	0.43	1.18	1.57	0.09	0.46	2.88
α	0.043	0.036	0.021	0.014	0.05	0.029	0.007
p	0.89	0.73	0.32	0.2	0.91	0.71	0.04

Table 6. ANOVA results for online help-seeking in Q&A between prior knowledge groups.

	HW2	HW3	HW4	HW5	HW6	HW7	HW8
Q&A	**3.78**	**4.4**	**7.41**	**4.54**	**7.17**	**5.23**	**2.21**
α	0.043	0.036	0.007	0.029	0.014	0.021	0.05
p	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**0.03**

In contrast, for the Q&A computer-mediated conversation, we found significant differences in online help-seeking between quartile groups across HWs 1-8 (ps<0.001). In general, higher-performing students sought help online in the Q&A more than the lower-performing groups. See Tables 7 and 8 for more details[7]. This finding suggests that higher-performing students, on average, sought help in the Q&A forum more than lower-performing students across all of the homework assignments.

Table 7. ANOVA results for online help-seeking in OHQ and Q&A between quartile groups.

		HW1	HW2	HW3	HW4	HW5	HW6	HW7	HW8
OHQ	F	2.96	3.13	0.09	1.4	0.48	2.64	4.69	0.54
	α	0.019	0.013	0.05	0.031	0.044	0.025	0.006	0.034
	p	0.03	0.03	0.96	0.24	0.62	0.05	**<0.001**	0.59
Q&A	F	7.12	6.84	10.16	10.1	4.96	11.93	5.89	7.57
	α	0.031	0.038	0.013	0.019	0.05	0.006	0.044	0.025
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.01**	**<0.001**	**<0.001**	**<0.001**

7 DISCUSSION

The landscape of help-seeking in most undergraduate courses has changed drastically compared to a decade ago when students mostly needed to seek help in face-to-face contexts. As help resources continue to populate online spaces, online

[7]Please note the alphas are sorted according to [4].

Table 8. Average OHQ and Q&A usage (in days) in quartile groups.

	Quartile group	HW1	HW2	HW3	HW4	HW5	HW6	HW7	HW8
Average OHQ Days	OH_Q1	0.96	1.12	1.24	0.67	0.78	1.28	1.09	0.74
	OH_Q2	0.89	1.13	1.30	0.79	0.78	1.06	1.72	0.74
	OH_Q3	0.63	1.38	1.34	0.46	0.84	0.97	1.30	0.84
	OH_Q4	0.57	0.82	1.28	0.58	0.92	0.70	0.91	0.65
Average Q&A Days	QA_Q1	2.95	3.46	3.39	3.32	3.00	4.09	3.40	2.40
	QA_Q2	2.57	2.55	3.09	3.06	3.00	3.77	4.26	2.40
	QA_Q3	2.32	2.81	2.47	2.57	2.31	3.46	3.51	2.33
	QA_Q4	1.63	2.10	1.91	1.77	2.25	2.32	2.66	1.45

help-seeking in resources may be occurring across multiple modalities. Most studies examining online help-seeking focus on a single context where help can be sought and typically miss information about students' online help-seeking in other modalities across help resources like computer-mediated conversations. Understanding how students seek help online and manage multiple modalities of online help resources to support their education is essential. It is especially important to study online help-seeking between multiple computer-mediated conversations for computer science domains which have arguably more online resources (e.g., computer-mediated conversations) than other domains [16]. By examining how students' seek help online between multiple modalities of computer-mediated conversations and assessing its relation to course grades, we gain deeper insight into how to best support students' education in OLEs at scale.

Our **first research question** examined online help-seeking behaviors in both OHQ and Q&A forums and assessed the extent to which help-seeking behaviors changed across homeworks. The results suggested that many students sought help in both the OHQ and Q&A forum and that the proportion of online help-seeking in both modalities of computer-mediated conversations across the homework assignments did not significantly vary over time. Further, it is probably not surprising that students sought a greater proportion of online help in the Q&A forum across the homeworks since they had access to help almost 24/7, whereas the OHQ computer-mediated conversation was only available at specific times, four days a week. Overall, our findings suggest the proportion of online help-seeking did not change across HWs 1-8 in both modalities.

