Students and Teachers Use An Online AP CS Principles EBook Differently

Teacher Behavior Consistent with Expert Learners

Miranda C. Parker
Georgia Institute of Technology
85 5th St NW
Atlanta, Georgia 30332
miranda.parker@gatech.edu

Kantwon Rogers
Georgia Institute of Technology
85 5th St NW
Atlanta, Georgia 30332
KantwonRogers@gatech.edu

Barbara J. Ericson
Georgia Institute of Technology
801 Atlantic Drive
Atlanta, Georgia 30332
ericson@cc.gatech.edu

Mark Guzdial
Georgia Institute of Technology
85 5th St NW
Atlanta, Georgia 30332
guzdial@cc.gatech.edu

ABSTRACT

Online education is an important tool for supporting the growing number of teachers and students in computer science. We created two eBooks containing interactive content for Advanced Placement Computer Science Principles, one targeted at teachers and one at students. By comparing the eBook usage patterns of these populations, including activity usage counts, transitions between activities, and pathways through the eBook, we develop a characterization of how student use of the eBook differs from teacher use. We offer design recommendations for how eBooks might be developed to target each of our populations. We ground our recommendations in a theory of teachers as expert learners who possess a greater ability to regulate their own learning process.

CCS CONCEPTS

•**Applied computing** → **E-learning;** *Interactive learning environments;*

KEYWORDS

eBook; CS Principles; log file analysis; expert learner

1 INTRODUCTION

Efforts to give every child an opportunity to learn computer science (CS) can not succeed without trained teachers. In response to this need, initiatives such as CS10K and Computing at School or communities like CS for All Teachers work to increase the number of teachers committed and equipped to teach CS. Additionally, greater understanding of how teachers learn CS is critical for growing the number of CS teachers, as this improved understanding may lead to developing learning opportunities that are catered to teacher learning styles. Through all of this, we recognize that there are time limitations for teacher availability. If we are going to provide professional development opportunities to all teachers, our primary challenge is to provide learning opportunities to in-service teachers so they can learn CS in their available time [1]. One strategy is to provide ebooks to teachers. Books are familiar to teachers and teachers can pace their way through books. EBooks can use interactive content to enhance learning and make it more efficient. As part of this strategy, we built an in-browser eBook for teachers learning how to teach the new Advanced Placement course: Computer Science Principles (AP CSP, or CS Principles) [9].

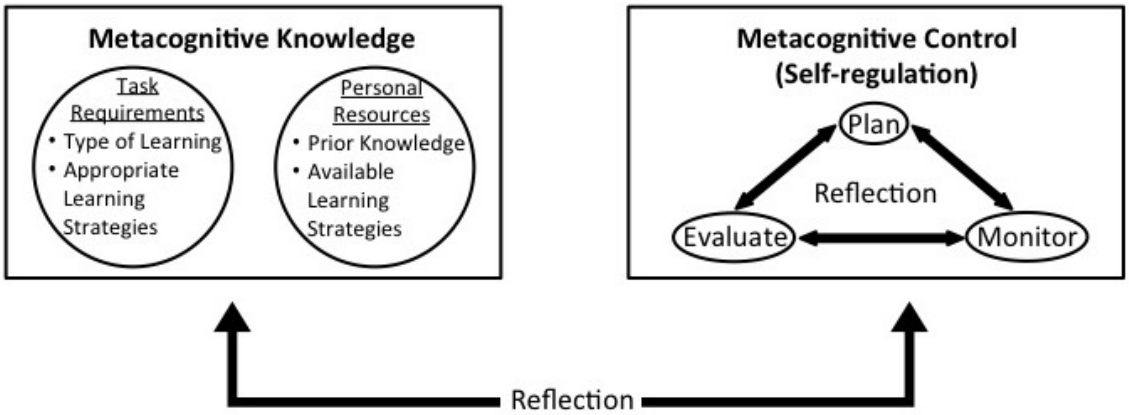
Our eBook for teachers learning AP CSP was designed using educational psychology principles and design-based research [9, 10]. Our approach is focused on providing worked examples interleaved with practice problems. Interactive elements in the eBook include multiple choice problems, fill in the blank questions, audio, videos, editable and executable code widgets, step-by-step code visualizations, and Parsons problems. It is different from a MOOC and strives to promote more learning and engagement than most MOOCS which are usually centered on video lectures and passive learning [9]. Our eBook is designed for teachers. It contains sections describing pedagogical content knowledge, which is how to teach computer science concepts and misconceptions, near relevant sections of content. We aim to provide the knowledge that CS teachers need, in an efficient and effective manner. We previously reported on a pilot study of teachers using the eBook and a larger study, including insights as to how the teachers were using this resource [7, 8, 10].

As part of building the number of teachers in K-12 CS, we wanted to ensure teachers had companion material to their eBook for their students to use. Several teachers from previous studies used their teacher eBook with their high school students during the pilot AP CSP class and intended to use it again the following year. In response to these needs, we developed and released a student version of the eBook that parallels the teacher version. The two eBooks have the same content, but the student version removes end-of-chapter exam answers and pedagogical content knowledge notes.

