Creating Guided Study Exercises for a Flipped Database Course

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Abstract

There is a preponderance of evidence that active learning is a successful way to engage students and increase achievement of learning outcomes, however, there are many challenges associated with implementing active learning. One concern is that it takes too much class time and not enough material can be covered during the term if lecture time is sacrificed to in-class activities. To address this, many instructors have turned to flipping their classes, that is, having students devote their solo study time to preparing for class, while group time is devoted to active learning. The individual student preparation can be accomplished through watching video lectures or reading a text, for example. But the big question here is: will students actually follow through and do the preparation?

The focus of this paper is on experiences flipping an introductory database class. In particular, what are the best practices for holding students accountable for preparing for class? The author has employed online reading quizzes as well as guided study assignments. Examples of assignments as well as multiple measures of student perceptions of learning are presented.

1. Active Learning

Active learning is constructivist rather than exposition-centered learning. Students are encouraged and supported in a learning process where they are directly engaged with and take responsibility for their own learning. The merits of active learning (as opposed to passively listening to a lecture) are well-documented. A meta-study by Freeman et al. (2014) examined 225 STEM education research efforts and came to the conclusion that the evidence for impact on student achievement is overwhelmingly positive for active learning techniques. Active learning is associated with higher exam scores while passive teaching styles are associated with higher failure rates. In addition, they conclude that “active learning confers disproportionate benefits for STEM students from disadvantaged backgrounds and for female students in male-dominated fields” (Freeman et al., 2014) citing studies with physics (Lorenzo et al., 2006) and biology (Haak et al., 2011) education.

Active learning covers a number of approaches as diverse as “problem-solving, worksheets or tutorials completed during class, use of personal response systems with or without peer instruction, and studio or workshop course design” (Freeman et al., 2014). A spectrum of techniques is illustrated in Figure 1, where the complexity and classroom time commitment increases from left to right in the graph. The techniques are described in further detail by The Center for Research on Teaching and Learning at the University of Michigan (O’Neal and Pinder-Grover). The meta-study by Freeman et al. (2014) focuses on research regarding classroom interventions, however, active learning can also take place outside of the traditional classroom. At the higher complexity end of the spectrum, site visits for experiential learning is an example of active learning outside of the classroom.

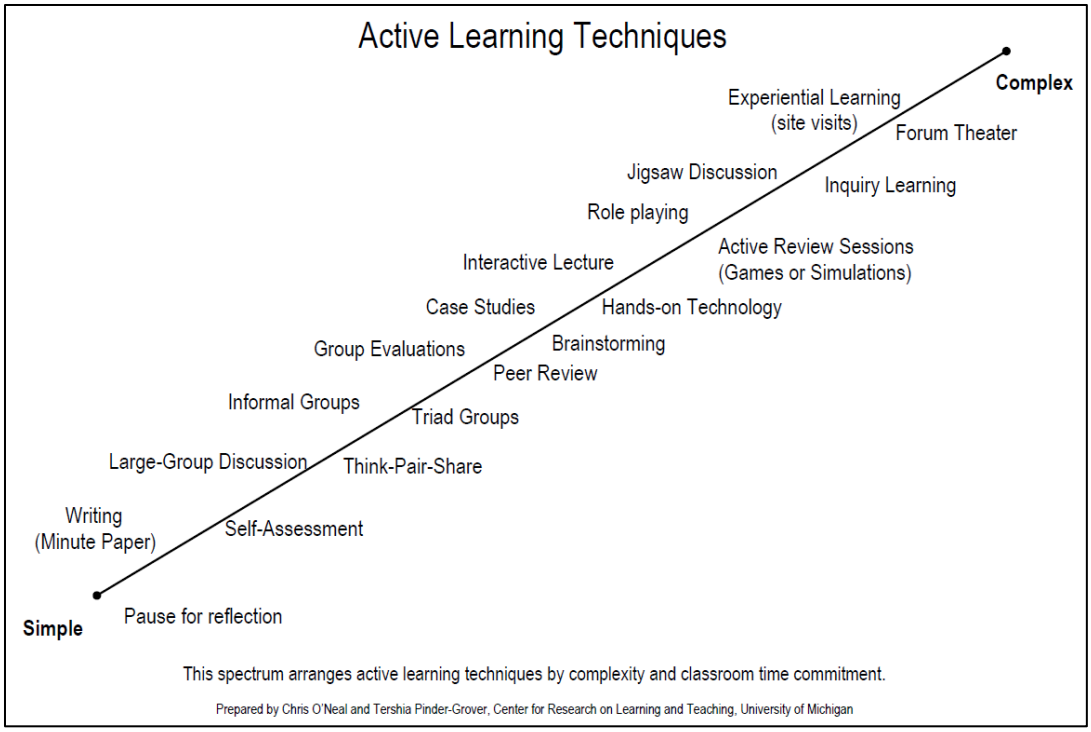


Figure 1. Active Learning Techniques (O'Neal and Pinder-Grover)