The **second research question** assessed whether relationships existed between students' online help-seeking across multiple computer-mediated conversations, assignment difficulty, and prior knowledge. Our results suggested that there were no relationships between assignment difficulty and online help-seeking for either of the help-seeking modalities. This finding does not support previous studies that found significant correlations between assignment difficulty and the proportion of online help-seeking [16]. A possible explanation could be related to several key challenges of using final homework grades. First, the class average on all homeworks was in the A letter grade range, indicating little to no variation in grades (median=93) which would allow IRT to better distinguish difficult from easier homeworks. Low variation stemmed from students' ability to resubmit their code as often as they like to get immediate feedback on the errors in their code and submit a perfect assignment. The second challenge is that the homework grades missed information on the process of learning, or changes made to code upon multiple resubmissions, by only focusing on final homework grades. Process data may better reflect assignment difficulty as a result [32]. Future work should utilize process data with high variability which might shed more light on how assignment difficulty might impact online

help-seeking in multiple computer-mediated conversations. This is especially important in computer science domains, where students can recompile code as many times as they need to.

Next, we examined differences between prior knowledge groups and online help-seeking across computer-mediated conversations. We did not find significant differences between OHQ usage and prior knowledge groups. However, our results showed significant differences between prior knowledge groups and online help-seeking in the Q&A forum, where students with more prior knowledge, on average, used the Q&A forum more compared to students with less prior knowledge. These findings are consistent with a previous study that found prior knowledge impacted online help-seeking in a discussion forum [34]. A possible explanation for the lack of relationships between prior knowledge and online help-seeking in the OHQ computer-mediated conversation could be that the OHQ was not helpful to students regardless of their prior knowledge. The results suggest that the Q&A forum was where most students sought help across all the homeworks.

Finally, our **third research question** found significant differences in online help-seeking in the OHQ modalities between quartile groups (ranked by grades) for HW7. In general, higher-performing students sought help online in the OHQ computer-mediated conversation more than the lower-performing groups for HW7. We did not find significant differences in online help-seeking in OHQ between quartile groups for homeworks 1 to 6 and 8. Overall, our findings suggest that the OHQ may not have been as helpful to students across the homework assignments, with the exception of HW7. We suspect this finding may be related to the topic of HW7 which was on linked lists. Linked lists/references are challenging and were identified by CS educators as some of the most challenging topics to learn for novice programming students [6]. This finding is similar to other studies that found that sometimes online office hours were beneficial to performance [15] and another study that did not find any significant relations between online office hours and performance [13]. In contrast, there were significant differences in online help-seeking in the Q&A forum between the quartile groups across all of the homework assignments. In general, higher-performing students sought help online in the Q&A more than the lower-performing groups on all the homeworks. Overall, this finding is rather consistent with previous studies that found that more online help-seeking in Q&A forums was related to better course grades [7, 36, 38]. This study contradicts findings from [34] which found that less online help-seeking in Q&A forums was related to better grades [34].

7.1 Implications for Applied Learning Analytics

Overall, our study suggested that the degree of prior knowledge the student had about CS1 topics negatively affected their online seeking behaviors, but only in the Q&A discussion forum. Higher-performing students sought help more online in the Q&A forum compared to lower-performing students. While higher-performing students sought help more online in the OHQ, but only for HW7, compared to lower-performing students. Implication of these findings can be used for applying learning analytics in higher education classrooms, especially for online programs. For example, instructors who include multiple online resources for students to seek help offer more opportunities for instructors to support their students' needs by utilizing students' help-seeking data to assess which students are seeking help online. Second, by collecting data on if and how often students are using multiple online help-seeking resources over the course of the semester, while also accounting for each students' prior knowledge, instructors are better equipped to meet their students' needs and use evidence to inform their pedagogical practices. For example, the more often students seek help online, especially in discussion forums, could be used as an indicator that students are self-regulating their learning [14], and thus there is no need for a pedagogical intervention. However, if the student is not seeking

help online, and their prior knowledge assessment indicates they do not know CS1 topics, the instructor may need to intervene to support SRL behaviors.

