Introducing Project-based Team Research into a C++ Programming Course

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Abstract

Introduction to C++ Programming is a required course by 5 programs in the College of Technology (computer, electrical power, mechanical, biotechnology, and computer information systems) with annual enrollment of more than 400 students. The course is mainly delivered face-to-face, but one section of the course was delivered online in the past. The course is suitable for students with little or no programming experience, yet offers the depth and rigorous treatment of theory and practice demanded by traditional C++ courses. Funded by the the Quality Enhancement Program (QEP) at the University of Houston (UH), we have revised the course to introduce research component and broadened the scope of 1 or 2 programming assignments to become a term research project. Students are required to collaborate in a team of 4-5 members to jointly search, identify, and solve a real-world problem. In this paper, results of this study after offering the course for one semester will be presented.

Introduction

Introduction to C++ programming is a primary software development course for all engineering technology programs and computer information systems major in the College of Technology. The course is offered as a three hour lecture course without discussion. Faculty usually asks students to write and practice examples during the lecture to improve studentsâĂŹ learning and hands-on capabilities. However, the offering of the course lacked a research component in the past. Given the nature of the course, students are normally given 6-7 programming assignments every semester, which allow them to practice all the important topics covered in the course. Funded by the the Quality Enhancement Program (QEP) an internal program at the University of Houston, we revised the course to introduce research component in order to broaden the scope of 1 or 2 programming assignments to become a term research project. Students will be asked to collaborate in a team of 4-5 members to jointly search, identify, and solve a real-world problem. The problem may include industry or academic research project. Since students who take this class are from 5 different programs, this background mix offers the potential of fostering interdisciplinary research work. Additional topics on effective library search, research methods, and technical writing are presented and uploaded to the Blackboard to enhance student learning experience.

Team-Based Research Approach

Due to high enrollment in each class (up to 60), students are required to form a group of not more than 5 to work on their research project. The planning for the faculty and students are listed as follows:

Week 1: Research project assigned. Students are asked to start by selecting a topic
Week 3: Introduction to research methods
Week 4: Introduction to library search and the UH Writing Center
Week 5: Presenting some sample projects and brainstorming
Week 6: Students submit a proposed topic
Week 8: Students submit a proposed research plan
Week 12: Students meet with the Writing Center
Week 14: Students present their project in class
Week 15: Final project is due

The instructor revises and approves each group's research topic based on originality, creativity, and expected development complexity, considering how feasible is the work to be completed by a group of students within the time constraints of the semester. As a result, students may receive suggestions to modify the project, or may be even asked to find a different topic. Once the topic has been established, students develop a plan to solve the problem, using the knowledge and skills gained in the course. The plan details the main objective(s), a brief description of the tasks to be completed, the expected role of each team member, and an execution schedule. The plan can be revised by the instructor to ensure the feasibility of the proposed research project and identify any need for a contingency plan. We developed lecture notes on research methods, library search, and best practices, which are presented to students during each semester. Based on this information, students will be expected to find a problem and make a research proposal, which may involve an industry or academic (e.g., from a faculty member) problem. We will encourage students to find their own research questions based on their individual interests or career path. For example, students who work in industry may suggest problems that they are involved at their workplace. We will also provide a list of suggested topics to students to guide their search or to use as an example.

Identification of Research Projects

Instructors will present a list of suggested topics and examples to students to guide their search or to use as an example from past semesters. In addition, we developed lecture notes on research methods, library search, and best practices, which are presented to students at the beginning of each semester. Based on this information, students are expected to find a problem and make a research proposal, which may include:

1. Individual interests or career path. For example, students who work in industry may suggest problems that they may have noticed at their workplace.

2. A problem presented by industrial advisory board members representing various industries

3. Faculty members in the department solving an applied research project

Students will be expected to review and report on existing literature and/or technical approaches that address their selected problem to make sure that their selected topic is not completely covered by another work and to gain background information. For example, students may be expected to compare the pros and cons of using different programming languages other than C++ for solving a given problem. Students will also learn how to cite others' work and the role of licensing agreements when adopting and extending existing software solutions. Team members meet with the Writing Center to receive further assistance on how to properly formulate their research proposal. Finally, students submit a written report and present their work in a short presentation to the class that last for 10–15 min including questions. The presentations normally include demonstration of the program that was developed for the research. The presentations are evaluated by faculty and all other teams in the class and and often span for a couple of sessions during the last week of classes because of the large number of students in each session.

