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Isolated versus integrated case studies: A comparison in the context of teaching complex and domain-specific IT applications

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Abstract

Previous research on IT fluency in connection with non-IT majors points at the increasing need for more "realistic" courses teaching the use of complex and domain-specific IT applications. That research also suggests certain desirable course design characteristics, of which one of the most important is the close integration of realistic case study-based material into one single course (as opposed to the less costly alternative of inserting single case study-based material into other courses). This paper describes a study in which the use of case study-based learning modules in an integrated way (i.e., as part of one main course) is compared against the use of those modules in isolation (i.e., inserted into other courses). The modules have been designed to teach complex and domain-specific IT applications in three main domains – anthropology, sociology, and chemistry. The study, which involved 76 undergraduate students, suggests that the integration of modules into one single course, when compared with the option of using the modules in isolation, significantly increased the level of perceptions of IT's potential for solving complex problems, perceived learning about specialized IT applications, and perceived learning about IT issues in general. The key conclusion of the study is that integration may be a desirable option regardless of the potential extra costs involved.

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1. Introduction

In today's world, the use of information technology (IT) transcends IT departments. That is, while in the past many complex IT applications would be run in an IT department upon request from users of other departments or areas of an organization, today it is often the case that the final users themselves have to be able to run complex IT applications to produce the results they need to do their jobs effectively. For example, a chemical engineer may have to become a proficient user of a complex molecular design computer program in order to be able to effectively contribute chemical compound ideas as a member of a new product development team. This type of situation places substantial pressure on users to be able to learn how to use (and often master the use of) complex IT applications (Bell et al., 2003).

The situation above is at odds with the way IT is normally incorporated into university curricula (Swezey, 2001), particularly as far as academic program "majors" are defined. While those students majoring in an IT-related discipline (e.g., computer science, information systems) are often exposed to a certain level of complexity in the IT tools they learn and use during their academic programs, non-IT majors are seldom exposed to IT tools whose complexity goes substantially beyond that of simple office and Web page design applications.

One solution to the above problem, proposed by Kock, Aiken, and Sandas (2002) and refined by Dougherty, Kock, Sandas, and Aiken (2002), involves developing "learning modules" in connection with complex and domain-specific IT applications. Following Knowles's (1984a, 1984b) andragogy theory prescriptions, which advocates that IT instruction for adults needs to focus more on process and less on content, Kock et al.'s (2002) originally proposed approach suggests that learning modules should revolve around realistic case studies and related hands-on assignments.

A relevant research question in connection with the learning modules discussed above is whether the learning modules should be: (a) incorporated into other courses (e.g., courses addressing other topics, whether IT-related or not) as isolated components; or (b) integrated with other similar learning modules into a course dedicated to exposing students to complex and domain-specific IT applications. This research question is addressed through this paper.

This paper describes a study involving 76 undergraduate students from a large state university in Northeastern USA, of which 44 participated in isolated case study implementations (option "a" above), and 32 participated in integrated case study implementations (option "b" above). The students were non-IT majors. The study compares perception-based quantitative and qualitative data from each type of implementation (i.e., isolated and integrated), and concludes that integrated case study implementations are generally more advisable, even though they are more costly to implement. Implications for future research and practice are also discussed.

2. Research background and hypotheses

Previous research has looked at the problem of teaching complex and domain-specific IT applications from a theoretical perspective. Of particular relevance for this study is the framework proposed by Kock et al. (2002) and refined by Dougherty et al. (2002), which itself builds on two well-known theories of IT education, namely minimalist theory (Carroll, 1990, 1998; Van Der Meij & Carroll, 1995) and andragogy theory (Knowles, 1975, 1984a, 1984b).

One of the contributions of Dougherty et al. (2002)'s work to the original work done by Kock et al. (2002) was to integrate previous theoretical ideas that were relevant in the context of teaching complex and domain-specific IT applications into what Dougherty et al. (2002) referred to as the information technology fluency (ITF) framework. The ITF framework assumes that the depth in coverage necessary for teaching complex and domain-specific IT applications would induce a certain degree of cognitive stress, especially when the learning modules related to the IT applications are presented in isolation.

One of the key propositions of the ITF framework refers to student *perceptions* of IT, and states that the integration of learning modules revolving around realistic case studies into one single course would mitigate the aforementioned cognitive stress, and thus have a positive effect on how students perceive IT's potential for solving complex problems as well as IT in general. These perceptions would, in turn, help students feel comfortable with complex and domain-specific IT applications, as well as IT applications in general, and thus increase the chances that those students would be more predisposed to invest their time and effort in similar learning endeavors in the future. This leads us to hypotheses **H1** and **H2**, shown below.

