ISSN: 1545-679X

Information Systems Education Journal

Volume 2, Number 27 http://isedj.org/2/27/ May 3, 2004

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Recommended Citation: Guthrie (2004). Integrating Programming and Systems Analysis Course Content: Resolving the Chicken-or-the-Egg Dilemma in Introductory IS Courses. *Information Systems Education Journal, 2* (27). http://isedj.org/2/27/. ISSN: 1545-679X. (Preliminary version appears in *The Proceedings of ISECON 2003:* §3211. ISSN: 1542-7382.)

This issue is on the Internet at **http://isedj.org/2/27/**

The **Information Systems Education Journal** (ISEDJ) is a peer-reviewed academic journal published by the Education Special Interest Group (EDSIG) of the Association of Information Technology Professionals (AITP, Chicago, Illinois). • ISSN: 1545-679X. • First issue: 8 Sep 2003. • Title: Information Systems Education Journal. Variants: IS Education Journal; ISEDJ. • Physical format: online. • Publishing frequency: irregular; as each article is approved, it is published immediately and constitutes a complete separate issue of the current volume. • Single issue price: free. • Subscription address: subscribe@isedj.org. • Subscription price: free. • Electronic access: http://isedj.org/ • Contact person: Don Colton (editor@isedj.org)

The Information Systems Education Conference (ISECON) solicits and presents each year papers on topics of interest to IS Educators. Peer-reviewed papers are submitted to this journal.

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Integrating Programming and Systems Analysis Course Content: Resolving the Chicken-or-the-Egg Dilemma in Introductory IS Courses

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Abstract

Most undergraduate IT programs require that students learn some computer programming as soon as possible. We have observed however, that in the subsequent systems analysis courses, students appear to have some difficulty in understanding how the design artifacts they create in their systems analysis course relate to the production of real computer programs. We believe that frequent comparisons of software design artifacts to final code improve students' ability to create good software designs. We also believe that student programming skill is directly related to software design skill. Two object-oriented systems analysis and design courses were taught at an undergraduate university covering identical concepts and content. One course however was supplemented with examples of working code that related to directly to the analysis and design examples used in the class. At the end of the two courses, the students' ability to integrate the design artifacts they learned about in class to actual code designs was evaluated through an exam that required shell code writing, reverse-engineering, and design improvement. The results indicated that students who were better programmers scored better on the evaluation exam. Students in the course that used code examples in class also performed significant better than students in the "traditional" course. This implies that students should be taught programming first (with some high-level architectural guidance), followed by the system analysis course. Systems analysis and design courses would also benefit from using code examples that relate to analysis and design constructs.

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1. INTRODUCTION

Most undergraduate IT programs require that students learn some computer programming as soon as possible. While students seem to learn the syntax of a computer language readily enough, the quality of these early programs in terms of logic, robustness and maintainability is very weak. This often leads faculty to wonder whether we would be better off teaching students how to design software first, before teaching them to code. Conversely, we have observed that when the systems analysis course follows the programming course, students appear to have some difficulty in understanding how the design artifacts they create in their systems analysis course relate to the production of real computer programs. Many systems analysis texts and courses that we have investigated treat the production of working computer programs very lightly if at all. Even texts dealing with

object-oriented designs and the UML, which were specifically created to address the creation of object-oriented programs, seem far removed conceptually from the world of programming in most chapters. This leaves us with a dilemma: which should come first, the programming course or the design course?

In this study we attempt to shed some light on this problem by examining student understanding of how their systems analysis artifacts relate to the production of code. We believe that programming skill is directly related to design skill. We also believe that early and frequent references that relate systems analysis concepts to final code production increase student understanding of the purpose of analysis and design processes, re-enforce learning and retention, and improve their ability to create robust designs. We test these hypotheses by comparing two courses in object-oriented systems analysis and design that cover identical material using the same textbook, but in one of the courses, we introduce and use actual code produced by the designs studied in class. Students in both courses were given an exam at the end of the course designed to test their understanding of how designs relate to actual code. The results clearly indicate that students who rate themselves as good programmers scored consistently higher than those who admitted to being less skilled in programming. The results also indicate that even students who rated themselves as being poor programmers performed better on the exam in the course where programming concepts were emphasized than those in the "traditional" course. This suggests that students should learn a programming language before the systems analysis and design course. Additionally, teaching strategies that use actual code could improve learning results in systems analysis and design courses.

