A Pilot Study on the Impact of Creative Achievement on Academic Achievement in Media-Oriented CS1

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1 Abstract

We present the results of a pilot study relating creative achievement and academic performance in introductory computer science courses. The experimental CS1 course was based on the Java-based Media Computing approach, with some deviations to emphasize concepts of object-oriented programming. Students' creative achievement was measured quantitatively using the Creative Achievement Questionnaire, a reliable and valid instrument. The study data comprises questionnaire results along with lab scores, exam scores, course grade, GPA, ethnicity, and gender for fifteen students, including four CS majors and eleven non-CS majors. No significant relationship was found between creative achievement and either GPA or course grade, although some more fine-grained relationships were discovered between creative achievement and specific kinds of assignments. A discussion of these relationships is provided, along with implications for practice and recommendations for future work.

2 Introduction

Teaching introductory Computer Science courses poses significant challenge. Students in introductory courses often have vastly different experiences and expectations, and hence motivating them to succeed is a difficult course design problem. There has been a great deal of research devoted to increasing student's motivation through engaging projects, with the goal that this will result in corresponding increases in retention, recruitment, and performance. Popular examples include multimedia computing [8, 18], "nifty" projects [14], and game-oriented coursework [1]. A common component of these is that they explicitly involve *creativity.* In fact, the creative aspect of the courses is named as a primary motivator for the students and success factor in many studies. However, as observed by Knobelsdorf and Romeike, there has not been much published work that addresses creativity explicitly [12].

This work is an attempt to discover and quantify the relationships between creativity and success in introductory computer science, and we do so by integrating techniques from creativity research and computer science education research. There are important differences between these two bodies of work, one of the most significant being that educators, by and large, agree that students' academic achievements can be assessed and validated; on the other hand, the quantification of creativity is more hotly contested. We therefore begin by identifying specifically what we mean by "creativity" and its measurement before explaining the context of the study.

2.1 Creativity and Creative Achievement

Creativity research explores many themes, including individual creativity, influences, creative products, and collaborative creativity [17]. There is neither a single accepted definition for "creativity" nor universally-accepted tools for measuring it. However, creativity is relative to both the creator and the context. For example, Boden [3] distinguishes between psychological and historical creativity, the former indicating an idea new to the creator and the latter, to a community. This was extended by Dasgupta [5], who further distinguished between *originality* (new and has value) and *novelty* (simply new). Dasgupta's model therefore has four classifications for creativity: psychological novel (PN), psychological original (PO), historical novel (HN), and historical original (HO). From a constructivist educational perspective [2], a common goal is for students to develop PO-creative ideas — ideas that are new to the student, even if they are not historic or original — while fostering the development of HN- or HO-creative ideas. For example, a student who builds a mental model of mergesort has been PO-creative: mergesort is not new to the Computer Science community, but the idea is new and valuable to the student.

Research has shown that creativity impacts education. Romeike [16] found that creative activities increase students' motivation thus enhancing their understanding of computer science concepts. Such creative activities cultivate creative characteristics in the students, such as fluency, flexibility, and creative problem solving. Similarly, Knobelsdorf and Romeike [12] report that high creativity is often associated with a desire to learn, explore, and understand. Lewandowski et al. [13] found that not only does creativity increase motivation but it also increases interest in Computer Science and as a consequence improves retention.

We note that, according to the definitions offered by the creativity research community, Computer Science is a undoubtedly a creative endeavor. Both practitioners and students create useful artifacts and models, regardless of where they fall in Dasgupta's taxonomy. By virtue of the discipline's connection to mathematics and engineering, creativity is ingrained in computer science, whether one is creating an interactive multimedia interface, an improved process model, or statistical analysis software.

Contemporary techniques for teaching computer science share a common characteristic: they leverage this creative aspect of the discipline. Researchers who cite creativity as a motivator reference such HN-creative (or even HO-creative) activities as creating multimedia exhibits, games, and visualizations. However, it is important to recognize that a student who is developing simple software to count Fibonacci numbers is engaged in a PO-creative endeavor, since the software and its result are new to the student.

