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Crosswords and Team Quizzes to Facilitate Teaching Physics at Susquehanna University

Samya Zain
Susquehanna University

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Samya Zain,[1]

[1] **Department of Physics, Susquehanna University**

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In a small liberal arts college, like at Susquehanna University, students come in with all backgrounds, from beginners to experts in the field of Physics. For the Intro Physics class as well as for the upper level Modern Physics class, I made up crosswords taken mostly from definitions and vocabulary words found in the chapter. The completed crosswords were due the day a new chapter was started. The crosswords are offered as a part of extra credit towards the students final grade, which provides the motivation and also makes the students read the chapter beforehand. The crosswords themselves we structured in such a way that they did not require a lot of effort; however they made a huge impact in terms of students familiarity with the materials that were to be covered in class.

I cannot claim to be an expert in pedagogy by any means, but I know that one problem with lecture courses is that students sometimes feel unengaged and just attending lecture can be a passive experience for students. The strategy for team work is simple and recognized widely as a good way to engage the students. I have tweaked this strategy to include “team quizzes”. At the beginning of each semester I divide the class into groups of 3-4 students each. The students team collaborates and works together on homeworks and problem solving, in-class as well as out-of-class. Once every two weeks or so, we have a graded team quiz. In a graded quiz, it is in the interest of all students to make sure that their team members are able to contribute, since the team is only as good as its weakest link.

I. INTRODUCTION

Most students have varying approaches to and motivations for learning. Hence they respond differently to different class room environments and instructional practices. The single one-size-fits-all approach, whihc I will refer to as the “singleton approach” to teaching cannot simultaneously meet the needs of every student in the classroom. However, this has dominated Physics education for centuries. In this model, students absorb the content of lectures and regurgitate said content on exams; passing with flying colors, without necessarily demonstrating or obtaining any success in the learning of physics. This method however, violates virtually every principle of effective instruction established by experts in educational psychology. [1–4]

In order to fix the system, a basic understanding of todays student is necessary. Todays students are profoundly different from the students of even a decade ago. Recent technological advances have had a major impact on student personalities, interests, and learning styles.

Historically speaking, the singleton approach has always been deficient, however its inadequacy is increasingly tangible due to the rapidly changing student. To put that change in perspective, todays average college graduate has spent only 5000 hours over their lifetime devoted to reading books but more than 10,000 hours with electronic gadgets of one form or the other, including but not limited to games, internet, cell phones etc. It is worth mentioning that the 10,000 hours do not include the 20,000 hours that they might have spent watching TV [5]. Then it falls on us as instructors to develop materials and courses that will develop student interest.

In order to start, let us look at people. According to G. Lawrence people in general can be broadly classified by the Myers-Briggs Type Indicator (MBTI) based upon their preferences pertaining to four scales derived from Jungs Theory of Psychological Types [6]. This information is summarized in Table .

Type 1	**Extraverts:** These people are triers, they will try things. **Introverts:** These people are thinkers, they will thoroughly analyze before performing an action
Type 2	**Sensors:** These are practical, detail-oriented, focused on facts and procedures **Sensing-Intuitors:** They are imaginative, concept-oriented, focus on meanings and possibilities
Type 3	**Thinkers:** skeptical, tend to make decisions based on logic and rules **Feelers:** appreciative, tend to make decisions based on personal and humanistic considerations
Type 4	**Judgers:** set and follow agendas, seek closure even with incomplete data **Perceivers:**adapt to changing circumstances, postpone reaching closure to obtain more data

TABLE I: MBTI Classification

Applying the above said facts about people to specifically students, and probling into a model developed by Felder and Silverman [7][8], a students learning style may be defined by the following four questions:

1. What type of information does the student preferentially perceive?
2. What type of sensory information is most effectively perceived?
3. How does the student prefer to process information?
4. How does the student characteristically progress toward understanding?

The student's mindset can be determined by the manner in which information is received and processed. A summary of classifiers and types is offered in Table II.

Although it is possible, it would be unreasonable to propose that instructors decompose the psychology of each student and make drastic yearly modifications to lesson plans to individually accommodate the needs of the current group of students. Such an approach would be too tedious and complex for an instructor to maintain if she has obligations outside of teaching one or two small to medium sized classes.

However, there has to be a near ideal middle ground that is more effective than the singleton approach yet not ridiculously strenuous on the instructor. Although this issue has received administerial attention and been the subject of much research there is still a need for much more research to be done.