Student Projects

During the pilot trial of introducing a team-based research project assignment to our introductory C++ course, the students developed an interesting array of research topics, possibly driven by the fact that they were enrolled in different study programs. Examples of some of these topics are:

- Spam e-mail filtering. The project addressed the roots and rationale of spam e-mail (unsolicited and sometimes malicious e-mail), as well as common techniques for both creating and fighting spam. By using e-mail spam data, the team developed a C++ program capable of reading an e-mail file and deciding with certain degree of accuracy, whether it contains spam or if it is a normal e-mail.

- Disease propagation model. The project studied the spreading of the Lyme disease–a common disease in the U.S. spreading from north-to-south and caused by the bacteria Borrelia Burgdorferi. In addition to analyzing the causes and propagation mechanisms, the team developed a C++ to model such propagation and to forecast the disease spreading in terms of the number of individuals affected by year.

- License plate recognition. The team studied optical recognition techniques. Despite the solution to this problem is far from trivial, the problem was moderated to the student's level of instruction by simplifying some of the assumptions regardless the source photographs. For instance, images were assumed to be noise free and taken at the right angle and magnification level. The team developed a C++ program that was able to acquire the letters and numbers from a license plate.

- Odds of a meteor hitting campus. The team investigated the risk of a meteor hitting UH campus using real meteor data from online databases. The project developed a C++ program to model the probability of such an impact given meteor characteristics, such as mass and traveling speed.

Grading

The scoring rubric is shared with the students when the project is assigned at the beginning of the semester to help them better understand the balance of the different activities in their final grade. The project grade accounts for 15% of the final course grade, so it is a significant component in a student's evaluation. However, a common problem often associated with group assignments is the lack of individual incentives to perform well given that normally everyone receives the same grade. Without a clear, individual incentive, it is easy for some members to free ride off the rest and still receive the same reward. To prevent this situation, each group receives a general score, but students receive a modulated score based on their individual contribution. The group score is given by a scoring rubric (Table 1) defining a standard quality assessment for 7 important aspects to be taken into account when doing research with a C++ flavor. Given the course topic, the students' ability to write correct and clear C++ code has great relevance (40%) in the evaluation.

ID	Concept	Weight
A1	Originality and complexity of the selected topic/problem	10%
A2	Use of C++	40%
A3	Creativity and novelty in solving the problem	10%
A4	Completeness of the solution, timeliness	10%
A5	Quality of the written report	20%
A6	Presentation	10%
		100%

Table 1: Scoring rubric used to evaluate the group performance of a research project.

Each aspect i ($i = 1, 2 \ldots 6$) of the group evaluation rubric has a weight w_i ($0 \leq w_i \leq 1$) that is judged by a value v_i ($0 \leq w_i \leq 5$). Table 2 shows the reference indicators. A value $v_i = 0$ would indicate that the group failed to provide material to be evaluated for category i. A group's score S is given by: $S = \sum_{i=1}^{6} w_i v_i$. However, each student's score is decided, in addition with the group score, with a self-evaluation showing the effort of each team member to the project development. Students are asked to agree with all participants what fraction of the total effort better represents their own contribution to the project, and with respect to each of the 6 evaluation activities shown in Table 1. An example of a self-evaluation table is depicted in Table 3 for a team of 5 students. Each column in the table adds to 100% and helps the instructor to understand how the different tasks were distributed among the students. Jointly, tables 1 and 3 allow a clear assessment of individual student performance and results, which is reflected in their final project grade.