2.2 The Creative Achievement Questionnaire

Creative achievement refers to the set of creative products generated by an individual. The Creative Achievement Questionnaire (CAQ), developed by Carson et al. [4], is an instrument for measuring creative achievement that has been shown to be reliable and valid. The CAQ is based on five assumptions:

1. that creative achievement is best assessed in a domain-specific manner;
2. that creative achievement implies possession of skills in the domain;
3. that recognition by experts is the most valid and practical criterion for judgement of accomplishment;
4. that recognition by a broad range of experts implies greater accomplishment;
5. and that fewer individuals attain higher levels of achievement.

These assumptions hold for this study as well. Note that justification for these, in terms of creativity research, is provided by Carson et al. [4].

The CAQ comprises 96 items over three parts. Part One presents a list of 13 areas of talent, and the participant writes a checkmark by those in which he or she self-identifies as having more talent than the average person. Part Two lists concrete achievements in ten domains of artistic and scientific endeavor: Visual Arts, Music, Dance, Creative Writing, Architectural Design, Humor, Theater and Film, Culinary Arts, Inventions, and Scientific Inquiry. For each domain, the concrete achievements are listed and ranked in order of increasing creative achievement, as judged by experts in the corresponding disciplines, and assigned weights from zero to seven points. Part Three consists of three questions that ask the participant to identify how others perceive his or her creativity, and it also provides a space for free-response statements regarding personal creative achievement. A subject's CAQ score is determined by adding the weighted scores from Part Two; Parts One and Three do not directly contribute to the CAQ score.

2.3 Media computing in CS1

The media computing approach was pioneered at Georgia Tech in a course for non-CS majors [8]. It involves teaching fundamental concepts of computing through manipulation of media. Specifically, the approach is data-first: students are introduced to the encoding representation of the data and are then gradually introduced to algorithms and programming concepts, such as conditionals and loops, as a useful way to manipulate that data.

The experimental course for this study used media computing themes in combination with some expanded lessons on object-orientation. Based on the themes of media computation and the results reported in the literature [10, 18], we hypothesized that there would be statistically significant relationships between creative achievement and students' performance in a media computing introduction to computer science. This hypothesis is founded in creative achievement as a predictor for future creative activity and in the relationship between creativity and motivation. Specifically, we hypothesized that creative achievement in the Visual Arts, Music, and Scientific Inquiry domains would correspond to high performance in corresponding media computing activities.

3 Approach

The experimental course was offered to a class of approximately 40 students in Spring 2009 at Ball State University, a primarily undergraduate institution. The course is required for Computer Science majors and Computational Physics majors, and it is often taken Music Technology majors as well. The master syllabus for the course calls for lessons grounded in imperative, object-oriented programming. Each week included three hours of lecture and a 75-minute lab. The lab assignments included problems to be completed during the closed lab as well as some to be submitted before the next lab meeting. Table 1 provides an overview of the semester's activities and their corresponding creative domains.

The experimental section used *Introduction to Computing and Programming with Java: A Multimedia Approach* [9] as a textbook for the first eight weeks of the fifteen week semester. During this time, assignments were given from the book in accordance with the multimedia themes. The remaining weeks of the semester were devoted to a deeper exploration of concepts of object-orientation, and media themes were carried into

Week	Lab Topic	Creative Domain
1	Introduction	N/A
2	Turtle Graphics	Visual Arts
3	Pixel Graphics	Visual Arts
4	Loops	Visual Arts
5	Nested Loops	Visual Arts
6	Nested Loops	Visual Arts
7	Conditionals	Visual Arts
8	Conditionals and Loops	Music
9	OOP	Visual Arts
10	OOP	Music
11	OOP	Music
12	OOP	Music
13	I/O	Music
14	Simulation	Scientific Inquiry
15	Searching and Sorting	N/A

Table 1: Overview of lab topics and corresponding creative domains, as identified in the CAQ

these lessons as well. For example, students learned the Strategy and Composite design patterns [6] by implementing vector graphics, animations, and audio playback software. The I/O project in week 13 dealt with MIDI-like stream parsing for music synthesis. The final two weeks of the semester took a twist on media computing, using the image libraries from Guzdial and Ericson to create a graphical simulation of diffusion limited aggregation (DLA) and Eden clusters [7]. The music synthesis and cluster growth simulation projects were designed to especially appeal to the Music Engineering Technology and Computational Physics majors in the class.