As such it is apparent that a more effective and robust teaching style must not require a significantly greater amount of effort on the part of the professor than the singleton approach. Both instructors and administrators are aware of the need for such a system; that is not over-encumbering on the professor, yet robust enough to appeal effectively to the range of student learning styles and ability levels that exist in a normal classroom environment.

Team work as an Effective Strategy

Team work as an effective strategy has been developed over the last couple of decades. Over this course of time much research has been done to prove the effectiveness of team work and its status[10]. Teamwork helps all students at nearly all levels of education, even though the vast majority of students are not immediately cognizant of its positive effects.

Discussion amongst groups of students must occur in a language that all group members are comfortable with. This forces students to be able to discuss physics in a manner that is understandable to their peers. This is very fundamental to understanding, as it forces the student to learn the meaning of the language of physics rather than memorize a series of meaningless orthographic symbols.

Students that are fluent in the "language" and are strong in the technical jargon, benefit from being required to perform and express physics in the common tongue. This ability expresses true mastery over the subject as it demonstrates understanding that extends beyond memorization of content.

Group work also generates more class participation than a teacher-delivered lecture. Additionally there is a subset of undergraduates who listen more respectfully to their peers than teacher, perhaps in part due to the similar ability level of undergraduates, particularly in regards to the teacher-student language difference. Students often feel more comfortable asking their peers for help. Teamwork also helps improve the teaching skills of the students and allows for the development of a lot of the upper level physics concepts.

II. WORK DONE AT SUSQUEHANNA UNIVERSITY

At Susquehanna University we have developed crossword puzzles and team quizzes that with the intent of accommodating all learning styles without the need for hyper-customization on the part of the professor.

The tools that I have developed for this intent and their effectiveness will be the subject of the remainder of this paper. It is a first in a series of studies designed to help identify the impact of these practices in a class room environment. Data presented here has been obtained for the Introductory Physics classes taught at Susquehanna University over a course of the past 4 years. This data has been used to form hypotheses and design experiments possibly for further study.

I. Crossword Implementation

For both the intro level Physics class and the upper level Modern Physics class I designed simple crosswords taken mostly from definitions in the chapter. The crosswords did not require a lot of work but made a huge impact in terms of student familiarity with class material. The crosswords were offered as extra credit towards the student's final grade so the motivation is

TABLE II: Understanding the Student's Mind Set by how they learn

1. Information preference		
Sensory learners	they learn by experiencing — sights, sounds, they are also called hands-on learners	tend to be concrete, practical, methodical,and oriented toward facts.
Intuitive learners	they learn by memorization	are more comfortable with abstractions theories, mathematical models mostly innovative problem solvers
2. Sensory Information Perception		
Visual learners	they learn by pictures, diagrams, flow charts, demonstrations	
Verbal learners	written and spoken explanations suite verbal learners best	
3. Information processing		
Active learners	learn through physical engagement activity or discussions	do not learn much in situations that require passive learning
Reflective learners	learn through introspection and reflection	do not learn much in situations that do not provide opportunity to think about the information being presented.
4. Progression towards understanding		
sequentially	in a logical progression of incremental steps	Tend to think in a linear manner are able to function with only partial understanding of taught material
globally	want to understand everything and have trouble applying material until they know everything[9]	should be given the freedom to devise own methods of solving problems and be exposed to advanced concets ahead of time

there to actually do it.

Samples of Crosswords:

Samples of the crosswords given to the students are given in Figure 1 and Figure 2. The crosswords were intentionally kept very simple and were taken strategically to encompass the important material covered in the chapter.

II. Strategy 2: Team Quizzes

The undergraduate students that comprise the Introductory Physics class at Susquehanna University are a mix of Biology, Earth and Environmental Science, Chemistry, Bio-Chemistry, Physics and Mathematics majors. The students are divided into two groups, one for Biology, Earth and Environmental Science students (Algebra), which I will refer to as the "*lecture*" class is mostly comprised of Juniors. The other class consists of Chemistry, Bio-Chemistry, Physics and Mathematics majors (Calculus), which I will refer to as the "*technique*" class is mostly comprised of Sophomores. Most incoming students lack the technical language of physics, and tend to memorize the words without the understanding that should be associated with the study of material.

