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Student-Generated Exam Questions in Microprocessors Courses

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1. Introduction

Microprocessors courses are fundamentals and required for all electrical and computer engineering students, and in certain cases computer science students as well. The course typically covers topics in hardware such as the internal components of a microprocessor (registers, buses, counters, etc.); software such as assembly instructions, directives, interrupt programming etc.; and interfacing such as memory addressing, address decoding, and accessing peripherals [1], [2], [3]. Many of these topics have hands-on experiments in a laboratory, allowing students to apply theoretical concepts to enhance the students' understanding of the subjects that are covered during the lecture.

However, during lectures, students often remain passive listeners, which reduces engagement and attention, which can lead to a decline in attention span and possibly lack of interest in the subject [4], [5]. This passivity is particularly problematic in microprocessor courses, where abstract concepts such as 2's complement arithmetic, memory addressing, and floating-point operations require sustained engagement for deep understanding, due to their inherent abstraction, further challenging students' ability to maintain attention during lectures.

Much research demonstrated that active learning, which aims to engage the students in their learning through activities or exercises, has a positive impact on student learning (e.g., [6]). Problem-based, discussion-based, flipped, collaborative, student-design learning are examples of active-learning pedagogy that demonstrated positive benefits in technical, communication, presentation, and/or teamworking skills [7]—[11]. Furthermore, research also demonstrated that students' engagement in composing learning material enhances student learning and communication skills [12], [13]. Despite the strong evidence supporting active learning, little research has examined how student participation in assessment design for microprocessor courses can enhance learning in microprocessor courses.

In this paper, we present an active learning approach to engage students in microprocessor classes, through designing, sharing, and presenting learning and assessment materials. The approach aims to combine in-class activities and take-home content-creation assignments. During the lecture, students are engaged in a Q&A and hypothesis discussion. These discussions will be used as a baseline for a take-home assignment to compose exam questions and answers, the Student Generated Exam-Question (SGQ) assignment. The students work in groups to compose their questions, post the questions and the answers on the platform, and present their contributions during the exam-review lectures.

We applied the approach in two of our microprocessor courses and quantified the findings by analyzing exam performance data, question type outcomes, and student survey responses. Overall, our results show that SGQ improved exam performance, strengthened topic retention, and received highly positive student feedback, indicating that student-generated questions are an effective and engaging strategy for microprocessor education.

2. Student-Generated Exam Questions (SGQ)

The premise of our approach is that students work in groups to create questions and solutions based on course material as preparation for the upcoming exam. The approach is structured such that students are guided throughout the process from the discussion of the topic during the lecture until the exam assessment.

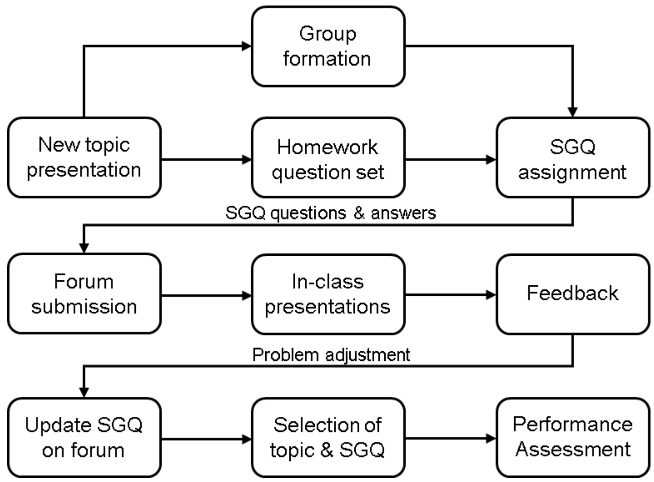

Figure 1. Flow of SGQ approach

2.1. Overall Flow of the SGQ Approach

Figure 1 depicts the flow of our SGQ approach. During the new topic presentation, the instructor presents a new topic, provides examples, and conducts a question-and-answer discussion with the students. The examples cover basic understanding of the new topic, while the Q&A discussions formulate hypotheses. These hypotheses are made of alternations, addition, or combination of the examples.