ID	1	2	3	4	5
A1	Poor topic and/or trivial solution	Somewhat acceptable topic/complexity	Acceptable topic and problem complexity.	Good topic and/or difficult to solve	Exceptional topic of great importance
A2	C++ code does not compile	Code has some problems and does not work as expected	C++ code works but is inefficient	Good code using basic C++ concepts	Clear and optimized C++ code. Well documented. Use of advanced C++ concepts
A3	Little creativity, bland, predictable	Few original touches enhanced the project	Acceptable creativity	Clever at times; thoughtfully developed	Clever and unique approach
A4	Inaccurate or misleading; missed deadlines	Somewhat accurate	Mostly accurate; some inconsistencies or errors	Accurate; very few inconsistencies	Completed all objectives; facts are precise and explicit; all phases completed on time; above and beyond expectations; used variety of resources
A5	Confusing; unclear objective and/or results	Somewhat organized; results need improvement	Organized and results are somewhat acceptable	Done thoughtfully, good organization. Results mostly clear	Very well organized and logical report with exceptional content and clear results
A6	Confusing; unclear objective and/or results; no demonstration	Somewhat organized; lack of convincing results; no demonstration	Somewhat acceptable presentation; average program demonstration	Good organization; catchy presentation; good program demonstration; audience shows interest	Very well organized and logical presentation with exceptional content and clear results; effective demo; audience interest

Table 2: Evaluation guide for each assessment aspect in the group evaluation rubric.

Name	A1	A2	A3	A4	A5	A6
Student 1	50%	25%	0%	10%	10%	0%
Student 2	50%	25%	0%	10%	10%	0%
Student 3	0%	0%	90%	60%	10%	50%
Student 4	0%	25%	0%	10%	10%	50%
Student 5	0%	25%	10%	10%	60%	0%
	100%	100%	100%	100%	100%	100%

Table 3: Student self-evaluation form.

Course Evaluation and Achievements

We used opinion surveys to evaluate variations in the students' perception with regards to their own abilities to conduct independent research. For this, we asked students, both at the beginning and at the end of the semester, to rate their confidence with respect to 7 dimensions, or abilities, commonly needed to do successful research. These abilities are indicated in table 4. The self-ratings were quantified using the following linear mapping: 1=Poor, 2=Needs improvement, 3=Competent, 4 = Good, 5 = Excellent for numerical analysis of the results. The survey is depicted in Figure 1.

Surveys were anonymous and paper based to minimize students' anxiety of being exposed to penalties and encourage them to reveal their real opinions. However, anonymous surveys can also make easier for participants to provide fabricated answers, in particular, if students think that they would not benefit from answering the survey. To reduce the impact of false responses, the results were corroborated with the outcome of the overall course evaluation done by QEP with online student responses at the end of the semester. The online survey included equivalent questions to the ones in the paper surveys complementing the student evaluation of the course.

Survey of Research Skills

Using the rating scale on the right, how would you describe your current skill level in each of the following research areas?

	Poor	Needs Improvement	Competent	Good	Excellent
Formulating a research question or problem – the ability to develop a question that is testable though a systematic process.	○	○	○	○	○
Identifying basic principles and knowledge that relate to a research question or problem – the ability to make connections between the research question and the basic principles and knowledge in the field or discipline that will be needed to solve it.	○	○	○	○	○
Developing a research plan to address or resolve a specific question or problem – the ability to create a logical plan laying out the process that will be used to investigate the research question.	○	○	○	○	○
Collecting data to help answer a research question or problem – the ability to use appropriate tools or instruments to collect relevant data that will help answer the research question.	○	○	○	○	○
Conducting analysis of data to help answer a research question or problem – the ability to use appropriate analytic techniques to make senses of data that will help answer the research question.	○	○	○	○	○
Communicating research findings through written assignments – The ability to clearly, logically and accurately report research findings in written formats (e.g. reports).	○	○	○	○	○
Communicating research findings through oral presentations – the ability to clearly, logically and accurately report research findings in presentation formats.	○	○	○	○	○

Figure 1: Students are asked to complete this survey at the beginning and end of the semester to evaluate their perception of their own abilities to do research.