At the beginning of each semester the class was divided into groups of 3-4 students each. The student's team collaborates and works together on homework's and problem solving, in-class as well as out-of-class. Once every two weeks or so, we have a graded "team quiz". In a graded quiz, it is in the interest of all students to make sure that their team members are able to contribute, since the team is only as good as its weakest link.

III. RESULTS AND OUTCOMES

The results and outcomes of using these techniques are dicussed below:

Crosswords

The crosswords were intentionally kept very simple and were taken strategically from the definitions and important material covered in the chapter. Since they did not require a lot of work and were extra credit, it made it easier for student to get motivated. It actually made a huge impact in terms of students familiarity with the materials that were to be covered in class.

Team Work Strategy

The "team quiz" strategy has worked even better than anticipated. Not only do the students learn in

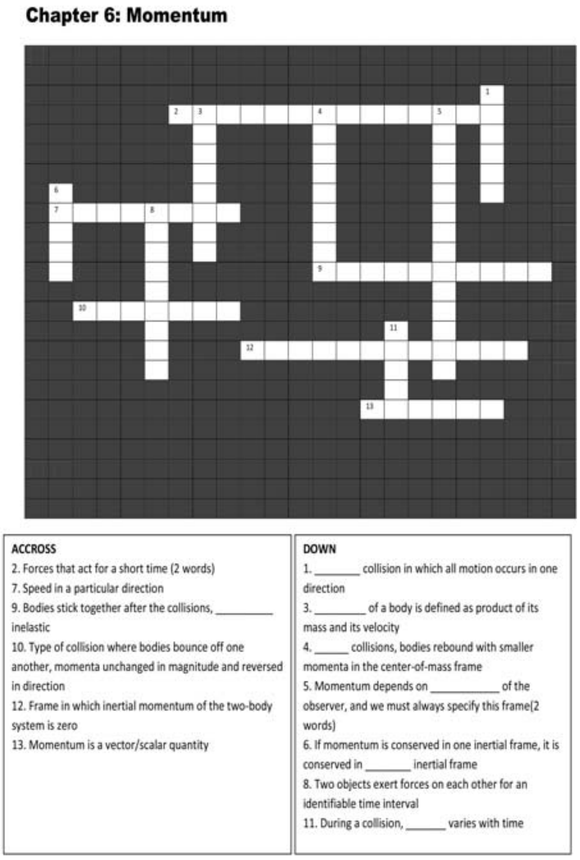

FIG. 1: Crossword Sample 1

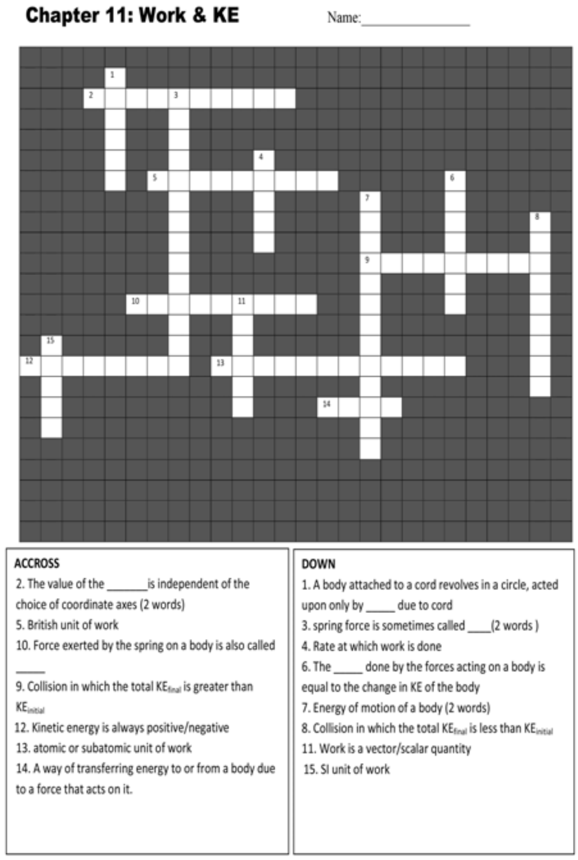

FIG. 2: Crossword Sample 2

an encouraging and productive environment but they also make sure that each of the team members is held to a higher standard. The questions were very helpful to start class discussions and in promoting student understanding. Less lecture from the instructor and more discussion between students is useful in promoting student understanding. It helps clarify conceptual questions that they may have by discussions with their peers.

