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A Field Study to Promote Undergraduate Student Learning Through Inquiry-Based Research

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ABSTRACT

The purpose of this study was to explore methods to promote effective undergraduate student learning through inquiry-based research in the classroom and to determine what the benefits of doing so might be. The study begins by outlining how undergraduate inquiry-based research increases the undergraduate student learning model and then lists steps to accomplish this process. The study outlines two options offered as a workable process to promote faculty and student inquiry-based in-class research. The first option is for undergraduate students to engage in inquiry-based research with the assistance of one-on- one mentoring by the instructor. The second option allows for teams of students to do research with the assistance of mentoring by the instructor. The results of this current study concluded that an undergraduate inquiry-based research program benefits students and faculty in several ways as described in this paper. The study findings may contribute to a better understanding of how colleges and universities can further promote undergraduate learning in the classroom though student-centered, inquiry-based research.

INTRODUCTION

"Tell me and I forget. Teach me and I remember. Engage me and I learn."

- Chinese proverb.

Most would agree that the purpose of research is to seek new knowledge, but many fail to realize that research is a conversation, often one that spans centuries. Aristotle used deductive reasoning based on observation to produce *Physics* (Aristotle, trans. 1996) and *Meteorology* (Aristotle, trans. 2006) textbooks. Sir Isaac Newton (Newton, trans. 1999) is sometimes credited as the first to describe the modern Scientific Method. Newton's methodology was a rigorous process of data collection and analysis. Among Newton's accomplishments are universal gravitation and the classical equations of motion. One hallmark of research is that it stimulates new thinking and application of previous work. Such was the case with L.F. Richardson's (1922) adaptation of Newton's equations of motion to account for motion of a gaseous atmosphere above a rotating earth. Richardson's work, in turn, could not be realistically implemented until the advent of digital computers when the first "proof of concept" model was run in April 1950 ("The History," 2016).

Promoting a successful undergraduate learning experience is a goal of colleges and universities. One of the ways to significantly enrich this learning experience is by requiring undergraduate students to engage in inquiry-research projects early on and regularly throughout their degree program (Boyer Report, 1998; Hancock & McCullough, 2007). Therefore, it behooves colleges and universities to purposely create an active learning environment across the institution, one dedicated to an inquiry-based research

culture with the objective of having faculty and students engaging in scholarly activities such as inquiry-based research through curricular or co-curricular learning opportunities. Such a policy will allow undergraduate students to attain the skills to investigate hypotheses, solve problems, advance knowledge utilizing various disciplines, and produce research papers of publication quality (ERAU, 2016).

To support development of pedagogically sound inquiry-research focused curricular, undergraduate students take an introductory research course, and then they practice to master these skills through a variety of research-based activities throughout their degree program (ERAU, 2016). One of the benefits of doing so is that students are taken to the higher levels of Bloom's Taxonomy such as application, analysis, and evaluation by working with the instructor in acquiring research data through a variety of techniques: analysis of extant data; analysis of subject matter; interviewing; observing; focus groups and quantitative surveys (Rosett, 1988). Such an educational approach can assist in shifting the undergraduate education focus from the knowledge and compression levels of Bloom's Taxonomy (Bloom, 1956) spent on activities designed to help learners recall facts and understanding, to promoting reaching the application, analysis, and evaluation level along with gaining critical thinking skills (Munzenmair & Rubin, 2013). Therefore, undergraduate degree programs that incorporate inquiry-based research have been said to have a positive impact to increase students' higher levels of learning, and increasing student retention, graduation rates and entrance into graduate programs (Crowe & Brakke, 2008).

Allowing an instructor and student joint inquiry-based research program designed to create a culture of active learning within the institution provides students with an ongoing source of one-on-one mentorship geared to a research culture university wide (ERAU, 2016). Therefore, after undergraduate students are introduced to the skills of research in an introductory research methods course that requires an English and statistics prerequisite (ERAU, 2016), they practice and master these skills through a variety of courses with research-based activities that are designed to gauge the progress of their research knowledge and skills throughout the curriculum of the students' respective degree programs (Boyer Commission, 1998).

We have found that it is not uncommon for undergraduate students to be abounding with curiosity, questions, and thoughts when introduced to inquiry-based research. Such student interest opens intellectual possibilities that will simulate original thought and critical thinking skills during their science, social studies, and humanities studies (Boyer Commission, 1998).

The following describes our research that consists of a two-option approach to promote and encourage student inquiry-based research that enriches undergraduate research learning and engagement to enhance faculty and student joint research.