After the lecture, the students are assigned a homework question set and group formation assignments. The homework problem set is based on the topic that is covered in the lecture, and it includes partial (on par with the examples) and holistic (on par with the hypothesis) questions that were presented during the lecture. To help students understand the homework questions and alleviate the time constraint during lectures, the solutions are posted on the course platform in text and recorded-video format once the homework deadline has passed. Concurrently, the students form groups to work on the student generated questions (SQG).

For the SGQ assignment, the students are tasked to compose questions and answers about the topic that was covered in class. The groups post their question sets on the course's forum for everyone in class to see. SGQ assignments are repeated for each topic included in the SGQ approach. All SGQ assignments for a module are due before the exam-review session of that module.

During the exam review sessions, in-class presentations are conducted by the student groups and moderated by the instructor. Students present their questions and answers to the class, one group at a time. Students engage in hypothesis discussions for the questions presented, investigate alternative scenarios, and discuss the answers provided by the presenting group. The instructor moderates the presentations, fixes possible mistakes in the question or answers, and provides feedback to the students. The groups adjust the questions and answers based on the feedback received from the students and the instructor and update their contributions on the course's forum.

For exam composition, the instructor selects a topic to be assessed with SGQ question(s) that was proposed by the students unmodified. To assess students' understanding of the subject, the instructor designs a problem similar to the selected, varying input parameters or variables. The SGQ assessment evaluates the students' understanding of the topic related to the question provided by the student and included in the exam. Following each exam the student performance is evaluated for the selected SGQ topic and for the overall exam.

To alleviate stress and encourage intrinsic inclination for participation, the SGQ assignments have no credit or penalty. However, the deadline once signed up for composing questions, students are encouraged to meet the SGQ deadline.

2.2. Group Formation and Topic Selection

The students are asked to form small groups to work on the SGQ assignment. They are asked to form small groups, due to the effectiveness of small sizes in group learning in engineering and technology [14], and alleviate unequal workloads among large groups of students [15]. Since self-selection has a positive impact on team performance by showing ownership of the group problems and having good cohesion [16], [17] and can lead to a more homogenous skill-level [18], students are free to self-form their teams. Although self-forming teams could have imbalanced skill set among their group members, instructor intervention can be beneficial in more sophisticated or senior courses (such as senior capstone), wherein complementary skill sets contribute greatly to project success [18], microprocessor is a fundamental course [3] that requires basic skill set covered in its prerequisites courses. Additionally, the SGQ exercises have a short timeline that does not require setting up long-term plans (e.g., as in a senior capstone course), and thus imposing additional requirements in team formation may adversely affect the timeline of the group formation process.

To increase students' interest in the activity, groups select the topic of their choice to work on for the SGQ assignment [19], [20]. The students are presented with the list of all the topics that are included in the SGQ assignment and that are due prior to the exam. The groups can elect to select the topic as soon as the assignment is posted or can wait until the topic is covered during the lecture.

To alleviate unfairness in topic selection, we employed a structured round-robin process. Each topic was initially selected by one group in sequence until all groups had the opportunity to select a topic. If topics remained after the first round, groups were invited to volunteer to take on an additional topic. In cases where the number of groups exceeded the number of available topics, two groups were permitted to work on the same topic; however, they were required to compose distinct and independently developed questions. This procedure ensured equitable participation while maintaining diversity and breadth of topic coverage.