7.2 Threats to Validity

To identify the extent to which the results of our study could be generalized, certain limitations need to be acknowledged. First, we only used grades when assessing the assignments' difficulty and students' performance. Given that students in the course had unlimited submissions with unlimited feedback, the grades were generally high. Using other data like the number of resubmissions could shed further light on which students had difficulty. Other limitations are the lack of qualitative data to better understand *why* students sought help when and how they did, and how they used the answers/information received. We also lack data that could help us explore how help-seeking behaviors may have differed across different demographic groups. We also acknowledge that the IRT model relies only on final grades to assign a difficulty value, and thus will fail to capture the difficulty in implementing a solution, especially in an environment where all the students tend to have very good grades (because of the unlimited submissions and immediate feedback). Furthermore, we did not collect data on when students used computer-mediated conversations beyond the Q&A forum and OHQ. For example, if students used an online search engine to seek help, we missed that information.

8 CONCLUSION AND FUTURE WORK

This study investigated online help-seeking behaviors of novice programming students across multiple computer-mediated conversations and assessed its relation to course grades. We found that more than 80% of students used the Q&A forum, whereas 46% of the students used OHQ across the homework assignments. We also found that students used OHQ more when working on assignments related to linked lists. Further, linked lists was the topic that generated the most traffic on the Q&A forum. Finally, our study revealed that online help-seeking occurring in OHQ and Q&A was associated with better grades on most homeworks.

Future studies might consider investigating other sources of data that holistically represent phases of help-seeking [28]. For example, what type of questions are students posting, and what answers (and from what sources of help, e.g., peer versus teacher), are received? To what extent do these factors vary by computer-mediated conversation and course grades? Another critical area of need for future research is to examine whether online help-seeking is different for under-represented minorities (URM) compared to more represented groups in programming and computer science. For example, examining whether differences in online help-seeking in multiple modalities occur between URM and non-URM in CS courses. URM in STEM often face stereotype threats [33], in addition to systemic oppression (e.g., racism, classism, and/or sexism), compared to non-URM students in CS education [35]. These experiences possibly (and plausibly) negatively affect URM students' self-efficacy, potentially heightening the cost of seeking help [19]. For instance, the student may avoid seeking help to avoid feelings of inadequacy. We must study the role of online help-seeking for diverse student populations especially in STEM domains so that we can best support all students' education in CS courses. Overall, by better understanding how and when diverse students seek help and its relation to grades, we can re-design computer-mediated conversational resources to better support students learning in introductory programming courses.

REFERENCES

[1] Vincent Aleven, Ido Roll, Bruce M McLaren, and Kenneth R Koedinger. 2016. Help helps, but only so much: Research on help seeking with intelligent tutoring systems. *International Journal of Artificial Intelligence in Education* 26, 1 (2016), 205–223.

[2] Roger Azevedo, Seth A Martin, Michelle Taub, Nicholas V Mudrick, Garrett C Millar, and Joseph F Grafsgaard. 2016. Are pedagogical agents' external regulation effective in fostering learning with intelligent tutoring systems?. In *International conference on intelligent tutoring systems*. Springer, 197–207.

[3] Brett A Becker. 2016. A new metric to quantify repeated compiler errors for novice programmers. In *Proceedings of the 2016 ACM Conference on Innovation and Technology in Computer Science Education*. 296–301.

[4] Yoav Benjamini and Yosef Hochberg. 1995. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal statistical society: series B (Methodological)* 57, 1 (1995), 289–300.

[5] Jens Bennedsen and Michael E Caspersen. 2019. Failure rates in introductory programming: 12 years later. *ACM inroads* 10, 2 (2019), 30–36.

[6] Peter Brusilovsky, Jonathan Grady, Michael Spring, and Chul-Hwan Lee. 2006. What Should Be Visualized? Faculty Perception of Priority Topics for Program Visualization. *SIGCSE Bull.* 38, 2 (jun 2006), 44–48. https://doi.org/10.1145/1138403.1138431

[7] Linda Corrin, Paula G De Barba, and Aneesha Bakharia. 2017. Using learning analytics to explore help-seeking learner profiles in MOOCs. In *Proceedings of the seventh international learning analytics & knowledge conference*. 424–428.