GENERALIZED OPTION 1

Phase 1

At the beginning of an undergraduate course that explores diverse fields to complement and contrast with their major fields of study (Boyer Commission, 1998) and requires students to conduct research, students are given an overview of the reasons to participate in inquiry-based joint research with the instructor. Among the reasons discussed are the following:

- Gaining skills that can be used throughout their time in the degree program and can be useful after graduation.
- Gaining a more in depth understanding of the discipline students are studying.

- Gaining an understanding of the advantages of showing authorship in a referred journal paper on a resume. The student would be the senior author. This will include writing the introduction, problem statement, literature review, and the draft of the final article. The student would work jointly with the instructor in data processing, statistical analysis, and interpretation of results. The instructor would provide data for mentoring in statistical analysis, research methods, and the duties of a senior author.

Next, students receive an overview of the research process to include the following:

1. Defining and/or articulating a research problem.
2. Identifying the major issues, problems, or questions surround the topic which includes background research on the topic using internet and library resources such as scientific journal articles.
3. Designing a course of action to solve a research problem using appropriate multidisciplinary principles.
4. Applying ethical principles in research.
5. Conducting research independently and/or collaboratively.
6. Developing decisions or conclusions based on the analysis and synthesis of evidence.
7. Communicating research results.
8. Students are briefed that their final research project will be written in the format of a scientific journal article. It will include the following sections: abstract, introduction, methods, results (with table and figures), discussion, conclusion, acknowledgements, and literature cited.

Phase 2

After the student identifies a research topic, he or she engages in a research project that has publication potential. The instructor mentors the student in any additions, deletions or other changes in order to prepare for the research. Students follow the research process to include the following:

- **Problem statement:** Student provides a draft problem statement, and instructor provides editorial suggestions. This includes a statement of problem importance. Student rewrites as needed.
- **Hypothesis:** Instructor discusses with the student the utility of a null and alternate hypothesis and how hypothesis testing related to statistical analysis. The student drafts a null and alternate hypothesis for instructor approval.
- **Literature review:** Students conduct a literature review, and the instructor will examine for completeness and the flow of the ideas.
- **Description of data:** The next step is for the student to gather data to test the hypothesis. The instructor will review the data, and will make suggestions if the data described are not adequate for the problem. Student rewrites as needed.
- **Research methods:** The instructor will explain the research methods available and which is appropriate for the data set and the hypothesis.
- **Statistical analysis:** The student may have completed an introductory statistics course, but experience in the use of inferential statistics or associated analysis methods will usually be lacking. Consequently, the instructor will need to mentor the student on statistical analysis specific for the data being analyzed. Since this is not a research methods or statistics class, instruction in these areas will be limited to the problem being analyzed.

Other methods and analysis are obviously possible, but the broad outline presented here will likely work for most quantitative research methods and analysis. The common process will be to evaluate assumptions, run the appropriate analysis, and compare the computed value ("F", "t", etc.) with the tabular value for that test. If the computed value is larger than the tabular value at a pre-specified

probability level, the analysis is declared statistically significant. Then, the null hypothesis is rejected and the research (or alternate) hypothesis is accepted (Gould & Ryan, 2013).

Operationally significant: Since, statistical significance does not guarantee practical or operational significance. The student and instructor must discuss what the analysis means in the "real world." Hopefully, there will be both statistical and practical significance. The statistical significance indicates there is a high probability that the results are not due to random chance, and a repeat of the analysis using different data would result in similar results (Gould & Ryan, 2013).

Publication: Instructor will mentor the student in finalizing the paper for publication. This will include ensuring that all publisher guidelines are met (format, media to deliver paper, hard copy, CD, etc.). Student will be briefed on the duties of a corresponding author.

Instructor mentors the student in any additions, deletions or other changes in order to prepare the paper for publication. It is presumed the student's paper will have, at a minimum, a draft problem statement, a literature review and a description of data to be used in the study.

GENERALIZED OPTION 2

Description: Inquiry-based research courses also can be by performed by an instructor led team of students to allow for joint and collaborative efforts (Boyer Commission, 1998). This also allows for a student who is not in the instructor's class to join the ongoing research project. The following is an example outline of Option 2.

Team Assignments

Assume a team of five students prepares a research paper based on data collected in five different global locations.