2.3. Guidelines for SGQ Composition

To help the students formulate problems for the SGQ assignment, we created the following criteria and guidelines:

1) To alleviate passive compositions, SGQ problems must not be exact replicas of the homework problems or the lecture examples
2) To maintain correlation to topics and ensure the problems do not deviate widely from the assessment objective, the students can use the homework problem set as a baseline and modify the provided parameters
3) To enhance student attention during the lecture, students are encouraged to take notes of the hypothesis analysis and compose questions based on these hypotheses
4) To ensure diverse set of questions, no more than one group can compose questions for a single topic

Aside from the guidelines, the students are free to create the questions in their own way. The questions can be in open- and close-ended forms, stepwise questions, additions to existing problems, computational, and/or analytical. The questions can be in a *why*, *how* or *what* format. Additionally, to help students understand the subject better, the students can compose questions they would like to know or confirm the answer to. This provides the students with the chance to think about any follow-up questions that they could not summon during the lecture. Furthermore, to have more depth in question design, the students can discuss the questions with other groups.

To provide students with sufficient time to work on the assignment, reduce stress and human error, SGQ is a take-home assignment [21]. Students can reflect on the lecture notes, look up material from the textbook, and do online searches and apply their knowledge to solve the SGQ assignment [22]. The students work within their group to compose their final questions and answers and post them on our course forum. The deadline for posting the questions is one day before the exam review lecture for the benefit of: (a) enabling students to skim through all questions before the review lecture, (b) allowing students to prepare follow up questions to the SGQ answers, and (c) giving the instructor time to inspect the questions and the answers and prepare supplementary content if necessary.

2.4. SGQ and Exam Preparation

The questions and answers submitted by the students on the course platform are reviewed by the instructor prior to the exam-review lecture. During the review lecture, the groups present their questions and answers to the class and answers and questions or concerns that arise by their peers. The instructor moderates the presentations, corrects erroneous answers, assists in answering follow-up questions, and ensures timely progress of the presentations. To help the group perform better on subsequent assignments the instructor also provides feedback about the delivery and the composition style of the questions (if applicable) to the groups [23].

The collection of the students generated questions comprises the pool of possible questions that can be present on the upcoming exam. To motivate the students to prepare and study all the questions and the topics with a tantamount of importance, the students are not informed which of the questions will be on the test—every SGQ is equally likely to be included on the test. It is highly likely that students are motivated to learn all of the SGQ to receive “guaranteed” points on the exam. However, the true value lies in the fact that students are rehearsing more examples of the topics covered in the class.

To assess the student retention of the information, the SGQ that is selected to be included in the test is unmodified. The instructor includes the question as is from the updated SGQ set on the course forum. To evaluate the comprehension of the topic, the instructor composes a very similar question to be included in the test. The latter question must vary enough from the SGQ to invoke the thought process for the principle being assessed, but not too much to be a completely different question.

2.5. Topics selected for SGQ

Table 1 lists the topics that are candidates for the SGQ assignments. Overall, there are five topics per module, 15 total for the course. To have a representative set of topics for SGQ and to complement the laboratory experiment, we selected a set of topics for each course module. We aimed to include topics that are abstract (e.g., 2's complement) or complementary to laboratory experiments (e.g., data processing instructions).

Table 1. List of SGQ topics per module for Microprocessors course

Module 1	Module 2	Module 3
2's Complement	Data Processing Instructions	Interrupt Handling
Base Conversions	Hand/manual Assembly	Interrupt Registers
Data sizes	Memory Address Decoding	Integer Mathematics
Endianness & Alignment	Memory Composition	Floating Point Mathematics
Arethmetic Instructions	Memory Bus Interfacing	Execution Modes

The order of the topics and their breakdown per module is related to the course design and timeline and not directly to the SGQ approach

2.6. Sample SGQ Assignments and

To illustrate the nuances of the questions among the lecture-examples, homework problems, and SGQ questions, we present a sample topic—memory address decoding—and its related assignments and assessments.

Memory address decoding concept is based on the fact that a memory system is composed of building blocks (chips), and to access a memory location, the address bits are used to enable and select a chip, select an address/line in that chip, and select the byte offset. During the lecture, students are presented with fundamental concepts such as calculating the memory system size, the number of chips required to build a memory system, the number of address bits needed to access the memory system, etc. scaffolding the memory address decoding concept. Also, the students are presented with examples and solutions on each of the fundamental concepts and are asked to answer simple questions. Subsequently, the students are presented with a simple memory system, and the address concept is presented and discussed. To solidify the understanding of the concept, a hypothesis analysis is followed, during which, the students are encouraged to alter the details of the example provided and present the answers based on the alternations.

