The Impact of Adding an Interactive Textbook on Student Performance and Satisfaction in a Freshman Introduction to Programming Course

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Abstract --This "Research to Practice" work in progress presents the results of a study of the impact of an interactive textbook on student learning and satisfaction in a freshman introduction to programming course taken by both computer engineering and electrical engineering in the spring of 2017. To enhance student performance in our Java course as well as increase their satisfaction, an interactive textbook for Java Programming from zynante.com was added to the set of required materials to see if the reported learning gains [1,2] would be repeated. Comparison is made between the spring 2017 cohort and the 2016 and 2015 cohorts who did not use the interactive textbook. Comparisons include (1) the percentage of students withdrawing from the course; (2) the distribution of final grades; (3) review of final exam performance, and (4) student evaluations of the instructor/course for the three classes. The results are unsupportive of an increase in student learning.

Keywords – interactive textbook, assessment

I. Introduction

An "Introduction to Programming" course offered in the first year of college presents significant challenges to some freshmen, particularly those without previous programming experience. Students still transitioning from high school habits to those needed for success in college also tend to struggle, notably when using text materials to guide their learning. Students report significant dissatisfaction with the course, particularly on course evaluations and comment on their need for additional support to help them learn the material.

Research shows that students spend more time working on activities available with an online, interactive, textbook compared to reading a traditional print textbook. The least prepared students show the most improvement, including those who have difficulty with text-based instruction [1]. Exam and project grades are higher for those students using an interactive textbook [2]. Both studies are for introductory programming courses.

In spring 2017, to enhance student performance in our Java course as well as increase their satisfaction, an interactive textbook for Java Programming from zynante.com was added to the set of required materials. Comparison is made between the spring 2017 cohort and the 2016 and 2015 cohorts who did not use the interactive textbook; the instructor, course structure, and print textbook were the same for all three groups. Comparisons include (1) the percentage of students withdrawing from the course; (2) the distribution of final grades; and (3) review of final exam performance. Another comparison which looks at the change in final grade with respect to the students' gpa is also done for the full class as well as for lower performing students. The results of these analyses are compared to those reported in [1, 2] to see if the gains that were observed in those works were also seen for the students at our institution. Finally, the effect of the use of the interactive textbook on student evaluations of the instructor/course for the three classes is also reviewed as a measure of student satisfaction with the change.

This paper is organized as follows: in the introduction, a summary of the rational for the study and the data used by the study to answer the question "does an interactive textbook enhance student learning and increase student satisfaction" are described. Next, a brief description of an interactive textbook is provided together with a summary of some of the research results which show positive responses to the question. The following two sections describe the class at Marquette University which uses the interactive textbook and summarize the results of the various performance benchmarks. The final section provides a concluding discussion of this work.

II. Interactive Textbooks

In this paper, the definition of interactive textbook put forth in [2] is used. An interactive textbook "refers to material involving less text, … having extensive learning focused question sets, animations of key concepts, and interactive tools" [2]. The background for this type of textbook, including the concept of and rationale for using such a textbook has been well reviewed in the background section of [2].

Several other eBooks which embrace most, if not all, of the learning strategies of the interactive textbooks are under development [3,4,5]. Faculty from Aalto University have developed and tested an interactive electronic textbook like the one used in this study with similar positive results [6], their work continues. While not strictly an interactive textbook, the use of similar interactive exercises to support an edX Massive Open On-line Course (MOOC) has also shown that students do engage positively with such materials [7].

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One of the authors of this paper became aware of the interactive textbooks offered by zynante.com during the 2015 Frontiers in Education Conference and became an early adopter for a spring 2016 digital electronics class. Based on the number of positive comments made by students in that class, this person recommended [8] that the interactive textbook for Java Programming from zynante be adopted for the Introduction to Programming class in 2017 particularly considering the positive results reported at American Society of Engineering Education (ASEE) conferences [1.2] and other venues as well as continuing research into strategies and methods to enhance interactivity as well as student behavior and performance.

In [2], the assessment of student progress promoted by the adoption of an interactive textbook was presented. Three different universities participated in this work—the University of Arizona with two courses in C/C++, an introductory course for freshmen and a second course at the sophomore level, the University of California at Davis taught MATLAB programming to engineering freshmen, and the University of Michigan presented elementary programming to non-engineering sophomore and junior level students which focused on the C++ language. In each case, the same instructor was involved in teaching the course first using traditional text material (books, notes), referred to here as the control cohort, and then a second time using the appropriate interactive textbook from zynante referred to as the test cohort. In general, the student work and associated points distribution used to determine final grades were similar for both cohorts. While individual grade items showed variation between test and control cohorts – some increased and others decreased, the final grades for each of the classes showed increases of 0.12 pts to 0.7 pts normalized to a 0-4 pt. scale. The gains for the lower half of the class ranged from 0.15 pts to 0.72 pts and the lowest quartile showed gains ranging from 0.2 pts to 0.93 pts. These results show that there is some effect on the overall achievement of students when using an interactive textbook. The question we posed was – would we also show an increase in achievement using the interactive textbook.