H1: Integrated case studies improve students' perceptions of IT's potential for solving complex problems to a greater extent than isolated case studies.

H2: Integrated case studies improve students' perceptions of IT in general to a greater extent than isolated case studies.

Another assumption of the ITF framework is that the depth in coverage necessary for teaching complex and domain-specific IT applications would make those modules less interesting and meaningful for students than more generic and "lighter" topics (e.g., basic Web site design), especially for students who are not particularly interested in the underlying subject matter or domain of IT application (e.g., molecular design).

The theoretical proposition leading to hypotheses **H1** and **H2** above relates primarily to perceptions of IT by students. A second theoretical proposition of the ITF framework that is relevant to this study relates to actual *learning* about IT, and follows from the assumption above. This second proposition states the integration of learning modules revolving around realistic case studies into one single course would make those learning modules more interesting and meaningful to students, and thus positively affect the students' perceived learning about specialized IT applications and IT issues in general. This leads us to hypotheses **H3** and **H4,** presented below.

H3: Integrated case studies lead to a higher degree of perceived learning about specialized IT applications than isolated case studies.

H4: Integrated case studies lead to a higher degree of perceived learning about IT issues in general than isolated case studies.

The four hypotheses above provide the basis for testing the ITF framework propositions in connection with the teaching of complex and domain-specific IT applications. Such test is particularly meaningful from a practical perspective because two of the most important outcomes of teaching initiatives such as those explored here are the *perceptions* that those initiatives impart on the students *and* the actual *knowledge* that the students take away from their participation. If the students are positive about how much they learned, but their perceptions of the learning experience are negative (and vice-versa), they will be less likely to participate in similar learning efforts in the future. Arguably, this would substantially affect their ability to engage in the kind of life long learning necessary to be effective users of ever-evolving IT tools.

3. Research method

One of the most widespread quasi-experimental designs in experimental research is the design Campbell and Stanley (1963) called ‘‘nonequivalent control group design’’, where the ‘‘control group’’ and the ‘‘experimental group’’ do not have pre-experimental sampling equivalence (as when, e.g., random assignment to experimental conditions cannot usually be ensured). This is the design employed here.

The hypotheses have been tested through a quasi-experiment employing a repeated measures design (Rosenthal & Rosnow, 1991) where the ‘‘control group’’ comprised students participating in isolated case studies and where the ‘‘experimental group’’ comprised students participating in integrated case studies. Given the type of quasi-experimental design chosen, non-parametric techniques (Siegel & Castellan, 1998) were used for quantitative analysis, and the results were extensively triangulated with the conclusions from a qualitative data analysis (Creswell, 1994; Maxwell, 1996).

3.1. Isolated and integrated case study implementations

In the isolated case study implementations, each of the three case studies described in Appendix A (in anthropology, sociology, and chemistry) was incorporated into a computer literacy course. The computer literacy course covered topics such as Microsoft Office and basics of using the World Wide Web. Students from three sections of the computer literacy course participated in the study, where each of the case studies (one per section) was taught at the end of the semester.

In the integrated case study implementations, each of the three case studies described in Appendix A were taught in an integrated way in one single course, whose pre-requisite was the computer literacy course mentioned above (the case studies had not been taught in those pre-requisite offerings). The main goal of the course was to teach students, through the case studies and other topics, how to devise general problem-solving strategies for using IT to deal with complex domain-specific problems. The other topics covered in the course in addition to the case studies emphasized the role of computers as universal simulators/modelers for solving complex domain-specific problems. Those topics ranged from data representation and algorithms to artificial intelligence applications.

The case studies were taught in the same way and by the same instructors in both the isolated and integrated case study implementations. Each case study was taught over two weeks through a combination of lectures, lab demonstrations, and lab work in connection with assignments. In the isolated case study implementations, case studies were included at the end of a computer literacy course, which was the first substantive IT course taken by the students at the university level. In the integrated case study implementations, case studies were included in a course that followed the just mentioned computer literacy course.

3.2. Participants and data collection

The study involved 76 undergraduate students from a large state university in Northeastern USA. The students were non-IT majors, and their ages ranged from 17 to 36, with a mean age of approximately 21. Sixty-eight percent of the students were males. Forty-four students participated in isolated case study evaluations, and thirty-two students in integrated case study evaluations.

After each case study was taught, students were asked to complete a questionnaire previously developed and validated by Kock et al. (2002) for the assessment of a pilot implementation of the case studies used here. The questionnaire contained quantitative question statements, answered on a Likert-type scale, as well as "qualitative" (i.e., open-ended) questions (see Appendix B).