IV. EVALUATION OF LEARNING GAINS

I have tried to evaluate the effectiveness of these ideas based on the student learning gains compared to the gains in traditional lecture classes not utilizing these ideas. We administered Force Concept Inventory Tests (pre-test, in the first week of the semester and post-test, administered in the last week of classes) and used normalized gain [11] to evaluate student learning progress. I have summarized the findings in Tables III and IV. The normalized gain was evaluated using the formula 1,

$$\text{Normalized Gain} = \frac{\text{Post-test - Pre-test}}{\text{Full-test - Pre-test}} \times 100\% \quad (1)$$

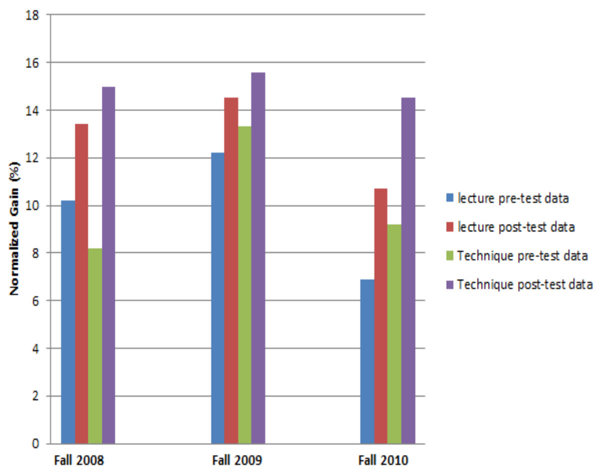

FIG. 3: Normalized Gain Percentage for all the Years tested

TABLE III: Normalized Gain Vs. Year

	students enrolled	Pre-test	Post-test	Normalized gain (%)	Gain over regular lecture
Fall 2008	A= 22 [a]	10.2 ± 4.6	13.4 ± 4.4	16.2%	15%
	C = 15 [b]	8.2 ± 3.6	15.0 ± 3.8	31.2%	
Fall 2009	A= 29	12.2 ± 7.3	14.5 ± 5.0	12.9%	1%
	C = 11	13.3 ± 6.6	15.6 ± 4.7	13.8%	
Fall 2010	A = 35	6.9 ± 6.3	10.7 ± 4.3 [c]	16.5%	9%
	C = 19	9.2 ± 8.7	14.5 ± 6.6 [d]	25.5%	
Fall 2011	A = 35	7.7 ± 2.7	X [e]		
	C = 19	10.5 ± 4.3	X [f]		

[a]A = Regular lecture
[b]C = Classes in which techniques were implimented
[c]number tested = 24
[d]number tested = 14
[e]missing data
[f]missing data

TABLE IV: Gain Boys Vs. Girls

		Pre-test	Post-test	gain
Fall 2008	Males = 7	7.0 ± 3.2	16.4 ± 3.6	40.9 %
	Girls = 8	9.3 ± 3.8	13.8 ± 3.7	21.7%
Fall 2009	Males = 7	16.0 ± 4.4	17.0 ± 5.2	7.1%
	Girls = 4	12.5 ± 2.6	13.3 ± 2.9	4.6%
Fall 2010	Males = 14	16.1 ± 6.8	18.7 ± 6.3 [a]	18.7%
	Girls = 8	8.4 ± 1.4	10.1 ± 2.2 [b]	8.3%

[a]number test administered to = 7 boys
[b]number test admisistered to = 7 girls

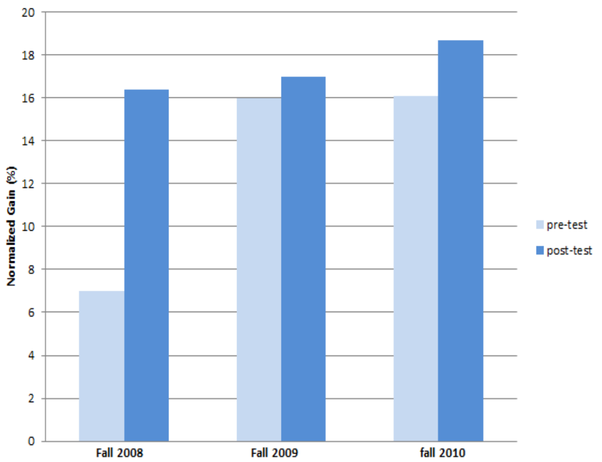

FIG. 4: Gain Comparison for the males in the Calculus Technique Class by Year, Pre-test score is represented by light blue and Post test result by Dark Blue