[8] Scott Crossley, Mihai Dascalu, Danielle S McNamara, Ryan Baker, and Stefan Trausan-Matu. 2017. Predicting success in massive open online courses (MOOCs) using cohesion network analysis. Philadelphia, PA: International Society of the Learning Sciences.

[9] Scott A Crossley, Shamya Karumbaiah, Jaclyn Ocumpaugh, Matthew J Labrum, and Ryan S Baker. 2020. Predicting math identity through language and click-stream patterns in a blended learning mathematics program for elementary students. *Journal of Learning Analytics* 7, 1 (2020), 19–37.

[10] Christo Dichev and Darina Dicheva. 2012. Open educational resources in computer science teaching. In *Proceedings of the 43rd ACM technical symposium on Computer Science Education*. 619–624.

[11] Stella Fayer, Alan Lacey, and Audrey Watson. 2017. STEM occupations: Past, present, and future. *Spotlight on Statistics* 1 (2017), 1–35.

[12] Zhikai Gao, Sarah Heckman, and Collin Lynch. 2022. Who Uses Office Hours? A Comparison of In-Person and Virtual Office Hours Utilization. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1* (Providence, RI, USA) *(SIGCSE 2022)*. Association for Computing Machinery, New York, NY, USA, 300–306. https://doi.org/10.1145/3478431.3499334

[13] Zhikai Gao, Collin Lynch, Sarah Heckman, and Tiffany Barnes. 2021. Automatically Classifying Student Help Requests: A Multi-Year Analysis. *International Educational Data Mining Society* (2021).

[14] Rita Garcia, Katrina Falkner, and Rebecca Vivian. 2018. Systematic literature review: Self-Regulated Learning strategies using e-learning tools for Computer Science. *Computers & Education* 123 (2018), 150–163.

[15] Braxton Hall, Noa Heyl, Elisa Baniassad, Meghan Allen, and Reid Holmes. 2021. The Efficacy of Online Office Hours: An Experience Report. In *Proceedings of the 2021 ACM SIGPLAN International Symposium on SPLASH-E* (Chicago, IL, USA) *(SPLASH-E 2021)*. Association for Computing Machinery, New York, NY, USA, 59–64. https://doi.org/10.1145/3484272.3484966

[16] Qiang Hao, Ewan Wright, Brad Barnes, and Robert Maribe Branch. 2016. What are the most important predictors of computer science students' online help-seeking behaviors? *Computers in Human Behavior* 62 (2016), 467–474. https://doi.org/10.1016/j.chb.2016.04.016

[17] Matthew C Jadud and Brian Dorn. 2015. Aggregate compilation behavior: Findings and implications from 27,698 users. In *Proceedings of the eleventh annual international conference on international computing education research*. 131–139.

[18] Katy Jordan. 2014. Initial trends in enrolment and completion of massive open online courses. *International Review of Research in Open and Distributed Learning* 15, 1 (2014), 133–160.

[19] Djordje M Kadijevich, Charoula Angeli, and Carsten Schulte. 2013. *Improving computer science education*. Routledge.

[20] Stuart A Karabenick and Jean-Louis Berger. 2013. Help seeking as a self-regulated learning strategy. (2013).

[21] Stuart A Karabenick and Myron H Dembo. 2011. Understanding and facilitating self-regulated help seeking. *New directions for teaching and learning* 2011, 126 (2011), 33–43.

[22] Stuart A Karabenick and Eleftheria N Gonida. 2017. Academic help seeking as a self-regulated learning strategy: Current issues, future directions. In *Handbook of self-regulation of learning and performance*, J. A. Greene D. Schunk (Ed.). Routledge, 421–433.

[23] Stuart A Karabenick and Richard S Newman. 2009. Seeking help: Generalizable self-regulatory process and social-cultural barometer. (2009).

[24] Michael J Lee and Amy J Ko. 2015. Comparing the effectiveness of online learning approaches on CS1 learning outcomes. In *Proceedings of the eleventh annual international conference on international computing education research*. 237–246.