2. BACKGROUND

Booth (2001) explains that the definition of "good learning" is evolving away from memorizing towards the development of an integrated set of skills including research, analysis, questioning and collaboration. This educational philosophy is being referred to as "Constructivism" (Gruender, 1996; Savery and Duffy, 1995). In their research on the use of CASE tools in education, Fowler et.al. (2001) explains that computer science students predominantly have a learning style that is both sensory and visual, and that 80% of all students are active learners. This suggests that courses taught in a traditional fact-memorization mode may be particularly unsuited for computer science students.

Compared to traditional academic disciplines, information systems and computer science are relatively new pedagogies. These new disciplines are strongly-related to practice and therefore most courses have a high skill component. Whiddett et.al. (2000) suggests that traditional lectures do not develop skills in students. Conversely they also note that skills learned "on-the-job" are too skill-based and do not generalize well to other contexts. This suggests that university courses should be a blend of both theory and practice, rather than strongly emphasize one approach over another.

In a study involving PASCAL programming students, Fleury (1993) noted that programming students have very different "thinking habits" and motives than those of professional programmers. In particular, he notes that student tend to have a short-term perspective focused on turning-in a working assignment, as compared to professionals who are far more concerned about future maintainability. This difference identifies that students are either not seeing or not being taught the larger picture in programming courses.

Perkins (1992) explains that when knowledge is "organized" and placed in a context, that the knowledge is easier to remember and more apt to be reused. Gal-Ezer and Zeldes (2000) state that "generative knowledge" as defined by Perkins preserves knowledge for a longer time, improves understanding, and is used actively.

Lebow (1993) and Savery and Duffy (1995) propose a number of teaching principles that implement constructivist pedagogy. The principles that relate to this research include:

- Provide a context for learning that supports autonomy and relatedness
- Embed the reasons for learning into the learning activity itself
- Anchor all learning into a larger task or problem
- Design an authentic task

3. RESEARCH HYPOTHESIS

Our research hypotheses are founded on the active-learning, constructivist teaching philosophies previously discussed. We believe that the students who have more programming experience are able to place their systems analysis learning more easily into a context, and are better able to conceptualize the end-result of their UML designs. This gives rise to our first hypothesis:

H1: Students who are better programmers will have a better understanding of the relationship between UML designs and final code.

Given the limited knowledge and experience of software engineering students in introductory courses, we feel that the reasons for the design (final code) should be embedded in systems analysis course content. Based on the constructivist principles of "Embedding the reasons for learning into the learning activity itself" and " anchoring" all learning into a larger task or problem" , it is our expectation that the use of programming code examples in systems analysis courses will improve learning. This gives rise to our second hypothesis:

H2: Students will create better software designs in systems analysis courses that use final code examples.

4. RESEARCH METHODOLOGY

Two similar introductory object-oriented systems analysis and design courses were taught during the same term at an undergraduate university. The primary focus of the course was learning the various UML diagrams and constructs. Completion of an introductory Java programming course was a strictly-enforced prerequisite. Both courses had similar gender demographics and size. Students were undergraduate business degree majors with declared information systems emphases. Both courses covered the same material and used the same textbook (Larman, 2002) The instructor teaching the traditional course was a senior member of the faculty with extensive knowledge of the subject, including the recent publication of a textbook on OO Systems Analysis and Design. The instructor teaching the integrated course was a newer member of the faculty with less experience and expertise, and had initially learned the course content by attending the senior faculty member's course two years previously. The two courses had a similar syllabus in terms of pace, exams, and projects. The instructor of the integrated course concurrently taught programming courses, the more senior faculty member had little or no recent programming experience either as a practitioner or instructor. The more experienced faculty member utilized a theoretical approach that did not emphasize any particular syntax rules or use code in any form. The instructor with current programming experience emphasized Java programming syntax in class, variable and method naming, and in method calls. Code was also used to illustrate the application of software "patterns". Students were shown actual code samples that related to UML interaction diagrams and class diagrams as part of the learning. Students were required to "reverse-engineer" simple java programs into corresponding interaction diagrams and class diagrams. Extra credit was offered to students who completed a simple UML design project that produced a working program. These uses of code appeared in lectures, in-class activities, projects, and exams.

The students' ability to integrate programming with systems analysis and design concepts was evaluated through a one-hour exam given to the students of both courses during the last week of a regular ten-week term (three quarters per academic year). The exam was not a formal part of the course; students were offered extra credit for completing the exam on a graduated scale: the better they performed on the exam the more extra credit points they earned. Total extra credit available amounted to approximately ½ of 1 percentage point in the overall course grade.