ICER '17, August 18-20, 2017, Tacoma, WA, USA

DOI: http://dx.doi.org/10.1145/3105726.3106189

Figure 1: Qualities of a expert learner from Ertmer & Newby



This process is similar to how teacher-student companion textbooks or study books are made. We hypothesized that the students and teachers would use the eBooks differently based on their goals and motivations to learn. We proposed a set of research questions to compare teachers and students using similar eBooks: *How does teacher use of the eBooks differ from student use? In what ways do they learn from the eBook differently?*

We answer these questions quantitatively with log file data from use of the student and teacher eBooks. This usage data focuses on use per activity type, attempts per problem, and progression through the book (both in terms of pages and time). Our data analysis is contextualized by interviews with teachers who use the eBooks. We use a theory of expert learners to frame our analysis and describe CS teachers' behavior using the eBook. This lens leads us to present design guidelines for teacher-student companion eBooks.

In the rest of this paper, we discuss background research on expert learners, detail our data collection and analysis, and present and discuss our findings and their implications for teacher and student eBook design in a computing context.

2 EXPERT LEARNERS

We viewed the teacher usage data through an expert learner lens [2–4, 6, 11, 18]. Expert learners are learners metacognitively aware of their process of learning. As Ertmer and Newby describes, they are strategic, self-regulated, and reflective [11]. We refer to less-expert learners (learners who are less strategic, self-regulated, and/or reflective) as novice learners in this paper. It is important to note that the difference between expert and novice learners is not just a quantitative difference in the content knowledge each has, but also a qualitative difference in strategies and approaches [11]. As Figure 1 describes, expert learners are defined by metacognitive knowledge and control. Metacognitive knowledge refers to not merely the learner's prior content knowledge, but their knowledge of learning strategies and how and when to apply them. Metacognitive control refers to the learner's ability to self-regulate through a cycle of planning, monitoring, and evaluating, all guided by the use of reflection throughout the process.

Within metacognitive knowledge, expert and novice learners apply a wide range of learning strategies. Zimmerman and Pons outline 15 strategies, including organizing, keeping records, environment setting, memorizing, and reviewing records [19]. In the context of the eBooks, learning strategies refer to the different activity types and the pattern in which they are used. The activities fall into categories of expository, worked examples, and practice problems. Patterns of activity use includes what activities are used the most, transition between activity types, and jumps between different parts of the eBook.

Metacognitive control includes reflection on plans, monitor, and evaluation of learning. Schraw presents a regulatory checklist within these three categories, which we summarize here [16]. Planning is when the learner cognates on the nature of the task at hand and their goal in learning the task. An expert learner also exhibits planning when they consider the time and resources they need to reach their goal. Expert learners monitor their learning by reflecting on their understanding of what they are doing and how it does or does not agree with their plan. Monitoring can also include asking if changes should be made to their plan or to their current actions. Finally, evaluating learning involves checking if the learner has reached their goal. An expert learner may ask themselves what worked, didn't work, and what they would do differently if they did it again.

When looking for explanations for the differences between teacher and student behavior, we found it productive to *explain teacher behavior in terms of expert learner behavior, and explain student behavior in terms of novice learner behavior.* We found that teachers usage behaviors mapped well to expert learning strategies described in research literature. Characterizing teacher and students in this way leads to design recommendations for intentional eBook designs that target each audience.

It is important to make a distinction between expert learner and expert teacher [17]. In our case, the teachers are learners and so we are discussing their expertise on learning, not their expertise on teaching.

3 METHODOLOGY

We performed a log file analysis on unique user profiles from 445 teachers and 516 students in the teacher and student eBooks respectively. Teachers and students were recruited to use the eBook through word-of-mouth. We advertised the eBook through email lists, blogs, workshops, and at conferences. When we released the student version, we encouraged the teachers to use the student version in their classes. According to IP addresses recorded in our system, the participants primarily came from the United States, but other countries from across the globe were also present in our user set.

We first looked at measures of use, like time spent on activities and number of times an activity was used. The differences in use led us to explore theoretical explanations. We came upon the expert learner hypothesis, defined hypotheses about strategies that experts might use in the ebook, and then did more log file analyses in order to test our hypotheses.

We ran Wilcoxon-Mann-Whitney tests on activity usage data to determine statistically significant difference in activity use among students and teachers. We grouped activities by the interaction types we included in the design of the eBooks: expository, worked examples, and practice. The activities were sorted accordingly:

- Expository
  - Text
  - Video
- Worked Examples
  - Code visualization
  - Audio
  - Code editing and running
- Practice
  - Multiple choice
  - Fill in the blank
  - Parsons Problem

This grouping based on interactivity allowed for clearer perception of differences in use of interactive elements.

We used Markov chain analysis on the log files to help illuminate patterns in students and teachers use of the eBooks [12]. Markov analysis refers to transition between states. In our analysis, we calculate the probability of a user transitioning from one activity to another. This probability analysis allowed for comparison in behavior in using the eBook features between students and teachers. These lead to further analysis based on perceived differences among the probabilities of transitions. For example, the difference in probabilities of a teacher transitioning from running active code to editing active code, and vice versa, compared to a student's transitioning between those activities leads to a deeper analysis in use of the active code function.