The CAQ was administered halfway through the semester. Graded course material and personal information were also collected. Graded course material included lab grades, quiz grades, exam grades, and final grade; personal information included gender, ethnicity, GPA, major(s), and minor(s).

4 Analysis

Participation in the study was voluntary, and complete data could only be collected for fifteen participants from the class. These participants included four declared computer science majors and eleven non-majors. There was too little variation in the population for gender and ethnicity to yield relevant results. Additionally, no students reported any creative achievement in the Dance domain.

The analysis revealed surprisingly few significant relationships (see Figure 1). Comparison of students' CAQ scores with their final grades, pre-course GPA, course exams, and the fifteen labs yielded no statistically significant results. Furthermore, no statistically significant relationship was found between the students' final

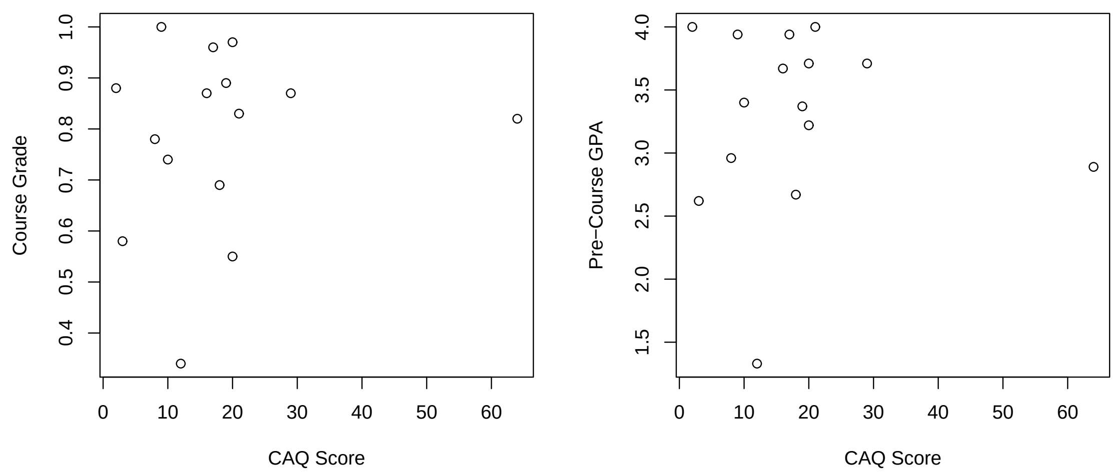

Figure 1: CAQ scores plotted against course grades and pre-course GPA for the experimental class. No statistically significant relationship was found among these factors, contrary to our hypothesis.

grades and the ten domains of artistic and scientific endeavors (CAQ Part Two), nor between GPA and the ten domains.

Subjects' scores in Part Two of the CAQ were compared against each of the fifteen labs. Of all combinations, only three were found to be statistically significant ($p = 0.05$). A positive relationship was found between Lab 4 and Music ($r = 0.519$), and negative relationships were found between Lab 4 and Architecture Design ($r = -0.521$) and between Lab 9 and Inventions ($r = -0.534$). Lab 4 was the students' second lab involving turtle graphics, and it introduced loops through Spirograph-inspired graphics. Lab 9 was the first lab explicitly on principles of object-orientation, requiring students to write three shape classes that implemented a common `Drawable` interface. This was also the first lab to incorporate pedagogical code reviews [11]. Note that pedagogic code reviews were used in three more labs after Lab 9, and Lab 10 was a direct extension of Lab 9, yet no significant relationships were discovered between these later labs and the CAQ creative domain subscores.