The research instrument contained two parts; a survey portion and a skills portion. The survey portion asked a variety of questions to determine the student's prior programming experience, education, and skill level. Gender demographic data was also collected. The skills portion consisted of three tasks to test student's ability to integrate programming with UML design. In the first task, students were required to write a shell Java program consisting of four classes from a sequence diagram and a class diagram. Task two required students to create a class diagram by reverse-engineering instructor-supplied Java source code. Task three required students to re-engineer a class diagram into "a better diagram based on your knowledge of three-tier architecture and software patterns".

The exams were evaluated by an independent teaching assistant with three terms of prior experience grading both systems analysis and Java course assignments. A total "percent correct" score was given to each exam with a moderate amount of explanatory notation included. All exams were evaluated in one session with the first group of exams graded being compared to the last group to control for familiarity bias. No significant bias was noted.

5. RESEARCH FINDINGS

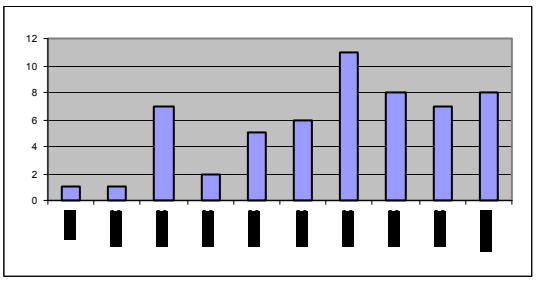
A summary of the findings is shown in Table 1.

Table 1 – Summary of Scores by Group

Score Distributions	0-10%	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	71-80%	81-90%	91-100%	Average
Overall	1	1	7	2	5	6	11	8	7	8	0.593
Traditional Course	1	1	5	2	3	5	7	3	2	2	0.502
Integrated Course	0	0	2	0	2	1	4	5	5	6	0.706
Poor Programmers	1	0	2	1	3	4	3	2	2	0	0.501
Okay Programmers	0	0	2	0	2	1	4	5	5	6	0.592
Good Programmers	0	0	0	0	1	0	2	2	1	3	0.720

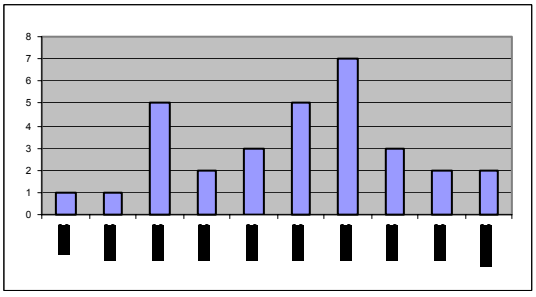
The average score for the entire group was .593. Scores showed a tendency towards a normal distribution with a marked skew towards 100% (Figure 1). Student performance on the evaluation exam ranged broadly, with about half the students (23/56) scoring above 70% which would be considered a "passing" grade in most courses. This figure is surprisingly low, given that this performance level could be a fair predictor of how well students really understood the material they were supposed to learn.

Figure 1: Distribution of overall student evaluation scores



The distribution of scores for the class taught "traditionally" (without the use of computer code) shows an approximate normal distribution of grades, with 20 out of 31 scoring between 31% - 80%. Two students scored in the 0%-20% range, and four students scored in the 80% - 100% range. Twelve students received scores less than 50%.

Figure 2: Distribution of Tradition Methodology Group Scores



The distribution of scores for the class taught with the use of computer program code integrated with systems analysis and design concepts are significantly skewed to the right, with 20 out of 25 scoring between 60% and 100%. Four students received scores less than 50% and no students received scores less than 20%.

Almost half the students surveyed rated themselves as "okay" programmers (24 out of 57). The distribution of "okay" programmers between the two courses was

even: 12/12. Eighteen students reported themselves as either being "poor" or "not so good". The distribution between the two courses was 10 in the traditional course and 8 in the integrated course. Nine out of the fifty-seven said they were "pretty-good" or "excellent", with the distribution as 4 in the traditional course and 5 in the integrated course. None classified themselves as "hackers", and five students in the traditional course did not answer that question. Students who rated themselves as "poor" or "not so good" averaged .501 with a normal distribution over most of the range (Figure 4). Students who said they were "okay" programmers averaged .592 with the distribution being skewed to the right except of a group in the 20% - 30% range (Figure 5). Students who rated themselves as "pretty-good" or "excellent" averaged .720 with a right bias (Figure 6).