To further characterize the user behaviors, we generated progression charts based on each users activities. For each user, we created a graphic to represent each activity they did in each chapter, what kind of activity, and at what time relative to when they started to use the eBook. These charts helped us identify and categorize user use of the eBook on an individual- and large-scale. After generating progression charts for all students and teachers, we eliminated progression charts that had fewer than three days of activity and less than five chapters with activities. Two researchers rated users in categories based on patterns of use visible in the charts. There were five categories for students and teachers, totaling ten categories. These categories included whether a user repeated whole sections of the book, went back and reviewed sections, skipped chapters, completed chapters in large amounts in short times (binged), and if they skimmed chapters by doing some but not all activities within. We computed inter-rater reliability on our ratings in each category using a quadratic weighted Cohen's kappa. The kappa value was greater than 0.8 for eight out of ten of the categories, and the remaining two were in the 0.61 to 0.8 range. After confirming reliability of our ratings, we calculated the average of each category for students and teachers and compared them between the two groups. We selected two progression charts from each group (students and teachers) seen in Figure 2 to provide specific cases of what the differences looked like on an individual level. We acknowledge these charts are not representative samples of each group, but rather serve as a case study of use.

We contextualize our findings through interviews we did with two teachers who use the eBook. These two teachers were interviewed because they were using the student eBook in their classes, not because they learned from the teacher eBook. Thus, their comments help us understand student eBook behavior, e.g., we have greater insight into what the students were being required to do with the eBook. They are not representative of teachers learning computer science with the eBook. We identified teachers to interview based on their students' eBook activities and emailed those teachers with requests for interviews. Both of the teachers we interviewed had prior experience teaching computer science (10+ years).

It is important to note that in this analysis we are not controlling to prior exposure to computer science or computing experience. The differences that we describe between the teachers and students may be due to a difference in their knowledge of the subject area. Since our analysis based on log files, we cannot presume intentionality. However, we expect that teachers or students with significant prior content knowledge would be unlikely to interact with the eBook to the extent that we see in our analyses. Teachers or students with significant prior content knowledge may be using our eBook less, or not at all. In any case, we do not have data on prior computing experience and cannot control for it in these analyses.

4 FINDINGS

We first establish that teachers and students do use the eBooks differently by statisically analyzing their interactions with the eBooks. We then present hypotheses of what an expert learner using the eBook would do, and what their use would look like in our data. We tested these hypotheses and present support for our teacher as expert learner hypothesis.

4.1 Differences in Usage Patterns

We gathered data from the log file analysis and processed it by counting the number of interactions within each activity type. For example, if a user ran the same code segment five times, that would count as five interactions with a code segment. We ran a Wilcoxon rank sum test to determine if there were differences in activity

Table 1: Wilcoxon Rank Sum Test on Activities by Interaction Type

Type	W	Sig.	Mean S	Mean T
Expository	254,934	0.000*	87.83	22.83
Worked Examples	249,124	0.000*	188.90	44.10
Practice	260,664	0.000*	153.87	20.30

levels, grouped by interaction types, between the students and teachers, as seen in Table 1.

For all interaction types, activity level was significantly higher for students rather than teachers. That is to say, students did more expository, worked example, and practice activities, on average. This supports the general claim that the students and teachers used their eBooks differently. This finding initiated our further analysis into *how* the students and teachers used the eBooks differently.

In addition to this, our initial analysis of the Markov chain data indicated distinct difference in behaviors. The transition probabilities are shown in part in Tables 2 and 3. From the tables, we know that teachers are more likely to run and then edit a code segment, or sequentially edit it, than students were. We also know that students are more likely to run a code segment and then immediately run it again. This is discussed in more detail in Section 4.3.

Progression charts (which are described in detail in Section 3) support our argument that teachers and students use the eBooks differently. We rigorously defined this difference by rating each valid chart in five categories: review, repeat, skim, skip, and binge. We performed inter-rater reliability using Cohen's kappa on each of the five categories for students and teachers. We found that on average, teachers binged their use of the eBook more than students, which is to say they completed more activities in one sitting on average. Additionally, students skimmed more than teachers, implying teachers did more activities in each chapter where students would only do some activities.

These points were in agreement with what we found during our interviews with teachers. Teachers noted they would look at the teacher eBook to see what was in it and how it might fit with their curriculum. They described "spot checking" the eBook and doing some activities throughout the chapters to see what was there. Meanwhile, the teachers would assign sections or problems from the student eBook for their students to complete. These teachers would use their eBook in one manner, and ask the students to use their eBook a different way.

4.2 Expert Learner Hypothesis

When thinking of teachers using this book as expert learners and students as novice learners, we developed hypotheses of what an expert learner would do with our eBook. We then compared with our findings, discussed in Section 4.3. As discussed in Section 2, we expect expert learners to demonstrate aspects of metacognitive control and knowledge.