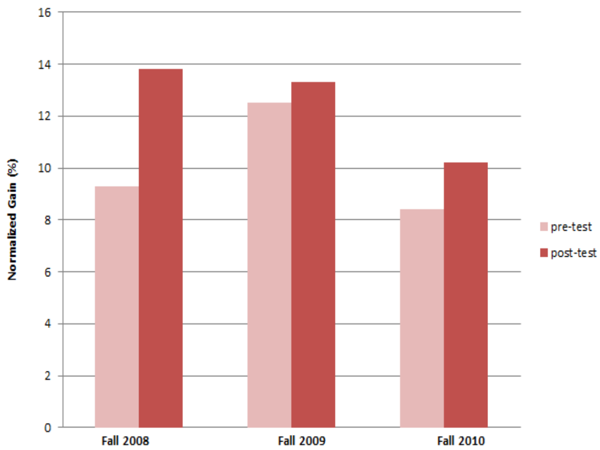

FIG. 5: Gain Comparison for the girls in the Calculus Technique Class by Year, Pre-test score is represented by light red and Post test result by Dark Red

V. STUDENT SURVEY

Some of the student comments that have attended the lectures in which the techniques were implimented are given below:

Crossword puzzles

Student 1 "I felt that the weekly crosswords were useful in the fact that they got the students to at least skim through the book and in my case actually read through the entire chapter. I feel students don't usually read the texts unless they are specifically assigned and this served as a way to get us to read the book on our own, which actually helped out a lot".

Student 2 "I thought the crossword puzzles were a useful way to reinforce the terminology used in physics. It was also a relaxed way to study and earn extra credit".

Group Quizzes

Student 1 "I didn't particularly care for group quizzes. I spent most of the time explaining the entire problem to people just so they could copy down the answers. I spent more time explaining things to other people than actually addressing things I was unsure that needed all my attention".

Student 2 "The group quizzes were helpful since you were able to use several minds to answer questions. When you work in groups, you are able to gain a perspective on questions you otherwise wouldn't have thought of."

VI. NEXT STEPS

For the purpose future study and evaluation of the findings, I am currently developing a student survey for the Calculus class taking the lectures using these techniques, a version of the Sample questionaire is given in V.

SUMMARY AND CONCLUSION

In conclusion, we find for our sample size that there was a marked difference observed in the gains for the simple lecture class Vs. the class that was implementing the techniques. The Algebra lecture class had an overall gain of 15.2 ± 6.5 % , whereas the Calculus Technique class had a 23.5 ± 6.3 % overall gain.

We also report that we observed a difference between the net gains achieved by the students on the basis of their gender. The overall gain for all years by the boys was 22.2 ± 3.7 % , whereas the girls accomplished a net gain of 11.5 ± 2.0 % .

ACKNOWLEDGEMENTS

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TABLE V: CROSSWORDS AND TEAM QUIZ SURVEY QUESTIONS

1. Are you a,
   a. Freshman b. Sophomore c. Junior d. Senior
2. What is your major?
3. Are you a
   a. Male b. Female
4. Did you attempt the crosswords in the class? What did you think of them?
5. On a scale from 1 to 5, 5 being the best, how satisfied were you with the crosswords?
   1(not satisfied) 2 3 4 5 (the best)
6. Did you work in teamwork in this class?
   a. Yes b. No
7. How many members were there in your team?
   a. 2 b. 3 c. 4 d. 5
8. Were you allowed to choose you own team or was the team assigned to you?
   a. Assigned b. chose our own
9. Did you feel like there were one or more people in your team that did not pull their own weight?
   a. Yes b. No
10. Did you have the option of firing a person that was not contributing to your team?
    a. Yes b. No
11. If so, did you have to fire any one?
    a. Yes b. No
12. What was the major reason for firing?
13. Did you yourself get fired from any team? What consequences did you have to face?
    a. No b. Yes, please explain
14. On a scale from 1 to 5, 5 being the best, how satisfied were you with the teamwork quiz strategy?
    1(not satisfied) 2 3 4 5 (the best)
15. What would you do differently to improve team quiz technique?