The dependent variables were "perceptions of IT's potential for solving complex problems" (PERITCOM; whose variation is predicted in H1), "perceptions of IT in general" (PERITGEN; whose variation is predicted in H2), "perceived learning about specialized IT applications" (LEARNSPEIT; whose variation is predicted in H3), and "perceived learning about IT issues in general" (LEARNGENIT; whose variation is predicted in H4). These variables were measured at the individual level of analysis (thus based on 76 data points) through the perception-related question statements developed by Kock et al. (2002); see Appendix B.

4. Quantitative analysis results

Table 1 shows basic descriptive as well as inferential statistics for each of the variables in both treatment conditions – i.e., isolated and integrated case study implementations. Descriptive statistics shown are means and standard deviations. Since the quantitative data did not conform to assumptions underlying standard parametric techniques for comparison of means (e.g., the number of data points was different for each treatment condition), a set of Mann–Whitney *U* tests

Table 1
Descriptive statistics and Mann–Whitney *U* test results

Variable	Mean isolated	SD isolated	Mean integrated	SD integrated	*Z*	*p*
PERITCOM	2.63	.93	3.13	.83	−2.46	<.05
PERITGEN	2.56	.80	2.84	.85	−1.53	.13
LEARNSPEIT	2.22	.88	3.16	.92	−3.91	<.001
LEARNGENIT	2.17	.97	2.69	.82	−2.08	<.05

Range: 0–4; midrange = 2.
PERITCOM = perceptions of IT's potential for solving complex problems.
PERITGEN = perceptions of IT in general.
LEARNSPEIT = perceived learning about specialized IT applications.
LEARNGENIT = perceived learning about IT issues in general.

(a non-parametric technique – see, e.g., Siegel & Castellan, 1998) were employed and its results are summarized through the Z and p values (last two columns on the right).

The mean values for all variables were above the midrange point (i.e., 2), which suggests that, in both isolated and integrate case study conditions, the case studies generally led to positive perceptions regarding: IT's potential for solving complex problems (PERITCOM), IT in general (PERITGEN), learning about specialized IT applications (LEARNSPEIT), and learning about IT issues in general (LEARNGENIT).

The Mann–Whitney U tests yielded statistically significant results in connection with PERITCOM ($Z = -2.46$, $p < .05$); LEARNSPEIT ($Z = -3.91$, $p < .001$); and LEARNGENIT ($Z = -2.08$, $p < .05$). The means for these three variables were higher in the integrated case study condition than in the isolated case study condition. These combined results provide general support for hypotheses H1, H3 and H4.

The Mann–Whitney U tests yielded statistically insignificant results in connection with PERITGEN ($Z = -1.53$, $p = .13$). Even though the mean value for this variable was higher in the integrated case study condition than in the isolated case study condition, the statistical analysis does not provide support for hypothesis **H2**.

Given that in the integrated case study implementations the same students provided the same questionnaire answers in connection with different case studies, a partial least squares analysis was conducted to assess the cumulative effect of repeated survey taking on the responses given by students participating in the integrated case study implementations (Chin, 1998). The partial least squares analysis suggests that the effect of repeated survey taking on the responses was not statistically significant.

5. Qualitative analysis results

The analysis of the text obtained through the qualitative questions (see Appendix B) employed two summarization techniques called "filtering" and "fusion", which build on text summarization techniques proposed by Miles and Huberman (1994) and Strauss and Corbin (1990).

The "filtering" technique focuses on reducing entire sentences to their core statements. Using this technique, a long-winded statement referring to the case study's contribution to an individuals' perception of IT's potential for solving complex problems is reduced to a simple statement, such as "demonstrates IT's potential for solving complex problems".

The "fusion" technique consists in "fusing" syntactically different statements into one single statement. For two syntactically different statements to be fused they must converge semantically (i.e., have the same apparent general meaning), as judged by the researcher based on his or her involvement with the research subjects and environment. For example, the statements "demonstrates IT's potential for solving complex problems" and "shows that IT is great for simplifying complex tasks", can be both fused into one statement, which could be the first of the two statements – i.e., "demonstrates IT's potential for solving complex problems". The application of the "fusion" technique also includes the calculation of frequencies of the resulting statements, and their ranking according to those frequencies.