An obstacle to implementing active learning is that it consumes classroom instruction time, reducing the amount of material that can be covered during an academic term. One way to address the concern is flipping or inverting the class. A pedagogical model for classroom flipping is described in the next section.

2. A Flipped Classroom Model

Two important ideas for the flipped model are the individual space and the group space. The individual space is where a student learns on their own, which ideally prepares a student to engage more fully in the group space activities by first encountering and becoming familiar with simpler learning outcomes. The instructor should provide guided practice resources and exercises for the individual space.

In the group space, usually in the classroom, the instructor can focus on more complex learning outcomes. The time and activities in the classroom can be broken down into several phases: (1) opening minutes: connecting with pre-class preparation, keeping students accountable for the preparation, and clarifying misconceptions, (2) middle of class: conducting the group activity, and (3) the closing minutes: debriefing the activity and reflection on issues and learning.
The post-group activity can be a continuation or extension of the in-class activity. The reader is referred to Talbert's book (2017) for an extensive discussion of the history and pedagogy of flipped learning as well as detailed instructions about how to design lessons and troubleshoot common problems.

The remainder of this section focuses on approaches to creating materials for use during the individual student preparation conducted prior to class.

2.1 Instructional Design Approaches in CS for the Individual Space

Maher et al. (2015) describe experiences flipping four different CS classes in a two-year period. They outline the main instructional design challenges as: how to structure the preparatory work, how to deliver content outside of class, how to design in-class activities, and how to structure student interaction to leverage social learning. Their study illustrates different ways to address each challenge, and they gauge the impact on student learning via student surveys and course evaluations. In the four classes discussed, the preparatory work consists of reading the textbook, watching (and in an upper level course, critiquing) videos, executing provided code samples, and taking online quizzes. Students consistently reported above average learning both from experiences outside of the classroom and during class compared to previous courses. Some students commented that they felt that they were graded on material that was "not covered then lectured after" (Maher et al., 2015). The authors conclude that while the preparatory work makes the in-class work more meaningful, it is important to communicate the purpose and benefits of the style of instruction.

Peer instruction is an active learning methodology originally deployed in physics (Crouch et al., 2007) that has been successfully used in many disciplines, including CS. Peer instruction includes both pre-work and a sequence of activities conducted during class. The in-class activities are a mini-lecture by the instructor, solo voting on a multiple choice question, group discussion, group voting, and then an instructor-led class discussion. Zingaro et al. (2013) investigate the role of pre-class preparatory work, specifically the reading quiz assigned to students to complete prior to class. The reading quiz has 2-3 questions based on content and one open-response question asking about areas of confusion, difficulty, or interest. The content questions are graded in 4 categories: blank, incomplete, complete but incorrect, and correct. The authors noted a submission rate of almost 80% in an introductory programming class, and 92% of the students agreed that the reading quizzes helped to identify difficult concepts. The quantity of responses indicate that students cared about using the opportunity to communicate with their instructors, and the instructors addressed the areas of difficulty and/or confusion in lecture, providing an immediate formative feedback loop.

Garcia (2018) introduces guided practice worksheets in addition to reading quizzes in introductory CS classes. The author states that pre-class activities can be challenging for students "who often do not have the skills necessary to critically engage with the assigned reading/viewing. As a result students often come to class under-prepared despite completing their pre-class activities" (Garcia, 2018). The guided practice worksheets have five sections: a high-level introduction, an assigned reading or occasionally a video link, basic and advanced learning objectives, and typically problems addressing the basic learning objectives. Garcia reports a 75% completion rate and positive correlation of worksheet completion with final course grades. Even though the guided practice and reading quizzes are a low percentage of the course grade, the high completion rate indicates that students valued the experience.