Figure 2 depicts a simple 1 KB memory system composed of eight 128 x 8 chips. The total number of address bits required is 10: 3 bits of the address bits are fed into a 3-to-8 decoder to enable one of the chips, and 7 bits to select a single address/line within the chip. No bits are needed for byte offset since the chip lines are 1 byte (8 bits) each and the system is byte addressable. Students hypothesize that the total size of the memory is increased or decreased to 4 KB/512 B, respectively, and recalculate the number of address bits and alter the dimensions of the decoder.

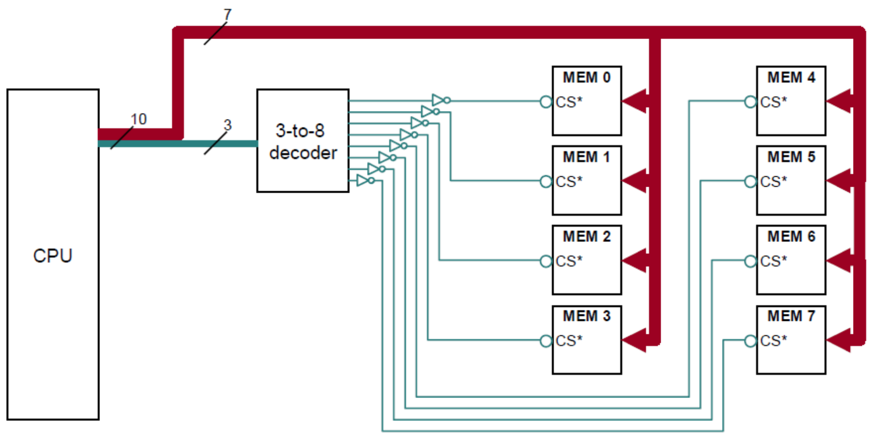

Figure 2. Address decoding of a 1KB memory system [24]

The homework problem set includes questions on the number of address bits required for various memory systems and chip sizes. For the SGQ assignment, the students composed similar questions with varying memory and chip sizes. One of the questions composed by the students stated, "For a 1KB memory module using 64x16 chips, how many chips are required? How many address bits, CS bits, and MUX bits are needed? Assume byte-addressable memory." Subsequently, the lecturer-composed question was "For an 8KB memory module using 128x32 chips, how many chips are required? How many address bits, CS bits, and MUX bits are needed? Assume byte-addressable memory."

In this example, the student- and instructor- composed questions are similar but not the same. By varying the system and chip sizes, the students are designing two memory systems with different numbers of chips, decoder sizes, mux sizes, and address bits. The change in the question triggers a full thought process to address the change in not only one variable, but multiple variables that are linked together.

3. Evaluation and Discussion

We evaluated our approach during two course offerings in subsequent semesters, *Course 1* and *Course 2*. The number of groups and SGQ questions are summarized in Table 2. For *Course 1*, there were 4 groups of 3 to 5 students each. The groups composed 4, 5, and 4 questions for modules 1, 2, and 3, respectively. For *Course 2*, there were 6 groups of 3 to 5 students each. The groups composed 13, 11, and 5 questions for modules 1, 2, and 3, respectively.

The topics and the SGQ that were selected to be on the exams are listed in Table 3. The Average Grade represents the average score the students obtained for that question, normalized to the question absolute score.