III. The Introduction to Programming Class Structure

The Introduction to Programming class in the department of Electrical and Computer Engineering at Marquette University is a three-credit class – consisting of 150 minutes of classroom instruction per week supplemented by a weekly hour and 50-minute discussion. This class is a required class for three programs, also called majors, in the college – Computer Engineering, Electrical Engineering and Biomedical Engineering. Between 10 and 15% of the students in the class come from outside the college; the three college programs are approximately equally represented in the remainder of the students.

The instructional team for the class consists of the instructor, a full-time faculty member, supported by two or three undergraduate teaching assistants recruited from among those who previously took the class and a graduate teaching assistant. All members of the team attend the lectures; the discussion sections are manned primarily by the teaching assistants. Over the course of the three years of this study, the same faculty member taught the class while the teaching assistants changed for each offering. The print textbook [8] used for the class also remained the same.

The items used to determine final grades in the course and the weight for each item for each of three years are shown in table I. Over the course of the three years of this study, the distribution of points is similar for the various course activities of homework (out-of-class activities), in-class activities, project and exams. In 2017, a participation category was added to the list of items used to determine the course grade. These participation points were assigned based on the completion of the assigned readings, participation exercises and challenge exercises in the Java interactive textbook. The recommended percentage of course points to "encourage earnest completion" of the interactive textbook activities is between 5 and 10 percent [9]. The distribution of activities and points is similar to those in the studies presented in [2].

TABLE I. GRADE POINT DISTRIBUTION

Grade Item	2015	2016	2017
Homework Exercises	35%	35%	20%
In-Class Activities	10%	10%	10%
Project	25%	20%	20%
Exams (including Final) (**best 3 of 4 exams in 2017)	30%	35%	40%
Participation	0	0	10%
Total	100%	100%	100%

The classroom experience is interactive with small lectures interspersed with relevant in-class programming exercises. During the exercises, the instructor and TAs roam the class room to answer questions, give suggestions, etc. The discussion section is used to assist the students in completing the homework exercises as well as to grade their short programs in person. Over the course of the three years, while the questions on the exams vary slightly, the same topical material was tested each time the class was offered. Final exams for all three years are virtually identical – questions were slightly rephrased and/or reordered. The only major change in the structure of the class beyond the addition of the interactive textbook in 2017 was to change the requirements of the final project to better match the material specifically covered in the lectures. In 2015 and 2016, the final project required that the students teach themselves some new material using instructor provided materials to efficiently complete the project.

IV. Performance of the 2015, 2016 and 2017 Student Cohorts in Introduction to Programmingt

The analysis of the performance of the three student cohorts was done with class data from the instructor on final exam scores and final letter grades aggregated with student record data of gpa, gpa in engineering and gpa in the major as well as the major designator. All student identifiers such as name and student id number were removed from the data prior to analysis by the co-author with no grading or record keeping responsibilities to ensure confidentiality.

The first two analyses done were the easiest to do – creating a histogram of letter grade distribution and looking at the final exam descriptive statistics for each of the cohorts. The grade histogram – given as percentage of students earning each letter grade from A through F as well as those who withdrew from the class is shown in Table II. All intermediate grades such as A-, B+, or B- were grouped with the primary grade designators, A, B, C, etc. Final exam statistics are shown in Table III for these same students.

TABLE II. GRADE HISTOGRAM – PERCENTAGE OF STUDENTS EARNING A LETTER GRADE

Letter grade	2015	2016	2017
A	59	59	44
B	29	26	29
C	6	14	11
D	1	0	7
F	1	2	4
Withdrawals	3	0	5
Total number of students	69	66	56

TABLE III. FINAL EXAM STATISTICS

item	2015	2016	2017
mean	78	64	68
median	78	66	75
hi	91	88	90
lo	50	25	23

One observation from these data is that the interactive textbook cohort has the highest number of the lower grades and withdrawals compared to the other two cohorts. In terms of the final exam statistics, the grades fluctuate in no pattern. Because the students could choose which three of the four exams to use, many students simply did not come to the final which would skew these data for the 2017 cohort.

Another performance comparison was done to see if there was evidence of "increased learning beyond expected" such as defined in [2] or [10]. To make this a quantitative comparison, the student's overall gpa was subtracted from the final letter grade for the programming class converted to its numerical equivalent [11]. For second semester freshman, the number of courses used to determine engineering or major gpas is very small and so these gpas were not used for the comparison. A positive value of this grade to gpa difference could be interpreted that the student has done better than expected. The average of this value might then be used as a measure of overall class achievement. For each of the three years, this value was calculated after all withdrawals were removed from the data set; the average differences are shown in Table 4 for all students and for those students who, for this study, were classified as lower performers based on gpa of 2.5 or less. These results also do not show an upward trend.