ID	Dimension
Q1:	Formulating a research question
Q2:	Identifying basic principles or knowledge that relate to research question or problem
Q3:	Developing a research plan to address or resolve specific question or problem
Q4:	Collecting data to help answer a research question or problem
Q5:	Conducting analysis of data to help answer research question or problem
Q6:	Communicating research findings through written assignments
Q7:	Communicating research findings through oral presentations

Table 4: Evaluation of students' perception towards doing independent research.

Student Response

Our experience introducing a research component into a C++ course was very positive and was well received by the students. Based on the anonymous surveys, we evaluated the variation in student perception about their confidence in doing research by comparing their responses at the beginning and end of the course. Forty-nine students completed the survey, who represent 83% of the total number of students in the class. We observed a positive variation in all the 7 aspects that we studied as depicted in Figure 2. The two major impacts were in the students' ability to communicate their findings in writing and during the oral presentation, and in developing a research plan. Figures 3–9 show the normalized histogram of the answers broken down by question number.

These results are very consistent with the ones obtained in the general course evaluation survey done at the end of the semester. The survey was answered by two-thirds of the students in the class and included questions similar to the paper survey, but with slightly different wording. Answers to the student ability to "formulate a research question or problem" was "very much" for 15% of the responders, "quite a bit" for 50%, "some" for 27.5%, and "very little" for 7.5%.

The ability to "identify basic principles and knowledge related to their research question or problem" was responded as "very much" by 25% of the students, "quite a bit" by 42.5%, "some" by 25% and "very little" by 5%. The ability to "your ability to âĂIJdevelop a research plan or address or resolve a specific question or problem.", "very much" by 32.5% of the students, "quite a bit" by 40%, "some" by 20% and "very little" by 5%. The ability to "collect and interpret data and information in an attempt to resolve the question or problem" was indicated as "very much" by 25%, "quite a bit" by 45%, and "some" by 27.5%. Finally, the "awareness of the responsible conduct of research" generated balanced results: "very much" by 30%, "quite a bit" by 37.5%, and "some" by 32.5%. In a few cases, some survey responders skipped answers and as a result, the sum of percentages may not add to 100% for some of the questions.

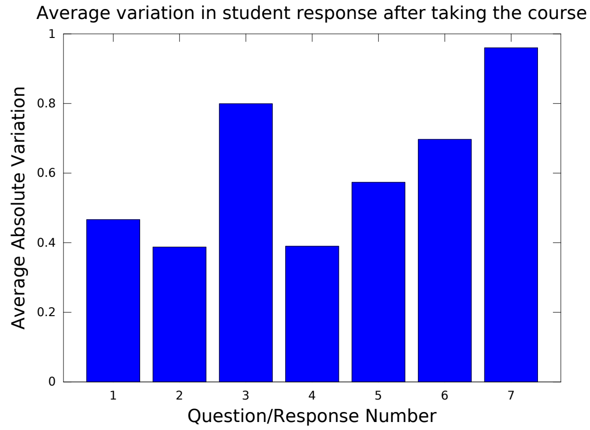
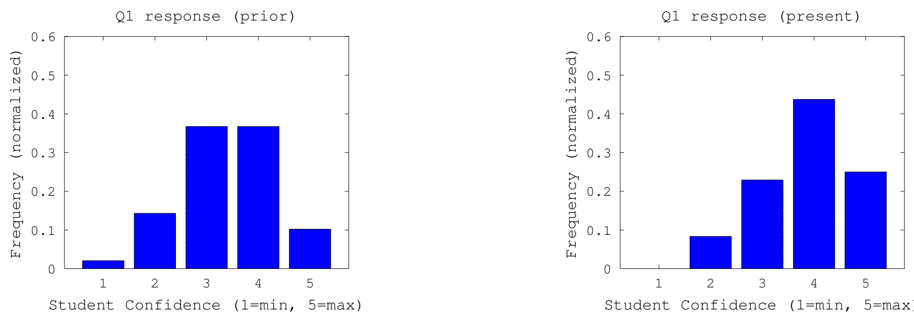
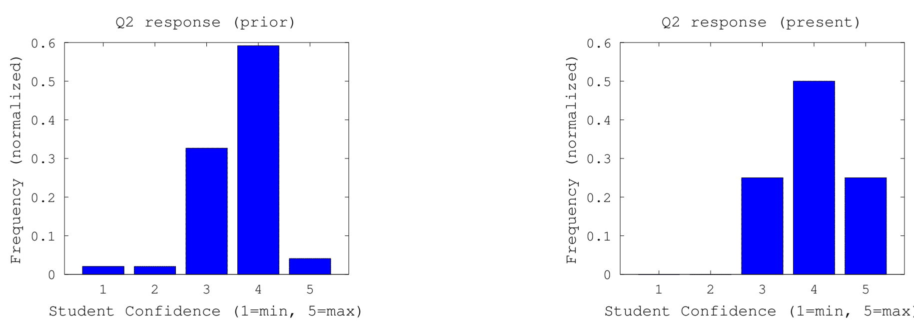