Table 2. Breakdown of number of groups and questions for two Microprocessors courses

SGQ	Course 1	Course 2
no. of groups	4	6
Students per group	3 — 5	3 — 5
no. SGQ, Module 1	4	13
no. SGQ, Module 2	5	11
no. SGQ, Module 3	4	5

The perfect score column represents the percentage of students who obtained a perfect score for that same question. The question types are varied to capture performance data for analysis purposes. The unmodified SGQ questions (S) are the questions provided by the students, unmodified, the lecturer/instructor-composed question (L) are modeled after S question, the hybrid question (H) are a student proposed by the student and a modified by the instructor, and the homework-assignment (W) are questions previously presented in a homework assignment, modified for the exam. The table is sorted by the course and module numbers (Course, Module).

Table 3. Summary of topics and selected SGQ on the exams for courses 1 and 2

Topic	Average Grade	Perfect Score	Question Type
Endianness	86.7%	50.0%	S
Hand Assembly	86.3%	46.0%	H
Memory Sys. Design	86.4%	33.3%	W
Interrupt Registers	90.0%	67.0%	S
Instruction Decoding	81.5%	74.1%	S
Address Decoding	85.6%	50.0%	S
Address Decoding	79.2%	48.0%	L
Memory Sys. Design	73.6%	16.0%	W
Interrupts Priority	96.7%	91.6%	S

The SGQ (S) type of questions received the highest perfect credit with 91.6%, 74.1%, 67.0%, and 50%, followed by instructor/Lecturer (L) questions 48.0%, and the Hybrid (H) questions. The least perfect credits averages were the homework-modified questions (W) with 33.3% and 16.0%. The high perfect scores for the S question were expected due to the students' knowledge of the exact questions a priori to the exam, and it can be attributed to memorization. Given the trend in the S questions, we conjecture that students had higher information retention on all SGQ topics, including the SGQ topics that were not present on the exam.

The L and H questions closely follow the S questions. This can be attributed to the fact that students were not only familiar with but also contributed to the composition of the question. Unlike the L and H questions, the W questions received the least perfect scores on the test. Although the questions were present in the homework and students had access to the solutions, the students did not participate in the creation of these questions. Based on these two observations, we conjecture that student involvement in question creation enhanced students' information retention and outweighed memorizing questions and answers.

Furthermore, the S questions received the highest average grade, compared to other types of questions—86.7% and 90.0% for Course 1, and over 81.5% for Course 2. Revealing that even if students did not receive a perfect score for the questions, they still performed better on SGQ questions than other types of questions. This reveals that SGQ do not automatically grant perfect scores, however, enhance the students' performance on the exams, by being involved in the question-and-answer creation. We can also conjecture that the students likely did not rely on memorization to study for the topic, but rather were knowledgeable in the topic (else, imperfect credit would also correlate with a very poor question score).

Table 4. SGQ impact on question scores

	Course 1	Course 2	Change %
# of SGQ	13	29	55.17%
Average grade	88.3%	87.9%	-0.45%
Average perf. Score	58.5%	71.9%	22.91%

In addition to the type of questions, the number of SGQ questions has a positive impact on the student performance. We calculated the average grade and the average perfect score of all S questions per course and summarized the results in Table 4. There were 13 and 29 SGQ for all SGQ topics for courses 1 and 2, respectively. The results show that a 55.17% increase in the number of student generated questions resulted in 22.91% increase in the perfect score and less than 0.5% decrease of the average score of the SGQ topics. The decrease in the average scores is negligible compared to the gains in perfect scores. Based on this outcome we conjecture that more student participation can lead to better comprehension and information retention.

To evaluate the SGQ impact on student learning, we also compared the outcomes of the SGQ courses to prior two course offerings that have the same module structures but did not include SGQ assignments. Table 5 summarizes the average exam scores for these courses.

Table 5. Average exam scores comparisons

Column1	Module 1	Module 2	Module 3
Course 1 & 2 average	70.4	82.6	74.1
Prior 2 courses ave.	68.6	80.1	74.3
% increase/decrease	2.62%	3.14%	-0.29%

Overall, SGQ had a positive impact on student performance on the exams. Modules 1 and 2 benefited from a 2.62% and 3.14% increase in performance. Module 3 exhibited a slight 0.29% decrease in performance. The increase and decrease in exam performance can be attributed to the student involvement in assessment design. For instance, students contributed 17 and 16 questions for modules 1 and 2, respectively, in courses 1 and 2, but only 9 questions for module 3 (Table 2). Based on these findings, we conjectured that SGQ can lead to higher exam grades overall and supplement our previous conjecture that more student participation can lead to better comprehension.