4.2.1 Metacognitive knowledge: Available and appropriate learning strategies. Within metacognitive knowledge, we hypothesize expert learners using the eBook would recognize the different learning strategies (i.e., the ebook activities) available to them, as well as how to best make use of those strategies. For example, we would expect an expert learner to try every activity type. Additionally, we would expect expert learner users to use the different activity types at different times to best make use of them.

4.2.2 Metacognitive control: Plan, monitor, and evaluate. Metacognitive control is the learner making choices about how they learn and what they do to learn. We would expect to see expert learners planning their learning, monitoring their understanding, and evaluating their learning.

An expert learner plans learning activities so that she learns. For example, an expert learner spaces learning activities rather than crams. Planning also involves setting their goal (learning AP CS Principles), taking sequential steps towards their goal (reading/doing one chapter at a time), and identifying any obstacles to achieving their goal (not understanding portions of the curriculum). They recognize the task demands, their personal resources (namely, time), and use their resources efficiently to meet demands. Given the nature of quantitative data as opposed to the internal nature of planning, we are only able to make shallow claims on whether the teachers are planning, and no claims on how they might be planning. This can only be rigorously addressed through detailed interviews with teachers and students that include questions specifically asking about their planning process.

Additionally, expert learners monitor their learning, which involves looking at their plan and decided how to take the next step. In the context of the eBook, this would involve going back to review a concept when the user reads a chapter that builds on that chapter.

Evaluating learning involves assessing the way the expert learner is learning and whether or not they are meeting their goals. We hypothesize an expert learner using the eBook would go back periodically to test their understanding and making changes to their learning strategies if their previous plan had not met their goals.

4.3 Hypothesis Testing

We tested our expert learner hypothesis and present our findings here. We break our findings down into metacognitive knowledge and metacognitive control, with further distinctions as previously discussed in Section 2. Expert learners are characterized by metacognitive knowledge, which is their knowledge of what learning strategies are available to them and how to apply those strategies. They can also be characterized by their metacognitive control, or their ability to cyclically monitor, plan, and evaluate their learning through constant reflection. We present supports for each of these parts in turn.

4.3.1 Available Learning Strategies. We know that students did significantly more activities from Table 1, but that only shows counts of each individual activity. After reviewing the progression charts, we noted that students may be doing *more* in the eBook in terms of activity use, but teachers were spreading their activity across different activity types. We provide charts to illustrate these claims.

Figure 2 shows two teachers' progression charts on the top row, and two student progression charts on the bottom row. The charts

Table 2: Probabilities of transition between and among activities in the student eBook

	Code Edit	Code Run
Code Edit	0.171	0.755
Code Run	0.222	0.475

Table 3: Probabilities of transition between and among activities in the teacher eBook

	Code Edit	Code Run
Code Edit	0.249	0.707
Code Run	0.322	0.407

contain colored dots in reference to the activities each user completed on an individualized time line. The X-axis is divided by chapters, and contains all activities across all chapters. The Y-axis is the time, in days, since the user started using the eBook to their last activity. Through these charts we can see how a user navigated through the eBook, what activities they focused on, and what their pacing through the eBook was.

The teacher progression charts have four distinct colors, identifying four distinct activity types that teachers primarily participated in (code runs and edits, Parsons, and multiple choice). For students, the bottom of Figure 2 paints a different picture. These charts are dominated by two colors, and thus indicate two different activity types that students focused on (code run and multiple choice). We can see the difference in usage between students and teachers, as teachers made use of more activities while learning CSP in the eBook. This observation is consistent with a claim of greater metacognitive knowledge as more use of different activity types indicates awareness of the different learning strategies available to the user.

4.3.2 Appropriate Learning Strategies. Teachers used the learning activities differently than the students (see Tables 2 and 3). Specifically analyzing the code edits and code runs, we can see in Table 2 that students are more likely to run a code segment and then immediately run it again (0.475 compared to 0.407). However, Table 3 shows that teachers are more likely to run and then edit a code segment, or edit and then edit it again (0.322 compared to 0.222, or 0.249 compared to 0.171). This pattern suggests teachers are exploring code, using the code editing and running area as a learning activity. Simply repeatedly running the code is unlikely to lead to any learning insights for the students. They are simply re-running the same, unedited code. We do not see evidence that the students are developing hypotheses about their code, then editing the code and re-running to test the hypotheses.

4.3.3 Plan: Not evident in quantitative data. We do not have evidence to make a claim that teachers, as expert learners, were planning their use of the eBook. We can begin to make an argument for teachers using spaced practice, an expert learner approach. A progression chart in Figure 2 supports a claim that teachers space their use of the eBook. This user sequentially uses the eBook, jumping back occasionally to re-visit previously completed activities. The user also spends three days (Day 18-20) repeating the same set of activities before continuing to the next chapter. These two aspects of the user's behavior in the eBook demonstrate a spaced practice approach to their learning. We do not know if that is a planned, intentional process, or simply when the teacher had time to use the eBook.