Figure 3: Distribution of Integrated Methodology Group Scores

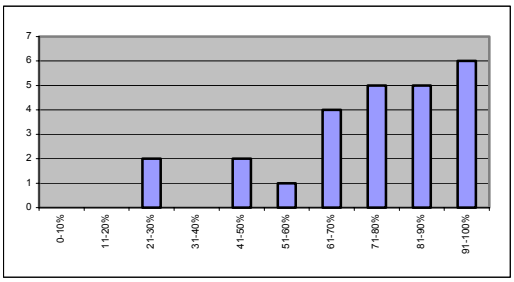


Figure 4: Distribution of "Poor" Programmer Scores

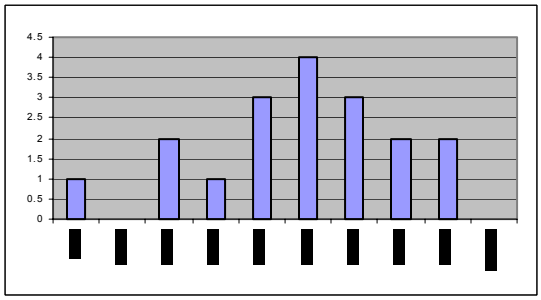


Figure 5:Distribution of "Okay" Programmer Scores

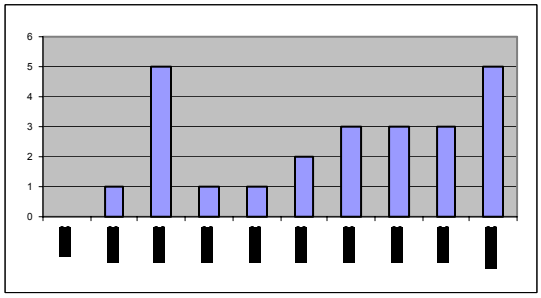
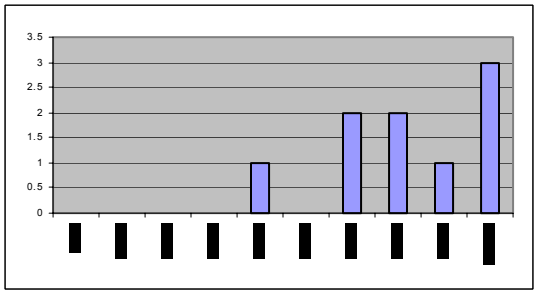


Figure 6: Distribution of "Good" Programmer Scores



6. DISCUSSION OF RESULTS

The results clearly show that a solid foundation of programming generally improves students' ability to relate their software designs to final code. We believe that this will result in "better" designs i.e.: easier for programmers to understand, more robust, more likely to be usable "as is", etc. Beyond the immediate results of this study however, we believe that both programming course content and systems analysis course content can benefit from an integrated approach. Suggestions for how this integration might be accomplished are as follows:

A. Programming Instructor use of UML

In cases where the instructor assigns a standard "project" to an entire course, the project assignment details can be provided to students using systems analysis constructs such as use cases, interaction diagrams and class diagrams. Our experience has shown that students are far more likely to understand a project assignment when the instructor includes a use case and UML diagrams. This shouldn't come as a surprise since the UML is based on "best-practices" relating to how to describe requirements to programmers. Admittedly, student creativity is sacrificed when the instructor provides extensive requirements, but since only the class shells are specified in the UML; good design documentation that is part of the project

requirements still provide ample opportunities for student creativity.

B. Trade Publications

Many software trade publications frequently feature UML diagrams in their articles. Students can be assigned to find recent articles that use the design artifacts the instructor is interested in, and write a brief summary of an article including a description and analysis of the design artifacts used.

C. UML Deliverables in Programming Assignments

Programming students are often required to submit print outs of their project source code along with the software files. Personal experience can attest that the printed code is seldom given more than a cursory examination by the instructor. Since the actual code is available for examination in the source files, it might be more instructive and productive for students to document their project design at a higher level using UML class and interaction diagrams. Some software tools will even generate the diagrams for the student, providing a clear linkage between the design artifact and final code.