There were two exams during the semester and a comprehensive final. Students' responses to Part Two of the CAQ were compared against the three exam grades, and the only statistically significant relationship was found between the final exam and Music ($r = 0.569$, $p = 0.05$). The final exam did not contain any questions regarding music or sound, although it did have a question on parsing that was based on the stream-parsing, MIDI-like music synthesis lab. Note that the exams scores were only compared against CAQ responses in toto; responses to individual exam questions (*e.g.* the final exam question similar to the I/O lab) were not included in the analysis.

T-tests were implemented to analyze the differences between groups of students by declared major. There was no statistically significant difference in CAQ scores between CS majors and non-CS majors, nor was there between art and science majors.

5 Discussion

This was a pilot study with only few participants, who themselves were not a random sample. Most of the students in the class were required to take the course as part of an academic program. Furthermore, this was an "off-sequence" offering: first semester freshmen intending to major or minor in Computer Science, and with adequate mathematics background, would normally take this course in the Fall. (Note that it was partially the fact that this was an off-sequence offering that made this experiment possible.) Despite these limitations, the results are intriguing and provide a springboard for future research.

Contrary to our hypotheses, student achievement in the Visual Arts, Music, and Scientific Inquiry did not correlate with performance in the corresponding labs. In fact, creative achievement, as measured with the CAQ, had very little impact on student performance at all. The relationships discovered in the analysis suggest that the relationships between creative achievement and academic success may be more subtle than we expected, or perhaps not exist at all. To wit, there are not obvious relationships between turtle graphics and either Music or Architecture Design, nor between object-orientation and Inventions. Surprisingly, where there are explicit relationships, such as between computational physics and Scientific Inquiry, we discovered no statistically significant correlation. Hence, the results of the analysis do not clearly point towards generalizable conclusions except, perhaps, that creative achievement is unrelated to performance in introductory computer science. This would itself be an important discovery, since it implies that past creative achievement is not a discriminating factor in computer science education. Additional studies are required in order to determine whether such a generalization holds.

In a media computing course, assignments may grant students a great deal of creative freedom, but the creativity itself is generally not graded. Student submissions may be praised for their ingenuity, which can be an important factor in developing pride and a sense of community within the classroom. However, if submissions are graded by traditional means, there is little reflection on the variety of creative activities a student incorporates. This implies that a more creative grading scheme may be required in order to complement students' creative freedom. Unfortunately, grading policy is often dictated by the institution and therefore presents an significant challenge for creative teaching.

Knobelsdorf and Romeike [12] point out that students may not unleash their creative potential in cases where they feel that they are "solving the professor's task," as opposed to working on something they find significant. That is, it is students' motivation that is key to success, and creative projects are a means to that end. This study did not include an investigation of students' attitudes towards the individual labs or assignments, but it is possible that a finer-grained study could tease out the relationships between attitudes, assignments, creativity, and success.

6 Conclusions and Future Work

Though results of the pilot study are inconclusive, they do suggest the presence of subtle relationships between creativity and computer science education. The CAQ has many advantages over other models of measuring creative achievement for such research: not only has it been proven reliable and valid, it is also easy to administer and to score. Conducting similar studies across multiple institutions, and even across multiple themes of introductory computer science, could clarify the influence of creativity on academic success in computer science.

Several factors point to motivation as a primary factor impacting student performance. Where "creativity" is informally stated as a reason for success, it is possible that it was the motivation associated with creative endeavor that was the primary factor. Further research is required to determine the strength of this relationship. Instruments such as the CAQ should be combined with measurements of student motivation such as the Motivated Student Learning Questionnaire [15].

There has not been much cross-fertilization of ideas between creativity research and computer science education research [12]. We propose that this would bear interesting and useful fruit, especially given the adoption of explicitly creative activities to improve motivation in computer science courses.

REFERENCES

[1] Jessica D. Bayliss and Sean Strout. Games as a "flavor" of cs1. In *SIGCSE '06: Proceedings of the 37th SIGCSE technical symposium on Computer science education*, pages 500–504, New York, NY, USA, 2006. ACM. ISBN 1-59593-259-3. doi: http://doi.acm.org/10.1145/1121341.1121498.