However, spaced practice is not unique to the teacher progression charts. The student progression charts also show a nice pacing of the eBook–one chapter at a time and spaced in time. However, we hypothesize this is more due to the course structure and teacher directions than the student's choice, considering this general pattern is seen across nearly all student users. This is in agreement with our interviews, where we found that teachers were assigning problems and chapters to their students on a weekly basis.

We need significant qualitative data before we can claim that teachers plan their learning when using the eBook. Interview or survey data could reveal whether or not teachers are goal-setting, identifying obstacles, recognizing task demands, or considering personal resources.

4.3.4 Monitor: Retrieval practices in progression charts. In comparing the student and teacher progression charts in Figure 2, we can construct an understanding of the way teachers monitor their learning. We found in our analysis of the progression charts that students repeated more than teachers. Students would more often repeat nearly all problems in a given chapter previously completed on another day. Teachers did this some, but on average less than the students. The progression charts discussed here display these characteristics. In both teacher progression charts, there are jumps back to previously visited sections of the eBook. These jumps are typically followed by a few activities, and then the users go back to where they were in the book before. The student progression charts also include jump-backs, but student jump-backs precede heavy activity use. Students are completely repeating all activities in a certain section, where teachers will choose a handful of activities. These actions demonstrate a difference in how the users are monitoring learning. Teachers may recognize when they do not understand or remember something, re-visit a problem to retrieve their prior knowledge on the topic, and then return to their place in the book. However, students may recognize when they do not understand a previously covered topic, but they fully repeat the entire chapter that contains the topic, thereby completing a less-effective method of reviewing through repeated activity use. An alternative explanation for the usage data is that teachers may be assigning students to review chapters so the students' behavior may not be indicative of their self-regulation.

4.3.5 Evaluate: Knowing when to quit on Parsons problems. Teachers evaluate their learning, which is shown through their behaviors with Parsons problems. Figures 3 and 4 show the number of times students and teachers attempted Parsons problems before getting it correct or giving up, i.e. they never submit the correct solution. The graphs can be read as the number of users that gave X number of attempts on Parsons problems, and then either answered correctly or gave up. It is clear from these graphs that teachers make less attempts before getting it correct and before giving up. Students,

Figure 2: Progression charts through the eBook for teachers (top row) and students (bottom row)