D. Reference Programs

We suggest introducing a simple object-oriented computer program at the beginning of the systems analysis and design course and then using it throughout the course to demonstrate how the various design constructs relate to final code. We have successfully used a simplified (bank) ATM machine program written in Java for this purpose. One strength is of the ATM program is that students are intuitively familiar with an ATM's functionality and the data inputs and outputs required. The reference program also serves to remediate students that have forgotten some of the syntax from their introductory programming course. The reference program has proven even more useful when teaching systems analysis and design courses to students that are unfamiliar with object-oriented programming, or who may have not been required to complete a programming course before taking the systems analysis course. When teaching systems analysis to students who have not had prior object-oriented programming experience, we assign the reference program as homework where the students are required to get the program to run on their own personal computer, then make some minor modifications to variables and functionality. This basic experience and review of the programming language gets the systems analysis course off to a quick start with everyone more or less at the same level.

D. Reverse Engineering

When teaching software reverse-engineering, students are provided with simple programs of typically five to ten classes, and are required to produce the interaction diagrams and class diagrams that would have produced the code. We first work through a reverse engineering example on the board with a very simple program. We then have the students form groups and work on a more complicated program during the class time. Finally, we assign a simple reverse engineering problem on a quiz or exam.

E. Shell Programs

As part of the final design project, students are required to write shell program classes (containing the class declaration, class variable declarations, and method declarations) based on their designs. If the designs are complex, then students can be assigned to write shell classes for one or two of the more important classes.

F. CASE Tools

Some integrated development environments (IDE's) or CASE tools can be used for both code design and code development. Rational Rose and Together are often used on for teaching, and both have the capability of converting UML class diagrams to shell computer programs in a variety of object-oriented languages including Java and C++. There are many other less known software tools available that can do the same thing. Many of these tools can also "reverse-engineer" an object-oriented software program and produce class diagrams based on the code. Even if these tools are not formally used in a student assignment, students can gain a lot of insight by going

through the process of code conversion in class or in a separate lab activity.

7. LIMITATIONS AND FUTURE RESEARCH

We recognize that there are several potential sources for error that could bias the results of this research. Since there were only two classes and two instructors that participated in this initial research, there is no control against differences in teaching style, personalities and "teaching quality". It is possible that at least some performance differences may be attributed to differences in teaching style, particularly since there were significant differences in age, experience and background from the two instructors.

Another potential source of research bias relates to how students select courses. Student have strong preferences to certain class days and times. Students also rely extensively on peer opinion when selecting instructors. Since course registration gives priority to students with more units completed, it is likely that a course that meets at a more preferred day and/or time, or where one instructor is preferred over another, is likely to have more experienced and/or mature students than another. Since one course met on Tuesday and Thursday late in the morning (ideal), and another met on Monday, Wednesday and Friday (less than ideal), there is the possibility that our findings may be influenced by an experience/maturity bias between the classes.

The survey instrument was developed by the instructor teaching the integrated approach and subsequently reviewed and approved by the instructor that used the traditional approach. Students from the class that integrated code and systems design had been exposed to all three research tasks in some form or another prior to taking the exam. Future research should use an independent third party to develop the exam so that it will not closely match the exercises that the students in the integrated approach have completed.

This research can be extended in several interesting ways. The first extension would be to reverse the research assumption and see if completion of a systems analysis course helps students to be "better" programmers. If this hypothesis also proves true, we may have to conclude that programming and systems analysis and design are not independent and separate disciplines, but are essential parts of "software development" skill. The choice would then be a matter of how much of each rather than "which one."

Another research extension considers the experience of the test subjects. This research examined introductory IS students with a minimum amount of skill and no practical experience. This limits the generalizability of our study to academic teaching situations. It would be very interesting to apply a similar research instrument to working professional systems analysts and programmers. The findings could inform decisions relating to training, hiring, and promoting of systems analysts and software project managers in an industrial setting.

8. CONCLUSION

Both hypotheses were supported by the research findings. It is clear that students who reported being better at programming performed better as a group on the evaluation than those who reported being less skilled in programming. It is interesting to note that students in general tended to be modest in evaluating their programming ability. It is also clear that those students who attended the "integrated" course that used code examples scored higher as a group. This implies that students integrate software engineering principles better when the relationship between the results of their designs are emphasized throughout the course. We believe that these results support widely used "folk pedagogies" (Booth, 2001) that introduce students to software engineering with a programming course followed by a design course. Given that program design has a huge impact on robustness and maintainability, we do not suggest however, that introductory programming courses should ignore teaching the basics of good design. Concepts such as three-tier architecture, separation of concerns, and iterative development are basic ideas that students can readily understand, yet provide a foundation of

good design practice right from the start. This study suggests therefore that the "chicken" should indeed come before the egg, but with proper course content, the chickens will be matured and ready to be productive "egg-layers" in the follow-on systems analysis and design courses.

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