Table 2 summarizes the analysis of positive and negative aspects as perceived by the student subjects. Positive and negative aspects for the isolated case study condition are shown at the

Table 2
Summary of the analysis of positive and negative aspects

	Positive aspects	Negative aspects
Isolated case study condition	P1 (54%) Learned about different facets of IT	N1 (38%) Boring use of IT and/or subject matter
	P2 (25%) Learned about IT's potential for solving complex problems	N2 (26%) Learned nothing relevant to major
	P3 (14%) Learned how to use a new IT application	N3 (12%) IT application slowness
	(7%) Other	N4 (12%) IT application complexity
		N5 (6%) Not generalizable to other fields
		(6%) Other
Integrated case study condition	P2 (43%) Learned about IT's potential for solving complex problems	N1 (42%) Boring use of IT and/or subject matter
	P4 (35%) Learned about the subject matter	N4 (29%) IT application complexity
	P1 (13%) Learned about different facets of IT	N3 (17%) IT application slowness
	(9%) Other	N5 (11%) Not generalizable to other fields
		(8%) Other

top part of the table; those for the integrated case study condition are shown at the bottom. Since only one main positive or negative aspect was derived from each student answer, the positive and negative percentages for each condition are cumulative and add up to 100%.

The summary shown in Table 2 suggests that two main positive aspects (P1-P2) were perceived in both the isolated and integrated case study conditions, with variations in the percentages of subjects perceiving each of them. Notably, the students' positive perception that they learned about IT's potential for solving complex problems (P2) was apparently more widespread in the integrated than in the isolated case study condition. Additionally, the perception by students that they learned how to use a new IT application (P3) was seen as a noteworthy positive aspect only in the isolated case study condition. In the integrated case study condition, the same was true for the perception by students that they learned about the subject matter (P4).

As far as negative perceptions are concerned, Table 2 suggests that four aspects (N1, N3, N4 and N5) were perceived in both the isolated and integrated case study conditions, with variations in the percentages of subjects perceiving each of them. One key negative perception by the students, namely that they learned nothing relevant to major aspect (N2), was apparently noteworthy only in connection with the isolated case study condition.

6. Discussion

This study suggests that the integration of case study-based learning modules into one single course, when compared with the option of using case study-based learning modules in isolation, increased the level of perceptions of IT's potential for solving complex problems by about 19%, the level of perceptions of IT in general by about 11% (which was found to be statistically insignificant), perceived learning about specialized IT applications by about 42%, and perceived learning about IT issues in general by about 24%.

Table 3
Summary of the results in connection with the hypotheses

Hypothesis	Supported?
H1: Integrated case studies improve students' perceptions of IT's potential for solving complex problems to a greater extent than isolated case studies.	Yes
H2: Integrated case studies improve students' perceptions of IT in general to a greater extent than isolated case studies.	No
H3: Integrated case studies lead to a higher degree of perceived learning about specialized IT applications than isolated case studies.	Yes
H4: Integrated case studies lead to a higher degree of perceived learning about IT issues in general than isolated case studies.	Yes

Table 3 summarizes the results in connection with the hypotheses. All hypotheses were supported by the analysis of quantitative data, with the exception of hypothesis **H2**. The qualitative analysis yielded evidence that generally supports the hypotheses and, more importantly, no evidence that clearly goes against any of the hypotheses.

Since the hypotheses were derived primarily from Dougherty et al. (2002)'s ITF framework, it can be concluded that the results of the study largely support the ITF framework. When seen in combination with the evidence provided by the studies conducted by Kock et al. (2002) and Dougherty et al. (2002), the evidence yielded by this study suggests that the ITF framework may be robust enough to provide a solid basis for future development of computer fluency curricula for non-IT majors in other universities.

Hypothesis **H2** was not supported by the analysis of quantitative data, which essentially means that the integration of several case study-based learning modules into one single course had no significant positive effect on how students perceive IT in general – even though, as indicated by the results in connection with hypothesis **H4**, students did perceive that integration as having a stronger impact on their learning of IT issues in general. The operative word here is "significant", meaning *statistically* significant, in connection with **H2**, since the quantitative data analysis suggests that a difference in perception levels existed and favored the integrated case studies, but was only about 11% (which yielded a .13 significant level – too high for the rejection of the null hypothesis).

It is reasonable to assume that developing individual case study-based learning modules and using them in isolation is a less costly and more flexible alternative than integrating several modules into one single course – which would arguably provide the "wrapping" needed for more effective learning. For example, one could easily imagine an IT instructor being interested in using one of the modules of this study (e.g., the chemistry module) in a course for non-IT majors to highlight one particular aspect of his or her course (e.g., graphical representations). One could also easily imagine a chemistry instructor having a similar interest.