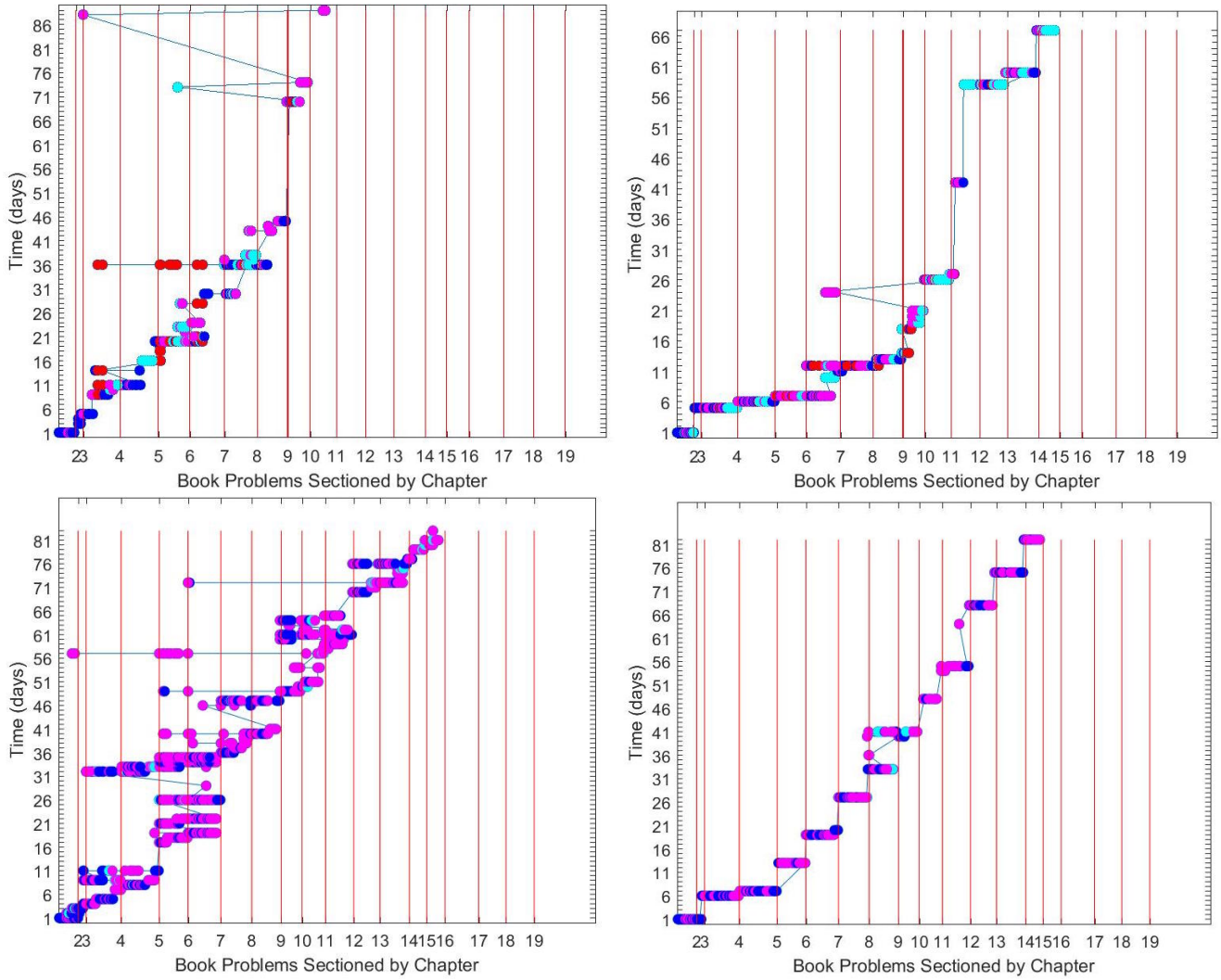


Figure 3: Teacher (left) vs. Student (right) On Number of Users Per Number of Attempts on All Parsons Problems Eventually Answered Correctly

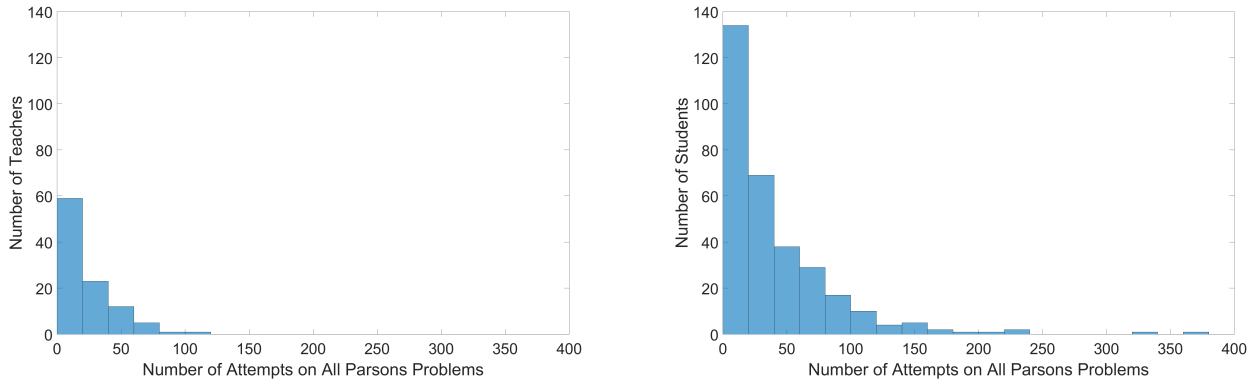
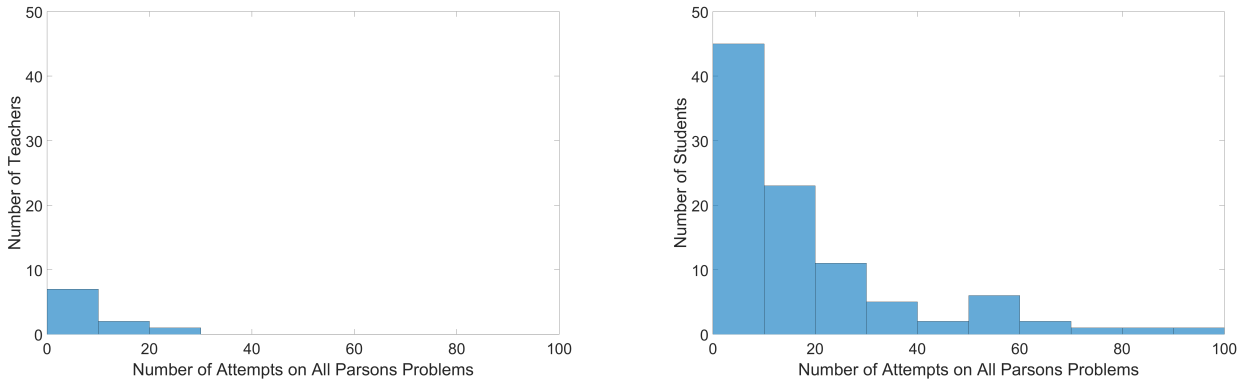


Figure 4: Teacher (left) vs. Student (right) On Number of Users Per Number of Attempts on All Parsons Problems Quit On



however, tend to try more times before reaching a correct answer or giving up. After further analysis, we discovered that students would even attempt a Parsons problem more times than there were permutations of answers. That is to say, students repeated distinct attempts multiple times, and occasionally still did not get the problem correct. This agrees with existing research on students getting stuck on Parsons problems and repeating the same incorrect permutation [13]. We hypothesize this pattern demonstrates that teachers were able to be cognizant of their attempts on the problem, and recognize when they were stuck. On the other hand, students tended to "flail" and try more attempts than possible, without evaluating their learning strategy.