2.2 Focus of this Study

The course that is the focus of this study was offered in a flipped mode, using a variety of activities, not limited to peer instruction. Aspects of peer instruction were utilized (reading quizzes, guided practice, in-class polls and quizzes) as well as cooperative quizzes, query challenges, problem sets, and forward and reverse engineering for database design. The content delivery was via instructor-created short videos (typically 10 minutes or less), with one exception that is discussed in the next section, along with optional, supplemental textbook readings. Prior to using the curated external video, student preparation was tracked using

online multiple choice quizzes administered through the university learning management system. The quizzes offer two advantages to the instructor: a deadline for completion prior to class can be established and grading is automatic. Students, however, expressed a near unanimous preference for guided studies over online quizzes when surveyed in class. This resulted in the instructor creating guided studies to accompany the videos; this paper studies the process, results, and impact of adding this to a course. Garcia (2018) claims that no prior studies have investigated the impact of guided practice on student preparedness for introductory programming; this paper is the first to examine the impact in a higher-level computer science class.

The instructor followed Talbert's model (2017) for both pre-class preparation activities and in-class structure. The opening minutes of class were devoted to questions about prior material, then connecting the pre-class preparation with the topics of the class session. The instructor walked around the room and tapped students to share their answers for the basic terminology/concept questions on the guided study. Open-ended or application problems would be discussed in pairs and then answers would be volunteered and discussed. While the guided study was under discussion, an in-class TA would walk around and note whether students attempted and completed the guided study. This set the expectation for preparing for class and made the students accountable to the instructor and the community of other students. It also provided an opportunity for students to use the terminology of the discipline in verbal communication, which this instructor noted had been lacking even in active learning settings. The rest of the class period would have activities to apply the concepts by working through problem sets in small groups, with instructor and TA help on call, along with other kinds of active learning experiences. The next section illustrates excerpts from guided studies developed and deployed for introductory database learning objectives.

3. Guided Studies in an Introductory Database Course

The introductory database course described and studied here is a first course taken by undergraduate computer science and software engineering students, students pursuing a minor in computer science, or students pursuing an analytics co-major offered jointly by Statistics and Information Systems and Analytics departments. The only prerequisite for the course is a data structures course. The course was offered as a flipped course with two sections and 29 students enrolled in each. Over the course of the semester, the instructor created 46 videos varying in length from 5 minutes to 12 minutes in length. As described by Talbert (2017), the instructor created an assignment to be completed before class and then conducted a variety of active learning approaches in the classroom.

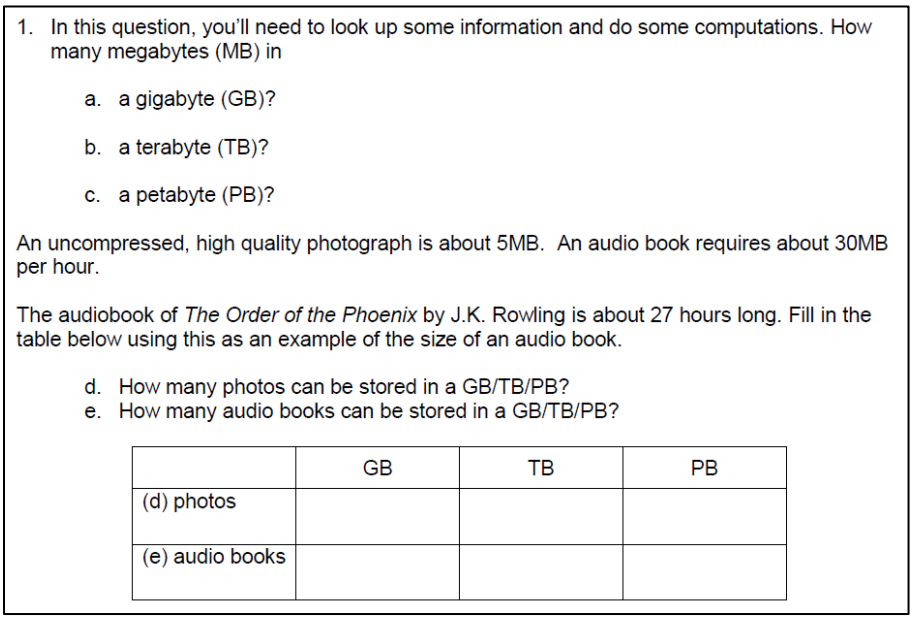
The first 3 weeks of the semester were devoted to learning how to interpret and write basic and aggregate SQL queries. The pre-class activities assigned to students consisted of watching videos. Lecture slides to accompany the videos were posted, and supplemental textbook readings were also available. Students were assigned online quizzes to complete prior to class.