Figure 2: Variation in student response per question after taking the course. Positive changes indicate better student confidence with respect to the given question.



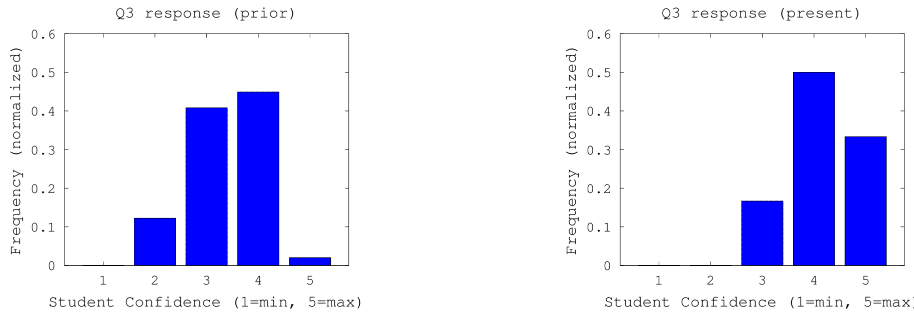
(a) (b)

Figure 3: Q1: "Formulating a research question". Frequency distribution of students' response: (a) at the beginning (average: 3.39), and (b) at the end of the semester (average: 3.85).



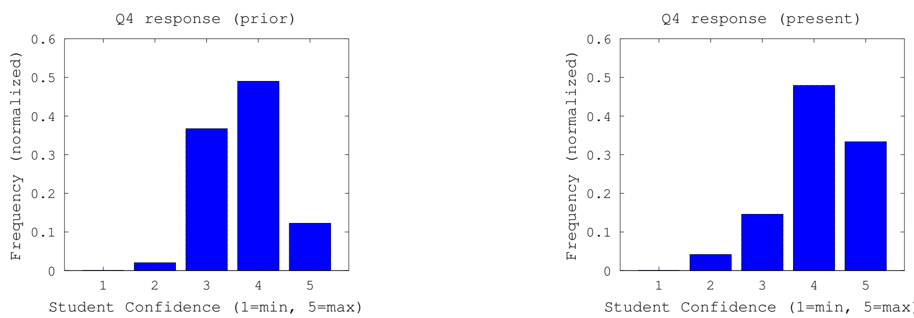
(a) (b)

Figure 4: Q2: "Identifying basic principles or knowledge that relate to research question or problem". Frequency distribution of students' response: (a) at the beginning (average: 3.61), and (b) at the end of the semester (average: 4.00).