In addition to performance outcomes, we examined the quality of student-generated questions from an instructor perspective. A question was considered of sufficient quality if it aligned with the intended assessment objectives and demonstrated appropriate scope and conceptual complexity. Minor inaccuracies in formatting, wording, or solution presentation were not considered indicators of poor quality, as these were routinely addressed during in-class review sessions. However, submissions that reflected fundamentally incorrect approaches or significant conceptual misunderstandings were categorized as requiring substantial revision. Across both course offerings, over 75% of submitted questions met the criteria for sufficient quality with minimal modification. We attribute this high proportion to the structured guidelines outlined of the SGQ assignment (Section 2.3). Importantly, the primary objective of SGQ was to engage students in higher-order thinking through the process of designing, analyzing, and refining assessment items.

4. Student Reception

To quantify student perceptions, we administered an anonymous survey using a five-point Likert scale. The response options were Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A), and Strongly Agree (SA). The summary of responses is shown in Table 6.
Overall, the students received the SGQ approach very positively. To quantify the student responses, we composed an anonymous survey and recorded the students' responses on a Likert scale. The summary of the responses is shown in Table 6. The survey results show that students overwhelmingly viewed the SGQ activity positively. The majority of students agreed (A) or strongly agreed (SA) that SGQ improved their understanding, increased confidence, enhanced communication, and made learning more engaging and enjoyable.

Table 6. Results of SGQ student anonymous survey

Question	SD	D	N	A	SA
SGQ assignment helped me understand the topics better	0.00%	6.30%	31.30%	12.50%	50.00%
SGQ helped me form study groups	6.30%	12.50%	43.80%	18.80%	18.80%
I enjoyed coming up with exam problems	0.00%	12.50%	31.30%	31.30%	25.00%
I am able to communicate better about the topic which I designed a question for	0.00%	0.00%	12.50%	37.50%	50.00%
I have more confidence in the topics for which I helped design a problem for	0.00%	0.00%	31.30%	25.00%	43.80%
This exercise made learning more engaging for me	0.00%	6.30%	25.00%	18.80%	50.00%
This exercise made learning more fun for me	6.30%	12.50%	18.80%	18.80%	43.80%

SGQ impact on forming study groups was more mixed, only 6.3% strongly disagreed (SD) and 12.5% disagreed (D) that the assignment helped them form groups. This is expected since forming groups was left for the students to perform without much instructor intervention. Similarly, only 6.3% disagreed that SGQ was engaging for learning the course's subject; and

6.3% found SGQ to make learning fun for them. This is also expected due to the diverse learning styles preferences of students. However, more than 62% of the students (18.8% and 43.8%) found the SGQ to make the learning more fun for them.

The survey results indicate strong student support for the SGQ approach. Students reported meaningful gains in understanding, communication, confidence, and engagement—core indicators of effective active learning. While the impact on forming study groups was more modest, the activity still showed a positive trend. Collectively, the data demonstrated that student-generated exam questions not only enhance cognitive outcomes but also promote affective benefits such as enjoyment and motivation, reaffirming SGQ's value as an active-learning strategy in microprocessor courses.