In the 4th week of the semester, the instruction turned to the topic of database terminology, concepts, models, and architecture. Instead of an instructor-created video, a link to an introduction to databases video (Widom, 2013) was assigned. Rather than creating a quiz about the video content, the instructor created a guided study assignment to accompany watching the video. It was intended to be a note-taking guide; it made explicit the important terminology and provided touch points for further discussion.

Example 1: Introduction to Databases Guided Study

Part 1 of the guided study asked students to define terms related to database functionality (massive, persistent, safe, multi-user, convenient, efficient, and reliable) as well as other terms and concepts from the video and the assigned textbook readings. Part 2 consisted of one discussion question: If memory sizes of computers are increasing rapidly, why are database management systems needed? Students were asked to write at least two complete sentences.

Part 3 of the guided study required students to do some independent lookup of information as well as to reflect and speculate. The first question is shown in Figure 2. The goal of the question was to help students to understand how storage sizes relate to some real world media objects.



1. In this question, you'll need to look up some information and do some computations. How many megabytes (MB) in

    a. a gigabyte (GB)?

    b. a terabyte (TB)?

    c. a petabyte (PB)?

An uncompressed, high quality photograph is about 5MB. An audio book requires about 30MB per hour.

The audiobook of *The Order of the Phoenix* by J.K. Rowling is about 27 hours long. Fill in the table below using this as an example of the size of an audio book.

d. How many photos can be stored in a GB/TB/PB?
e. How many audio books can be stored in a GB/TB/PB?

	GB	TB	PB
(d) photos			
(e) audio books			

Figure 2. A Guided Study Investigative Question

The second question in Part 3 asks students to reflect on their software usage for the previous 24 hours, recall terminology, and perform a speculative synthesis of the two. The first part of the second question appears in Figure 3. The first part of the question collects information about what software the student has interacted with, what kinds of data it stores, and what kinds of queries/requests for data are made based on their interaction with the software. The responses were recorded in a table (not shown). The second part of this question asked the student to speculate about which of the database functionalities (massive, persistent, safe, etc.) applied to their software.

2. Dr. Widom states that you have probably used a database in the last hour. She is essentially speculating that most students use a database in every waking hour without even realizing it. Think about the last 24 hours ... what software systems, apps, or embedded hardware/software systems have you used? Narrow it down to those that use some form of stored data.

    a. Pick three of them to discuss and fill in the top row of the table below (1)-(3).
    b. Speculate about what data they store in the second row.
    c. Speculate about what kinds of queries or requests for data are made by the system in the third row.

Figure 3. A Guided Study Reflection and Speculation Question

During the first few minutes of class, the instructor and TA took a few minutes to walk around the class and record credit for completing the guided study. The completion rate for this first guided study was 100% in both sections. A lively discussion ensued, especially around the reflection and speculation questions. An informal poll (raising hands) was taken regarding whether the students would prefer reading quizzes or guided studies for subsequent lessons. The vote was nearly unanimous in favor of guided studies. This is somewhat surprising given that the reading quiz average scores were reasonably good (4.03/6, 4.81/6, 9.91/10, and 3.81/5), had 100% participation, and the guided study was 4.5 pages long. The instructor was expecting the assignment with the shorter time commitment to be the approach favored by students; however, guided studies were not graded for correctness, and the discussion in class was certainly more engaging than going over a multiple choice quiz. For subsequent lessons, guided studies were created, for a total of 10 during the semester. This is about one per week, starting in the 4th week.

Example 2: Entity Relationship Interpretation Guided Study

In week 5 of the semester, conceptual database design using the Entity-Relationship model begins with exercises to motivate the study and to practice learning the diagram conventions. The guided study includes questions such as:

1. Why is it a good practice to create a conceptual design before creating an implementation schema?
2. Why use the ER model for conceptual design?
3. What is design capture?

Students are asked to sketch the conventions, thus learning to associate the terminology with the graphical representation of it. The next exercise is to complete sketches and describe the meaning in sentences, thus learning to interpret an Entity-Relationship diagram. An example is shown in Figure 4. Learning to do modeling is scaffolded by learning the syntax first and then learning how to explain the meaning of the syntax with a concrete example.

a. Indicate n:1 (many to one) cardinality for the *shares* relationship by writing it on both sides of the diamond.
b. One roommate maps to at least _____ and at most _____ instances of *apartment*.

c. One apartment maps to at least _____ and at most _____ instances of *roommate*.