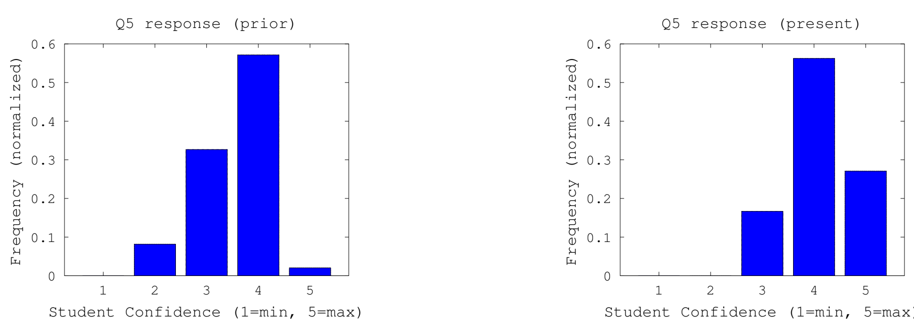
(a) (b)

Figure 5: Q3: "Developing a research plan to address or resolve specific question or problem". Frequency distribution of students' response: (a) at the beginning (average: 3.37), and (b) at the end of the semester (average: 4.17).



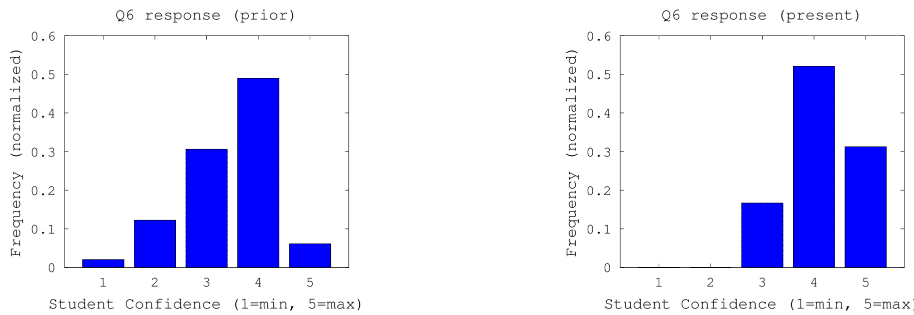
(a) (b)

Figure 6: Q4: "Collecting data to help answer a research question or problem". Frequency distribution of students' response: (a) at the beginning (average: 3.71), and (b) at the end of the semester (average: 4.10).



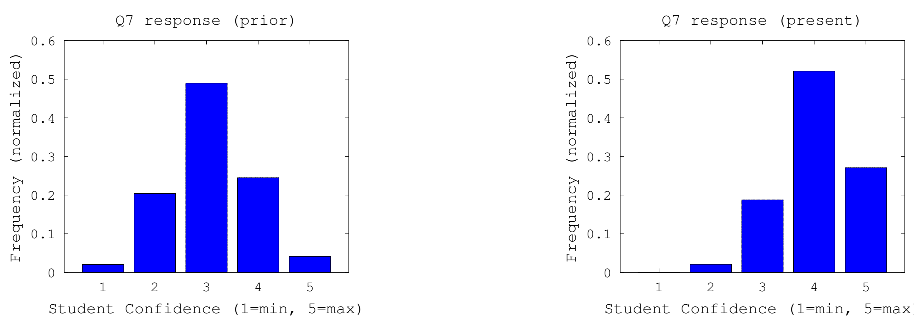
(a) (b)

Figure 7: Q5: "Conducting analysis of data to help answer research question or problem". Frequency distribution of students' response: (a) at the beginning (average: 3.53), and (b) at the end of the semester (average: 4.10).



(a) (b)

Figure 8: Q6: "Communicating research findings through written assignments". Frequency distribution of students' response: (a) at the beginning (average: 3.45), and (b) at the end of the semester (average: 4.15).



(a) (b)

Figure 9: Q7: "Communicating research findings through oral presentations". Frequency distribution of students' response: (a) at the beginning (average: 3.08), and (b) at the end of the semester (average: 4.04).

Conclusion

The use of a project-based research assignment as a teaching vehicle for the course *Introduction to C++ Programming* will have a positive and major impact for students of the College of Technology as it is a core course required by 5 programs. We conducted a pilot trial with very positive results and good student acceptance as evidenced by pre/post survey results, which indicate that studentsâĂŹ knowledge and experience of research methods greatly improved during the course of the semester. The project-based research assignment has been currently adopted by two sections of the course and we expect that the proposed course enhancement will serve to increase students' skills and interest in research, as well as to give them a realistic application for the knowledge that they gain in the classroom.

References

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