[2] Mordechai Ben-Ari. Constructivism in computer science education. In *SIGCSE '98: Proceedings of the*

twenty-ninth SIGCSE technical symposium on Computer science education, pages 257–261, New York, NY, USA, 1998. ACM. ISBN 0-89791-994-7. doi: http://doi.acm.org/10.1145/273133.274308.

[3] Margaret Boden. What is creativity? In Margaret Boden, editor, *Dimensions of Creativity*. MIT Press, 1994.

[4] Shelley H. Carson, Jordan B. Peterson, and Daniel M. Higgins. Reliability, validity, and factor structure of the creative achievement questionnaire. *Creativity Research Journal*, 17:37–50, 2005.

[5] Subrata Dasgupta. *Creativity in Invention and Design: Computational and Cognitive Explorations of Technological Originality*. Cambridge University Press, 1994.

[6] Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides. *Design patterns: elements of reusable object-oriented software*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 1995. ISBN 0-201-63361-2.

[7] Nicholas J. Giordano and Hisao Nakanishi. *Computational Physics*. Benjamin Cummings, 2 edition, 2005.

[8] Mark Guzdial. A media computation course for non-majors. In *ITiCSE '03: Proceedings of the 8th annual conference on Innovation and technology in computer science education*, pages 104–108, New York, NY, USA, 2003. ACM. ISBN 1-58113-672-2. doi: http://doi.acm.org/10.1145/961511.961542.

[9] Mark Guzdial and Barbara Ericson. *Introduction to Computing and Programming with Java: A Multimedia Approach*. Prentice Hall, 2006.

[10] Mark Guzdial and Andrea Forte. Design process for a non-majors computing course. In *SIGCSE '05: Proceedings of the 36th SIGCSE technical symposium on Computer science education*, pages 361–365, New York, NY, USA, 2005. ACM. ISBN 1-58113-997-7. doi: http://doi.acm.org/10.1145/1047344.1047468.

[11] Christopher Hundhausen, Anukrati Agrawal, Dana Fairbrother, and Michael Trevisan. Integrating pedagogical code reviews into a cs 1 course: an empirical study. In *SIGCSE '09: Proceedings of the 40th ACM technical symposium on Computer science education*, pages 291–295, New York, NY, USA, 2009. ACM. ISBN 978-1-60558-183-5. doi: http://doi.acm.org/10.1145/1508865.1508972.

[12] Maria Knobelsdorf and Ralf Romeike. Creativity as a pathway to computer science. In *ITiCSE '08: Proceedings of the 13th annual conference on Innovation and technology in computer science education*, pages 286–290, New York, NY, USA, 2008. ACM. ISBN 978-1-60558-078-4. doi: http://doi.acm.org/10.1145/1384271.1384347.

[13] Gary Lewandowski, Elizabeth Johnson, and Michael Goldweber. Fostering a Creative Interest in Computer Science. In *Proceedings of the 36th SIGCSE Technical Symposium on Computer Science Edication*, pages 535–539, 2005.

[14] Nick Parlante. Nifty reflections. *SIGCSE Bull.*, 39(2):25–26, 2007. ISSN 0097-8418. doi: http://doi.acm.org/10.1145/1272848.1272876.

[15] Paul R. Pintrich, David A. F. Smith, Teresa Garcia, and Wilbert J. Mckeachie. Reliability and Predictive Validity of the Motivated Strategies for Learning Questionnaire (Mslq). *Educational and Psychological Measurement*, 53(3):801–813, 1993.

[16] Ralf Romeike. Creative Student – What can we Learn from Them for Teaching Computer Science? In *Proceedings of the 6th Baltic Sea Conference on Computing Education Research*, pages 149–150, 2006.

[17] Mark A. Runco. *Creativity: Theories and Themes: Research, Development, and Practice*. Academic Press, 2006.

[18] Allison Elliott Tew, Charles Fowler, and Mark Guzdial. Tracking an innovation in introductory cs education from a research university to a two-year college. *SIGCSE Bull.*, 37(1):416–420, 2005. ISSN 0097-8418. doi: http://doi.acm.org/10.1145/1047124.1047481.