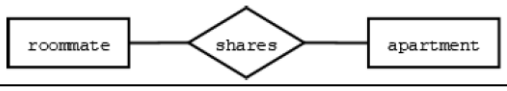
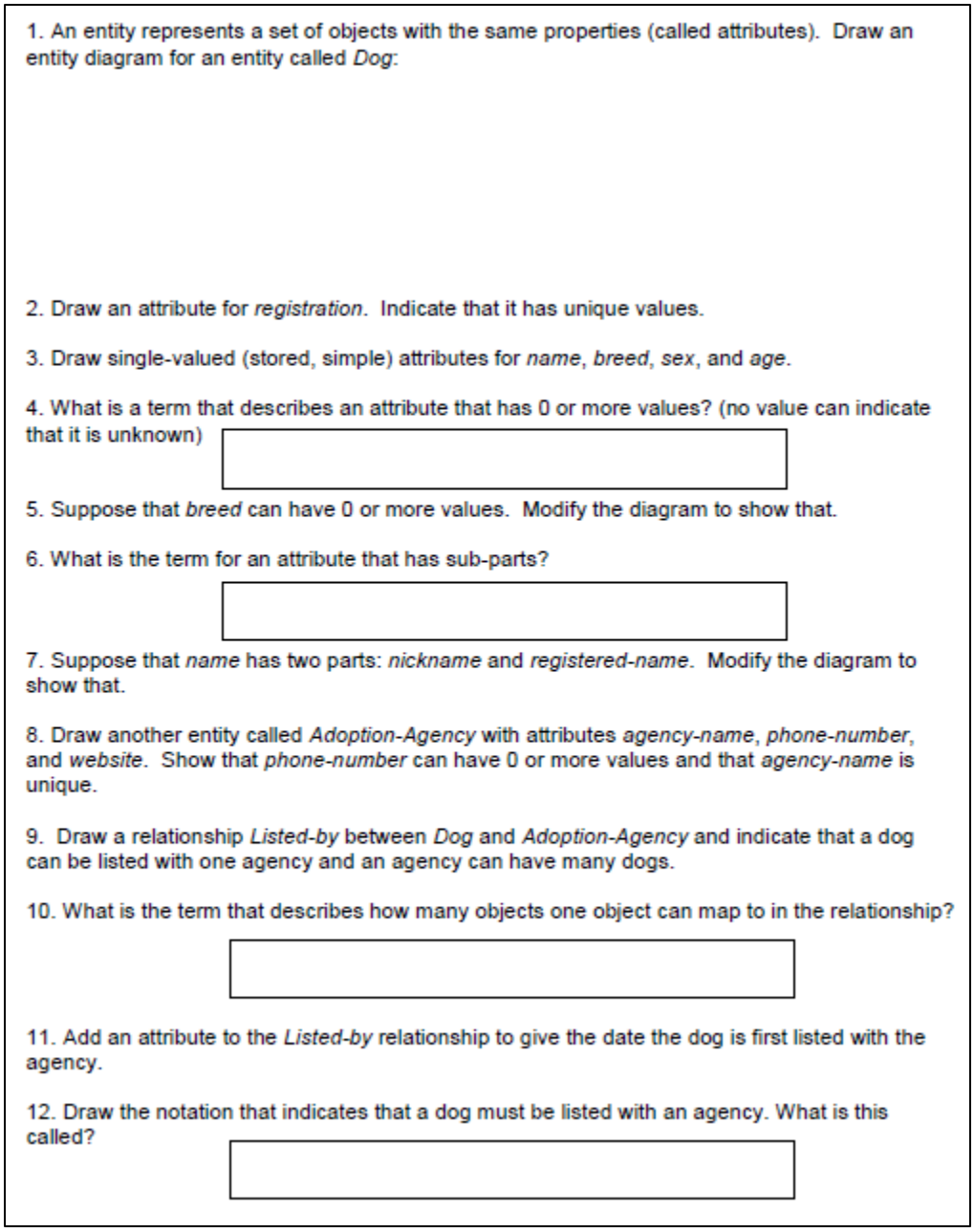


Figure 4. A Guided Study Recall and Interpretation Question

Once students have gained familiarity with the graphical conventions and their meaning, they can begin to create Entity-Relationship diagrams from descriptions. This process is called design capture.

Example 3: Design Capture Guided Study

This guided study example teaches creation of an Entity-Relationship diagram by successively augmenting a design in a step-by-step fashion. An excerpt of the guided study is shown in Figure 5. The remainder of the guided study includes additional practice problems.