TABLE IV. AVERAGE DIFFERENCE (CLASS GRADE - OVERALL GPA

	2015	2016	2017
All students	-0.023	0.16	0.064
Lower Performers	-0.37	0.276	0.203

Each of the above performance analyses were also carried out for the students in each of the three programs. In none of these program cases was there unequivocal proof of improvement in the performance of the 2017 cohort compared to the other two years.

V. STUDENT SATISFACTION IN INTRODUCTION TO PROGRAMMING

End of semester course evaluations provided by the 2016 cohort showed a lesser level of satisfaction in the course than had been demonstrated by the 2015 cohort in both content and instruction, even though the academic performance of the two groups was not dramatically different. In fact, the 2016 cohort appears to perform better than previous groups apart from the final exam statistics. One of the reasons that the interactive textbook was added to the mix of materials for the course in 2017 was to see if the additional instruction with immediate feedback might give the students a more positive view of the course. It appears that this addition has worked for that.

Shown in Table V are the results from the course evaluations for selected questions relating to global review of the course, review of the class and review of instructor. In each of these questions, and the other 9 questions on the evaluation there was an increase in value between 2016 and 2017 ranging from 0.1 to 2 points. Comparing the 2015 and 2017 cohorts shows similar trends – with increases occurring for 7 of the additional 9 questions and holding the same for the other two of the 9 questions.

Review of the written comments for the three years also shows increased satisfaction. The written comments for class feedback were distributed into the following categories: "class quality", "instructor quality", "availability of help", "class mechanics", "book" and "other". In each of these categories, the number of negative comments decreased between 2016 and 2017 except for the class mechanics category. The book category has the most dramatic increase in positive comments – all of which mentioned the interactive textbook as a positive contributor to their learning. The written comments for instructor feedback had only two categories: "instructor quality" and "other". In instructor quality, the number of positive comments increased by a factor of 3 while the number of negative comments was reduced by that same factor of 3.

VI. DISCUSSION

This paper presents the results of a study on the use of an interactive textbook to enhance student learning and student satisfaction to see if results comparable to those found by other researchers [1,2] using the same interactive textbook would be obtained**.** The metrics used in this study do not show an increase in student performance though it appears that the satisfaction of the students with the course, in general, was significantly improved.

It's important to recognize that this study is not, and never has been, an attempt to replicate the study discussed in [2]. "Only direct replications, which repeat an experiment's procedure, can disconfirm or bolster a previous study [12]". Our study is simply an "in-house" assessment of the use of an

interesting approach to teaching and learning that shows promise based on the studies of others. It's our first attempt to "weigh (our) own evidence" [13]. As such, this has been an amazing learning experience.

Some of the usage evidence made available for our course(s) by zynante duplicates other research observations [14] regarding percentages of activity completion. Anecdotal evidence we've just started to hear is in line with other things observed regarding the "tiredness factor" and blatant cheating [15].

For the spring 2018 offering of the Introduction to Programming course, the decision was made to only use the interactive textbook, eliminating the print textbook from the supplies list for the class. We intend to review student achievement using the measures described in this paper for this new cohort to make sure that they achieve, at the very least, the same level of achievement as previous classes and maintain or improve the satisfaction demonstrated by the 2017 cohort.

Generation Z and the last of the Millennial learners may need these interactive teaching materials to match the achievement of previous generations of learners simply because this is the way they have learned to learn.

TABLE V. SELECTED QUESTIONS FROM COURSE EVALUATIONS

Table 5: Selected Questions from Course Evaluations			
Overall Class Evaluation	2015	2016	2017
How was the class as a whole?	3.9	2.7	4.1
How was the content of this class?	4.2	3.1	4.5
Responses: [**E**] Excellent=6 [**VG**] Very Good=5 [**G**] Good=4 [**F**] Fair=3 [**P**] Poor=2 [**VP**] Very Poor=1			
Class Evaluation	2015	2016	2017
This class positively impacted my problem-solving ability.	4.8	4.1	4.9
Assistance/help was readily available outside class.	4.6	4.3	5
Responses: [SA] Strongly Agree=6 [A] Agree=5 [SA] Somewhat Agree=4 [SD] Somewhat Disagree=3 [D] Disagree=2 [SD] Strongly Disagree=1			
Instructor Evaluation	2015	2016	2017
The instructor provided explanations that reduced confusion.	3.6	2.2	3.7
The instructor was interesting.	3.8	3.1	3.6
Responses: [SA] Strongly Agree=6 [A] Agree=5 [SA] Somewhat Agree=4 [SD] Somewhat Disagree=3 [D] Disagree=2 [SD] Strongly Disagree=1			
Response rate	51%	63%	54%
% responders with written comments	79%	62%	57%

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