[25] Samiha Marwan, Anay Dombe, and Thomas W Price. 2020. Unproductive help-seeking in programming: What it is and how to address it. In *Proceedings of the 2020 ACM Conference on Innovation and Technology in Computer Science Education*. 54–60.

[26] Quinn McNemar. 1947. Note on the sampling error of the difference between correlated proportions or percentages. *Psychometrika* 12, 2 (1947), 153–157.

[27] Arie Nadler and D Jeffrey. 1986. The role of threat to self-esteem and perceived control in recipient reaction to help: Theory development and empirical validation. In *Advances in experimental social psychology*. Vol. 19. Elsevier, 81–122.

[28] Sharon Nelson-Le Gall. 1981. Help-seeking: An understudied problem-solving skill in children. *Developmental review* 1, 3 (1981), 224–246.

[29] Dimitris Rizopoulos. 2007. ltm: An R package for latent variable modeling and item response analysis. *Journal of statistical software* 17 (2007), 1–25.

[30] Ido Roll, Vincent Aleven, Bruce M McLaren, and Kenneth R Koedinger. 2011. Metacognitive practice makes perfect: Improving students' self-assessment skills with an intelligent tutoring system. In *International conference on artificial intelligence in education*. Springer, 288–295.

[31] Ido Roll, Ryan SJ d Baker, Vincent Aleven, and Kenneth R Koedinger. 2014. On the benefits of seeking (and avoiding) help in online problem-solving environments. *Journal of the Learning Sciences* 23, 4 (2014), 537–560.

[32] José A Ruipérez-Valient, Yoon Jeon Kim, Ryan S Baker, Pedro A Martínez, and Grace C Lin. 2022. The Affordances of Multivariate Elo-based Learner Modeling in Game-based Assessment. *IEEE Transactions on Learning Technologies* (2022).

[33] Jenessa R Shapiro and Amy M Williams. 2012. The role of stereotype threats in undermining girls' and women's performance and interest in STEM fields. *Sex roles* 66, 3 (2012), 175–183.

[34] David H Smith IV, Qiang Hao, Vanessa Dennen, Michail Tsikerdekis, Bradly Barnes, Lilu Martin, and Nathan Tresham. 2020. Towards Understanding Online Question & Answer Interactions and their effects on student performance in large-scale STEM classes. *International Journal of Educational Technology in Higher Education* 17, 1 (2020), 20. https://doi.org/10.1186/s41239-020-00200-7

[35] Dustin B Thoman, Jessi L Smith, Elizabeth R Brown, Justin Chase, and Joo Young K Lee. 2013. Beyond performance: A motivational experiences model of stereotype threat. *Educational psychology review* 25, 2 (2013), 211–243.

[36] Shu-Fen Tseng, Yen-Wei Tsao, Liang-Chih Yu, Chien-Lung Chan, and K Robert Lai. 2016. Who will pass? Analyzing learner behaviors in MOOCs. *Research and practice in technology enhanced learning* 11, 1 (2016), 1–11.

[37] Kurt VanLehn. 2011. The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational psychologist* 46, 4 (2011), 197–221.

[38] Mickey Vellukunnel, Philip Buffum, Kristy Elizabeth Boyer, Jeffrey Forbes, Sarah Heckman, and Ketan Mayer-Patel. 2017. Deconstructing the Discussion Forum: Student Questions and Computer Science Learning. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education* (Seattle, Washington, USA) *(SIGCSE '17)*. Association for Computing Machinery, New York, NY, USA, 603–608. https://doi.org/10.1145/3017680.3017745

[39] Philip H Winne and Allyson F Hadwin. 2008. The weave of motivation and self-regulated learning. In *Motivation and self-regulated learning*, D. Schunk B. Zimmerman (Ed.). Routledge, 297–314.

[40] Jiayi Zhang, Taylor Cunningham, Rashmi Iyer, Ryan Baker, and Eric Fouh. 2022. Exploring the Impact of Voluntary Practice and Procrastination in an Introductory Programming Course. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1.* 356–361.