1. An entity represents a set of objects with the same properties (called attributes). Draw an entity diagram for an entity called *Dog*:

2. Draw an attribute for *registration*. Indicate that it has unique values.

3. Draw single-valued (stored, simple) attributes for *name*, *breed*, *sex*, and *age*.

4. What is a term that describes an attribute that has 0 or more values? (no value can indicate that it is unknown)

5. Suppose that *breed* can have 0 or more values. Modify the diagram to show that.

6. What is the term for an attribute that has sub-parts?

7. Suppose that *name* has two parts: *nickname* and *registered-name*. Modify the diagram to show that.

8. Draw another entity called *Adoption-Agency* with attributes *agency-name*, *phone-number*, and *website*. Show that *phone-number* can have 0 or more values and that *agency-name* is unique.

9. Draw a relationship *Listed-by* between *Dog* and *Adoption-Agency* and indicate that a dog can be listed with one agency and an agency can have many dogs.

10. What is the term that describes how many objects one object can map to in the relationship?

11. Add an attribute to the *Listed-by* relationship to give the date the dog is first listed with the agency.

12. Draw the notation that indicates that a dog must be listed with an agency. What is this called?

Figure 5. A Guided Study Application and Creation Question

Other topics covered in guided studies were: models and architectures, reverse engineering, functional dependencies, normal forms, normalization, physical database design, and B+trees.

4. Evaluation of Impact

The impact of adding guided studies to a flipped course can be gauged in a few different ways: completion rate (Zingaro et al. 2013, Garcia 2018) and student satisfaction (Maher et al. 2013) are two metrics that have been used in previous studies. Completion rates for all 10 guided studies were nearly 100% for the students attending class. The completion rates were formally tracked for the first half of the semester but only informally tracked in the second half since it did not appear necessary (the students had shown a high degree of accountability and continued to participate in class; it was not evident that any significant portion of students were unprepared.) In future offerings of the class, participation and degree of completion could be more consistently tracked. Student perceptions regarding the efficacy of guided studies were collected in four different ways: (1) anonymous surveys conducted by the instructor, (2) a small group instructional diagnostic (SGID) survey conducted by another faculty member, (3) university-administered, online course evaluations, and (4) an anonymous follow-up question about why guided studies were preferred to quizzes.

4.1 Resource Impact on Student Learning

In order determine which resources students felt had contributed to their performance on the first exam in the course, an online, anonymous survey was administered to the class. The students were asked first to rate to what degree a course activity or resource contributed to their learning, then they were asked to rate the top 4 most impactful resources. An open-ended question requested any other comments. The response rate on the survey was 51/58 students (88%).

Table 1. Resource Survey after First Exam

resource/activity	average	N/A (not used)
working/discussing practice exam problems in class	4.14	3.92%
working problems in class with others	4.06	0.00%
instructor solution to practice exam problems	4.02	8.00%
previous example exams	3.85	7.84%
reworking in-class problems	3.85	7.84%
watching recorded lectures	3.67	0.00%
guided study questions	**3.63**	**0.00%**
writing queries with Teradata or other SQL DB	3.48	9.80%
reading the notes (slides)	3.43	13.73%
taking the simulated exam online	3.37	15.69%
study group outside of class	2.79	45.10%
discussion board (Piazza)	2.49	23.53%
professor or TA office hours	2.45	56.86%
reading the textbook	2.42	48.00%

A list of the resources/activities preceding the first exam and the weighted average of responses appears in Table 1. The question was phrased as: *To what degree did each course resource contribute to your achievement on the exam? Use "N/A" if you didn't use a resource; use "not at all" if you used it and it was not helpful.* The N/A responses are illustrated in the table but were not used in computing the weighted average. The question responses were *not at all* = 1, *a little* = 2, *moderately* = 3, *a good amount* = 4, and *a great deal* = 5. The contribution of the guided

study questions for exam preparation was reported to be in the *moderately* to *good amount* range, and it was one of the resources that all respondents used.

The students were also asked to rank the resources in terms of usefulness, and the top four responses were (1) working problems in class with others, (2) guided study questions, (3) watching recorded videos, and (4) reworking in-class problems. The only open-ended comment that referred to guided studies is:

> *I find the guided studies are only helpful if I watch the lecture first, take notes on my own, and then watch again doing the guided study. This essentially triples my time spent doing the homework and seems like a lot to do for every single class period.*

The student is expressing some dismay about the amount of effort put into completing a guided study, but this represents the ideal scenario for a flipped class since the student is engaging with the course material in a number of ways prior to class. This seems to indicate that more communication from the instructor is needed to explain what the students should be doing and why.