5 DESIGN RECOMMENDATIONS

As demonstrated, students and teachers are different and need differentiated designs for eBooks. We know that having a design that is more beneficial for novices can be ineffective for expert learners through expertise reversal effect [14]. We present here design recommendations that are derived from explaining teachers' use as expert learners and students' use as novice learners.

We cannot design simply based on usage data. From this data, we can't know if users were frustrated and needed more support, or did exactly what they wanted to do. However, we can design based on our hypotheses about teachers attempting to use expert learner strategies and students using novice learner strategies. Our design recommendations aim to make the teachers more efficient as expert learners, and to help students develop better learning strategies.

5.1 Teacher eBook Recommendations

Our design recommendations for the teacher version of the eBook are presented in Table 4.2. Based on the aspects of expert learning presented previously, we developed recommendations on how to promote or enhance the presence of expert learner behaviors.

Teachers used multiple activity types. However, not all activity types that were available were used much, and some were rarely used. In case the issue is lack of awareness of the different features of the eBook, we could introduce all types of activities before the content of the book or in the context of the book, e.g. with tutorials throughout the introductory chapters.

We believe teachers monitor their learning through retrieval practices. Teachers tended to jump back to skim previously covered content. This practice could be aided by adding links to allow for quicker navigation between main topics.

Teachers' use of Parsons problems suggests that they might have been evaluating their learning and deciding what might be useful (and what might not be). Design recommendations regarding evaluation involve creating more assessments to gauge understanding. Alternatively, an adaptive assessment could be made that the user could navigate to at any time and would test their understanding of all topics the user had already covered.

We could not make a claim as to how teachers plan their learning. Further detailed interviews would better inform our understanding of this aspect of the teachers' expert learning. Until then, we refrain from making design recommendations based on this aspect of the expert learner hypothesis.

5.2 Student eBook Recommendations

We hypothesize that students are novice learners. As such, our design recommendations for the student eBook are different from the recommendations for the teacher eBook.

Students could be prompted to monitor their learning through guided or adaptive problems. Adaptive Parsons or code problems would prompt the students if an ineffective method was used, such as runs without any edits, or if there was a repeated run from a prior attempt. A guided problem would identify when a student tried more than half the possible solutions or submissions to a problem and prompt the student to move along or ask for help.

Evaluation of understanding and learning could take the form of unlocking chapters. Chapters could be presented as objects that are locked. The locked chapters could only be unlocked when the user demonstrates knowledge and understanding of the topics covered prior to that chapter.

Students could be encouraged to plan their learning through promoting spaced practice. This could take the form of incentivizing students to log in everyday to keep their "streak" of activity. Alternatively, we could schedule the system to send email or text reminders to students to log in to learn and practice their skills.

Table 4: Current Expert Learner Behavior and Teacher eBook Design Recommendations

Expert Learner Behavior	Current eBook Use	Evidence	Design Recommendation
Available Learning Strategies	Multiple activity types used	Figure 2	Make all learning strategies that are available clear
Appropriate Learning Strategies	Run and edit code rather than run and then run again	Tables 2, 3	None; "appropriate" may differ based on learning goals
Monitor	Retrieval practices	Figure 2	Quicker navigation between main topics and keywords through hyperlinks at each mention to its initial description
Evaluate	Know when to quit on Parsons problems	Figures 3, 4	Create more benchmarks for assessing understanding, or an adaptive benchmark that can be visited at any point in the book
Plan	Not present	Not present	None available

We are making recommendations that our hypotheses and evidence support, and as such do not have a recommendation as to whether to promote expert learning techniques within the student version of the eBook. Alternatively, there could be more added to the teacher book on how to teach expert learning skills [5]. There is a careful balancing act of how much scaffolding to put in the student eBook. If too much scaffolding is put in, it could get in the students' way or interfere with learning [15]. However, if too little scaffolding is added then you are presuming the user is an expert learner with metacognitive skills to guide them through the eBook.

6 CONCLUSIONS

Students interacted more with the eBook than teachers, on average. However, more interaction does not mean more learning. Rather, it might indicate more flailing, and less effective and efficient learning. We believe the interactions students had with the eBook are characteristic of a novice learner, unaware of how to best learn. This can be seen by their flailing tactics, massed practice, and erratic progression through the book. On the other hand, teachers interacted with the activities in the eBook statistically significantly less. We argue that the interactions they did have promote greater learning. They tended to space their practice, know when to quit, and go through the eBook in a reasonable manner.

We set out to discover how teachers use the eBooks differently than students, and in what ways they might learn differently. We used an expert learner lens to help understand those differences, which is how we frame this discussion. In establishing that students and teachers use the eBook differently, we used statistically significant results on activity use which showed students did more activities across expository, worked examples, and practice activities. It would be easy to look at those numbers and claim that students learned more, were more motivated to learn, or more engaged in their learning, because they did more. However, we hypothesize that students did more activities in ways that did not apply appropriate learning strategies. While teachers did fewer activities, they seemed to do activities using learning strategies and monitored those strategies to check on what was best for them.