1. Instructor briefs all participating students on the intent, scope and importance of the project.
2. Hypothesis: Instructor discusses the utility of a null and alternate hypothesis, and how hypothesis is related to statistical analysis.
3. Literature review: The instructor assigns a sub category of the data for description needed for the literature review. For example, each student is responsible for data for one of the global locations being studied.
4. Research methods: The instructor assists the student team in the research method selected, and explains to the members why it is appropriate for the data set and the hypothesis or hypotheses.
5. Statistical analysis: The students should have already have completed an introductory statistics course, but experience in the use of inferential statistics or associated analysis methods may be lacking. Consequently, the instructor will need to mentor the student team on statistical analysis specific for the data being analyzed.
6. Under the mentor of the instructor, Student A merges the five data sets and runs descriptive statistics for the merged data. Student B graphs the data. The instructor and all students meet to evaluate the data and determine if the data meet the assumptions of the proposed analysis and discusses any potential data problems. Student C writes the paper introduction and literature review sections and references. Student A writes the methods section. Student D runs a statistical program to analyze the data. Student E compares the statistical analysis with the hypothesis and drafts the results section. Student B drafts the conclusion and summary sections. Student D drafts the abstract and acknowledgements. The instructor and all students meet and review the assembled research paper.

7. The instructor meets with the student team and advises that the usual process will be evaluation of assumptions, then runs the appropriate analysis and compares the computed value ("F, "t", etc.) with the tabular value for that test. If the computed value is larger than the tabular value at a pre-specified probability level, the analysis is declared statistically significant. The null hypothesis is rejected, and the research (or alternate) hypothesis is accepted. The instructor will lead the student team through this process.
8. The instructor briefs the student team that statistical significance does not guarantee practical or operational significance. The students and instructor must discuss what the analysis means in the "real world". Hopefully, there will be both statistical and practical significance. The statistical significance indicates there is a high probability that the results are not due to random chance, and a repeat of the analysis using different data would result in similar results.
9. The project can then be readied for publication: The instructor meets with the student team and reviews the draft paper. Then, the team assembles the entire document and carefully edits the paper to ensure consistency with the publisher's guidelines.

Useful Topics for Instructors to Emphasize to the Students

First time researchers often have minimal understanding of the impact assumptions can have on the research process. Violating the assumptions for a test statistic can result in incorrect or confusing results. Students should be encouraged to test their data to assure that all assumptions are met. In addition to assumptions, the authors have observed student issues with other aspects of the research process. A common problem is the expectation that data will be available when, in fact, certain restrictions may apply. Some data have security restrictions, other data may be regarded by a private company as proprietary. Occasionally data may be in paper copy only or in coded format that would require a major expenditure of time to convert to an easy-to-use format. Data with embedded errors may pose different, but serious, difficulties. Problems related to ethics and privacy should be addressed before the project begins. These concerns may apply to any data not collected by the researcher. Attention to potential data problems could minimize severe problems later.

CONCLUSION

The purpose of this study was to explore how to promote effective undergraduate learning through inquiry-based research. It is concluded that students' participation in pedagogically sound inquiry-based research results in numerous benefits for students and instructors such as the following: 1) Students tend to be become very engaged researching selected topics related to their degree program, thus furthering their learning process beyond course subject learning outcome requirements; 2) The learning process of both instructor and students is enriched, particularly in subjects of interests, 3) There is increased confidence in undergraduate students regarding their specific area of undergraduate study; 4) Students receive the benefit of having the instructor's vast experience of inquiry-based research process and analysis of data through a one-on-one mentorship (Madan & Teitge, 2013); 5) A research-supportive curriculum provides undergraduate students with a learning experience rooted in the process of discovery through research and inquiry (ERAU, 2016); 6) Students create purpose statements and hypotheses that allow for understanding of how to apply inquiry-based research designs throughout their science, humanities, and social sciences course subject material; 7) An inquiry-research based learning approach can assist in shifting the undergraduate education focus from the knowledge and compression levels of Bloom's Taxonomy (Bloom, 1956) that is spent on activities designed to help learners recall facts and

understanding, to promoting application, analysis, evaluation levels (Munzenmair & Rubin, 2013); 8) Students and faculty can further benefit by allowing more practicing and mastery level research-related and focused assignments (ERAU, 2016); 9) Undergraduate curricula are strengthened with the addition of inquiry-based research and critical thinking skills research methods courses; 10) Faculty gain personal satisfaction from mentoring and witnessing students publish papers; 11) Inquiry-based research can lead to new knowledge, benefiting communities, and increasing opportunities for further research and grants; 12) Students are provided with the opportunity to develop a research paper that has publication potential.

Final Thoughts

The purpose of this study was to explore how to promote effective undergraduate learning through inquiry-based research in the classroom and the benefits of doing so. This paper outlined two options offered as a workable process to promote faculty and student inquiry-based research. Additionally, the results of this current study concluded that an undergraduate inquiry-based research program benefits students and faculty in several ways. If this is to work, the faculty must "buy in" on this process. From discussions with other faculty, it became clear that they are very interested in working with student inquiry- based research. In sum, it was determined that student inquiry-based research is an excellent process for increasing the educational value of the undergraduate learning process by having a positive impact on undergraduate curricula and students' degree program experiences.

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