The resource study was administered a second time after the second exam. Slightly fewer resources were available (for example, executing SQL queries did not apply), and the question ranking the resources was not included. The results were similar for repeated categories, with guided study rated at 3.27. The response rate was 39/58 (67%).

4.2 SGID Feedback

A representative from the university's Center for Teaching Excellence (a faculty member in another department) facilitated a small group instructional diagnostic (SGID) at midterm in the course with one section. The facilitator had the students work in small groups to discuss answers to two questions:

1. What is helping you learn in this course? (Figure 6)
2. What would make learning in this course more effective for you? (Figure 7)

The student answers are then used to create survey questions; when the students take the survey, they indicates whether they agree, disagree, or are neutral with respect to the responses. The student responses are summarized in Figures 6 and 7.

#	Question	Agree		Neutral		Disagree		Total
1	In-class group work	92.59%	25	3.70%	1	3.70%	1	27
2	At-home video lectures	74.07%	20	11.11%	3	14.81%	4	27
3	Examples Prof does in class	92.59%	25	3.70%	1	3.70%	1	27
4	Homework interpretation in class	81.48%	22	18.52%	5	0.00%	0	27
5	Thoughtful, planned out activities	77.78%	21	22.22%	6	0.00%	0	27
6	Learning concepts outside of class and then practicing in class	74.07%	20	25.93%	7	0.00%	0	27
7	Third-party discussion platform	29.63%	8	55.56%	15	14.81%	4	27

Figure 6. What is Helping You Learn in This Course?

Several of the responses in Figure 6 refer to activities associated with guided study, although they do not mention “guided study” explicitly. Items #4 and #6 could be interpreted as referring to guided studies since the only homework (not counting the two course projects) would be guided studies (#4) and learning concepts outside of class (#6) would involve completing guided studies.

#	Question	Agree		Neutral		Disagree		Total
1	Doing more examples on computer in class	66.67%	18	18.52%	5	14.81%	4	27
2	Aligning project due date based on lecture timeline (to be able to use content from lecture on project)	62.96%	17	37.04%	10	0.00%	0	27
3	Guided study comprised of problems involving content instead of summarizing videos	74.07%	20	14.81%	4	11.11%	3	27
4	Post homework solutions	81.48%	22	18.52%	5	0.00%	0	27
5	Use database examples from industry - connections to the real-world	70.37%	19	25.93%	7	3.70%	1	27

Figure 7. What Would Make Learning in This Course More Effective for You?

In the responses shown in Figure 7, guided studies are explicitly mentioned as an area for improvement (Item #3). A high proportion of the class agreed with the statement that more content should be included in the guided studies, rather than summarizing videos. The instructor would contend that the purpose of the guided study is scaffolding the basic learning objectives (i.e., summarizing video content) and preparing for doing more advanced work in class. However, it is interesting to note that 74% of the class is actively requesting work that they could do to prepare for class.

4.3 Course Evaluations

In this section, excerpts from the open response questions of the university course evaluations are presented. The course evaluations are anonymous and administered online; for the course studied here, there was a response rate of 51/58 (88%). All excerpts that are relevant to guided studies are included here. General comments about other aspects of the course or about the instructor are omitted. The first question concerns “the strengths of the course:”

- *The guided studies due before each class help students to learn on their own and have a better understanding of the material.*
- *Using video lectures, notes, slides, and handouts is a really great combination to teach material and reinforce participation.*
- *The before-class worksheets were more effective than the before-class quizzes we had earlier in the semester.*
- *Guided studies made it easy to learn.*

A second open-ended response question requests “suggestions for changes that could improve your learning:”

One thing I wish I knew going into this course is that it is almost entirely flipped classroom. This was the downside to this course, in my opinion. The students in this class have spent the last 14-16 years in school primarily being lectured at during class and then coming home and doing the homework. I found the flipped classroom implementation to be detrimental. I found myself ignoring lectures as homework assignments when I was too busy, and then being lost half the time when doing the classwork.

It can be observed that four students thought of the guided studies on their own (unprompted) at the end of the semester and mentioned them positively as a strength of the course. The suggestion for future improvement mentions that the student was unprepared for class when he or she did not complete the "homework" (aka watching videos and completing guided studies.) Not everyone adjusts to or welcomes the paradigm shift associated with flipped learning. Based on the course evaluations as a whole, however, the instructor would contend that most students embraced active (flipped) learning. Every categorical measure of course quality exceeded both the departmental and university averages, and there were many positive comments about the course delivery. The students were told on the first day of class that the course was flipped (and why), and it also appears on the course syllabus that was posted in the learning management system prior to the start of the semester. In the future, appropriate designations in the university course listings will be sought by the instructor.