Because we are using log files, we do not know the users' contexts of use. We cannot distinguish between different uses of the ebook, such as a teacher preparing lesson content versus learning concepts for herself, or a student studying for a test versus completing a homework assignment. Different contexts would likely lead to different patterns of use, e.g., a teacher would be expected to do fewer practice exercises when preparing a lesson, but more when learning for herself. We cannot make claims about how contexts drive use. However, we can claim that the patterns we see do cross contexts. We look at the behavior of each subgroup in the aggregate, regardless of any individual's goals in any particular situation of use. Future research should explore how teachers and students use ebooks differently in different contexts. What we offer here is an initial description, to provide guidance for developers aiming to support computing teachers or computing students. Our finding is that students and teachers use ebooks differently, whatever their contexts, and that should inform design. We believe these findings contribute to the emerging understanding and design of computing education through eBooks.

The difference in learner profiles between students and teachers suggest a need for eBook designs that cater to each learner. With teachers as expert learners, more activities could be provided that provide more benchmarks, connection between topics, and activity tutorials. Students as novice learners need more scaffolding in activities such as through guided or adaptive Parsons problems. The design could also encourage some form of spaced practice with review problems that connect to previous topics learned, perhaps at the beginning of a chapter.

ACKNOWLEDGMENTS

The work is supported by the National Science Foundation under Grant No.: 1432300 and the National Science Foundation Graduate Research Fellowshipnder Grant No. DGC-1148903. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

[1] Klara Benda, Amy Bruckman, and Mark Guzdial. 2012. When Life and Learning Do Not Fit: Challenges of Workload and Communication in Introductory Computer Science Online. *Trans. Comput. Educ.* 12, 4, Article 15 (Nov. 2012), 38 pages. DOI : https://doi.org/10.1145/2382564.2382567

[2] David C Berliner. 1994. Expertise: The wonder of exemplary performances. *Creating powerful thinking in teachers and students* (1994), 161–186.

[3] Barry K Beyer. 1987. *Practical strategies for the teaching of thinking*. ERIC.

[4] Ann L Brown and Judy S DeLoache. 1978. Skills, plans, and self-regulation. *Children's thinking: What develops* (1978), 3–35.

[5] Deborah L Butler and Philip H Winne. 1995. Feedback and self-regulated learning: A theoretical synthesis. *Review of educational research* 65, 3 (1995), 245–281.

[6] Michelene TH Chi, Robert Glaser, and Marshall J Farr. 2014. *The nature of expertise*. Psychology Press.

[7] Barbara Ericson, Mark Guzdial, Briana Morrison, Miranda Parker, Matthew Moldavan, and Lekha Surasani. 2015. An eBook for teachers learning CS principles. *ACM Inroads* 6, 4 (2015), 84–86.

[8] Barbara Ericson, Steven Moore, Briana Morrison, and Mark Guzdial. 2015. Usability and usage of interactive features in an online ebook for CS teachers. In *Proceedings of the Workshop in Primary and Secondary Computing Education*. ACM, 111–120.

[9] Barbara J Ericson, Mark J Guzdial, and Briana B Morrison. 2015. Analysis of interactive features designed to enhance learning in an ebook. In *Proceedings of the eleventh annual International Conference on International Computing Education Research*. ACM, 169–178.

[10] Barbara J Ericson, Kantwon Rogers, Miranda Parker, Briana Morrison, and Mark Guzdial. 2016. Identifying Design Principles for CS Teacher Ebooks through Design-Based Research. In *Proceedings of the 2016 ACM Conference on International Computing Education Research*. ACM, 191–200.

[11] Peggy A Ertmer and Timothy J Newby. 1996. The expert learner: Strategic, self-regulated, and reflective. *Instructional science* 24, 1 (1996), 1–24.

[12] Mark Guzdial. 1993. *Deriving software usage patterns from log files*. Technical Report. Georgia Institute of Technology.

[13] Juha Helminen, Petri Ihantola, Ville Karavirta, and Lauri Malmi. 2012. How do students solve parsons programming problems?: an analysis of interaction traces. In *Proceedings of the ninth annual international conference on International computing education research*. ACM, 119–126.

[14] Slava Kalyuga, Paul Ayres, Paul Chandler, and John Sweller. 2003. The expertise reversal effect. *Educational psychologist* 38, 1 (2003), 23–31.

[15] Lauren Elizabeth Margulieux. 2016. *Using subgoal learning and self-explanation to improve programming education*. Ph.D. Dissertation. Georgia Institute of Technology.

[16] Gregory Schraw. 1998. Promoting general metacognitive awareness. *Instructional science* 26, 1 (1998), 113–125.

[17] H Lee Swanson, James E OfiConnor, and John B Cooney. 1990. An information processing analysis of expert and novice teachersfi problem solving. *American Educational Research Journal* 27, 3 (1990), 533–556.

[18] Claire E Weinstein and Gretchen van Mater Stone. 1993. Broadening our conception of general education: The self-regulated learner. *New directions for community colleges* 1993, 81 (1993), 31–39.

[19] Barry J Zimmerman and Manuel Martinez Pons. 1986. Development of a structured interview for assessing student use of self-regulated learning strategies. *American educational research journal* 23, 4 (1986), 614–628.