Table 7. Results of the course evaluation questionnaire

Question	SD	D	N	A	SA
The course was organized in a manner that helped me understand the underlying concepts.	0.0%	0.0%	0.0%	13.6%	86.4%
The course gave me the confidence to do more advanced work in the subject.	0.0%	0.0%	0.0%	22.7%	77.3%
My ability to communicate about this subject has been enhanced	0.0%	0.0%	0.0%	27.3%	72.7%
The classroom environment was inclusive and welcoming to all students	0.0%	0.0%	4.5%	18.2%	77.3%

Furthermore, we analyzed the student responses to the anonymous course evaluation, which was provided to students by our institution. Table 7 presents the findings of all Likert scale questions in the survey. The results further reinforced the positive impact of the SGQ framework. Students unanimously agreed that the course was well organized and that it enhanced their conceptual understanding and confidence to pursue more advanced work. Additionally, 100% of students reported improved ability to communicate about course topics, aligning strongly with the communicative and metacognitive goals of the SGQ approach. There were no comments that indicated disagreement, rather, all comments were positive. One notable comment related directly to our SGQ approach stated, "…I really liked the idea of making student practice exam problems by actually developing them"

Additionally, the SGQ approach supports ABET teamwork outcomes through structured group activities. In particular, the SGQ activities target ABET student outcomes related to teamwork, including collaboration, shared decision-making, and building on others' ideas. Students worked collaboratively in small groups to plan, design, and present their SGQ questions and solutions, sharing ideas and analyzing problems systematically. Groups were required to build upon each other's contributions, establish expectations, and make joint decisions regarding question composition. Survey responses indicate that students perceived improvements in collaboration, engagement, and their ability to work effectively in teams. While longitudinal or pre/post-test metrics were not collected, the combination of exam results and survey feedback provides meaningful evidence that SGQ fosters teamwork skills in addition to conceptual understanding of microprocessor topics.

5. Considerations and Conclusion

There are a few limitations that should be considered. First, SGQ can be time-intensive in a fast-paced microprocessor course. The activities require dedicated in-class time as well as additional student effort beyond existing course requirements, including laboratories, homework assignments, quizzes, and exams. Second, because SGQ benefits from broad participation, its impact may be reduced in very small class settings where the number of student generated questions is limited. These factors suggest that the effectiveness of SGQ depends on thoughtful integration into the course structure and sufficient class size to sustain a diverse pool of student contributions.

Implementing the SGQ approach requires moderate additional faculty effort beyond standard course activities, including reviewing student questions, moderating presentations, and providing feedback. Class resources include a course forum for posting questions, typically available on online platforms such as Canvas, Blackboard, or similar systems. Dedicated in-class time for Q&A and review sessions is also required. Instructors should note that SGQ consumes lecture time, particularly for reviewing student-generated questions during the exam-review session, which may need adjustment in tightly scheduled courses. Group logistics, such as forming teams and assigning topics via round-robin, are straightforward and scalable; larger classes may benefit from teaching assistant support. Overall, SGQ is feasible in a variety of institutional contexts with modest additional effort.

While SGQ involves student-chosen topics, we view this as a strength because allowing students to select topics of interest encourages engagement and ownership of the work. Potential concerns, such as inadvertently cueing correct answers or uneven question difficulty, are addressed through instructor moderation during exam-review sessions. Instructors review submitted questions, provide feedback, and adjust explanations or clarifications as needed, ensuring a fair and balanced assessment while preserving the benefits of active student participation.

In conclusion, we presented an approach for engaging students in the design of learning and assessment materials in microprocessor courses through Student-Generated Exam Questions (SGQ). Our approach combines activities in the lectures and take-home assignments to keep the students engaged in their learning. We applied our approach to two course offerings, and the results showed clear evidence of improving student learning outcomes. Students scored higher on SGQ-related exam questions, with perfect-score rates reaching 91.6%. Survey data further supported these outcomes: over 85% of students agreed that SGQ improved their understanding, communication, and confidence, and over 90% rated the course as well organized, confidence building, and inclusive. These findings demonstrated that SGQ is an effective active learning strategy that enhances retention, performance, and overall learning experience in microprocessor courses.

Future work will investigate the longitudinal effects of SGQ on knowledge retention and student performance in subsequent courses. Examining how the skills, engagement, and conceptual understanding gained through SGQ persist over time in follow-on courses will provide insight into its lasting impact on learning outcomes.

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