4.4 A Follow-up Question

A brief follow-up survey was sent to the students in the class in the next semester to ask them why they preferred guided studies to quizzes. The response rate was very low (only 5 students responded). All of the responses are included here:

- *Guided worksheets allow us to better demonstrate the knowledge we have learned in a practical way rather than just memorizing facts for a reading quiz. Worksheets also allow us to ask the professor and TA questions while we are doing them to make sure we are on the right track.*

- *Guided Studies made me do the readings and get more out of it. If you have to just take a quiz you do not have to actively read which is better for learning.*

- *Guided practice worksheets are graded on completeness and was representative of how hard someone worked whereas the reading quizzes were based on correctness in which you had opportunities to fail regardless of time spent on material.*

- *In my own personal experience, guided practice worksheets enable me to get a better understanding of the material, quicker, and in a less stressful manner than taking a quiz post-reading over and studying the material.*

- *As I study over the material, I can work alongside on the worksheet and reinforce what I'm studying to make sure that I understand it. With a quiz, I may have to spend much more time than is actually necessary to feel confident enough to take a quiz that will impact my grade (which is also more stressful).*

These responses indicate that guided readings encourage students to prepare and increase what they learn from doing the preparation, and they are less stressful since they are not graded.

Discussing the guided practice answers in class also allows for interaction with the instructors to clarify remaining issues and solidify understand of concepts.

5. Reflections

The intent of assigning guided studies is to increase student preparedness and readiness for participation in active learning activities in the class sessions. In this paper, the author reviewed best practices for structuring flipped learning as well as particular applications in computer science courses. Three guided studies for an introductory database course were illustrated, followed by multiple measures of student perception of the efficacy of guided studies. The author concludes that the approach was effective for learning and valued by students.

In future studies, the author plans to

1. track the completion rate of guided studies more closely to see how it relates to achievement of learning outcomes. The completion rate was tracked in the beginning of the semester, but tailed off toward the end because it did not seem necessary.

2. investigate the impact of flipping the course on achievement of learning outcomes by comparing test scores of flipped and non-flipped courses for similar questions; achievement of learning outcomes (i.e., test scores) was not examined in this study because there were many different types of active learning interventions and it would be hard to separate out the impact of guided studies alone.

3. implement the advice of practitioners of peer instruction (Zingaro et. al., 2013, Garcia, 2018): have the guided study be due one hour before class so that it can be sampled for areas of confusion/difficulty that can be addressed in class.

4. perform backwards design of guided studies from exam questions (Garcia, 2018), making certain that lower level and higher level learning outcomes are both addressed in guided studies and classroom activities.

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Bibliography

Crouch, C. H., Watkins, J., Fagen, A. P., & Mazur, E. (2007). Peer instruction: Engaging students one-on-one, all at once. *Research-based reform of university physics*, *1*(1), 40-95.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.

Garcia, S. (2018). Improving classroom preparedness using guided practice. *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*, 326-331.

Haak D.C., HilleRisLambers J., Pitre E., & Freeman S. (2011) Increased structure and active learning reduce the achievement gap in introductory biology. *Science*, 332(6034), 1213–1216.

Lorenzo M., Crouch C.H., & Mazur E. (2006) Reducing the gender gap in the physics classroom. *Am J Phys,* 74(2), 118-122.

Maher, M. L., Latulipe, C., Lipford, H., & Rorrer, A. (2015). Flipped classroom strategies for CS education. *Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, 218-223.

O'Neal, C. and T. Pinder-Grover, Active learning continuum, Center for Research on Learning and Teaching, University of Michigan, http://www.crlt.umich.edu/sites/default/files/resource_files/Active%20Learning%20Continuum.pdf, date accessed: 1/4/2019.

Talbert, R. (2017). *Flipped Learning: A Guide for Higher Education Faculty*. Stylus Publishing.

Widom, J. (2013). Introduction to databases, https://www.youtube.com/watch?v=D-k-h0GuFmE, date accessed: 9/14/2018.

Zingaro, D., Bailey Lee, C., & Porter, L. (2013). Peer instruction in computing: the role of reading quizzes. *Proceeding of the 44th ACM Technical Symposium on Computer Science Education*, 47-52.