This study, however, provides evidence that the integration of several case study-based learning modules into one single course will have a higher impact on student perceptions of IT's potential for solving complex problems, perceived learning about specialized IT applications, and perceived learning about IT issues in general. This impact, according to this study, will be particularly strong for perceived learning about specialized IT applications. This finding suggests that, if the goal of using case study-based learning modules is to help students learn about complex and domain-specific IT applications, then integration may be a desirable option regardless of the extra costs involved.

One might argue that certain curricular constraints may make it difficult to add an additional IT course to non-IT major programs. One of those constraints, and perhaps the most important, is the lack of credit hours available for students to take courses outside their discipline – either as program requirements or electives. We would counter argue that, given the demand for complex IT expertise in non-IT areas, motivated by the increasing use of specialized IT applications in a variety of domain areas, a course such as the one incorporating integrated case study implementations discussed here has become very necessary.

7. Conclusion

We have described in this paper a study involving undergraduate students, whose majors were not traditional IT majors (e.g., information systems and computer science), from a large state university in Northeastern USA. Of those students, approximately 58% participated in isolated case study implementations, and the remainder in integrated case study implementations. Our main conclusion was that integrated case study implementations are generally more advisable than isolated case study implementations, even though the former are often more costly to implement than the latter.

Our integrated case study implementation incorporated complex IT applications in three main disciplines, namely anthropology, sociology, and chemistry. Given this, one could ask the question as to whether a more comprehensive set of disciplines should be covered in the course. Our answer to that question is that probably three disciplines are enough, because the goal of the course is not necessarily to teach the use of complex IT in all disciplines relevant to non-IT majors, but to give the students an appreciation of how IT is likely to be used in practice by professionals in relatively narrow fields. That is accomplished by incorporating a small number of learning modules that have the same general structure (e.g., that are case study-based) into the course. That number cannot be too large, since there are other elements in the course that need to be incorporated into the course – e.g., ''refresh'' lectures on introductory IT topics, introduction to the case study-based method, exams and quizzes, and final project. Based on our experience, the number of disciplines covered should be around 3, and no more than 5, assuming a single semester-long course.

Of course, much more research is needed in the future to clarify issues raised by our study. For example, it is possible that the difference in goals of each case study implementation could have biased the students' perceptions, and thus the outcomes of our study. This is an issue that can be addressed in future research, with the caveat that it would probably be difficult to compare isolated and integrated case study implementations with a significantly different research method, particularly one that imposed less realistic experimental controls on the structure of the course and behavior of the students. We tried to be as realistic as possible regarding the likely implementation of each approach (i.e., isolated and integrated) – actual implementations would involve the elements that were present in our study, such as clearly stated goals compatible with the particular approach adopted.

Based on the results from the current study we are exploring several avenues for future research. One of the results that we found particularly interesting in the current study was the difficulty in delineating between the ideas and goals embodied in "computer literacy" versus "computer fluency". That has led us to attempt to more precisely define exactly what constitutes "computer fluency" and what students think such a course should contain to be of most use to them. We are currently revising our initial questionnaire and hope to test it with several non-IT classes in the near future.

We are also continuing to disseminate information about our course through our Web site and workshops. We have discovered that many people are interested in "massaging" this course and adapting it to their own needs. We hope to obtain additional information from instructors who are constructing such courses so we can continue to refine our model (and framework) and make the course more focused. One particular observation is that such a course might best "blossom" within a single college taught by several colleagues who could better integrate their different case studies within a common theme (e.g. such as in a College of Education, Business, Social Studies, etc.).

Appendix A. Case study descriptions

A.1. Modeling human behavior over time and space: Deforestation in tropical America

This case study examines the expansion of tropical forest farmers and the accompanying deforestation in Central Panama during the time period from 9000 to 2000 years ago through the use of simulations carried out in a geographic information system (GIS) environment. The question addressed is whether the human groups inhabiting Central Panama were behaving in an evolutionarily sound fashion; that is, did they make decisions that tended to maximize their returns for effort expended? The archeological and ecological data used in this case study comes from 15 years of research in Panama. It includes maps of the 20,000 sq km study area, showing elevations, hydrologic features, and soils; rainfall and temperature data for various locations; and a database of archeological site information, with location, age, size, and function. The principal software tools are Idrisi and ArcView.

A.2. Occupational and age cohort consequences of the industrial transformation, 1980–1990

This case study examines and evaluates possible explanations for the shifts in occupational distribution that have occurred in the United States between 1980 and 1990. There are two general explanations: (1) since industries differ in their occupational distributions, patterns of industrial growth and decline will produce changing occupational distributions; and (2) changes in the organization of work within an industry because of technology and new organizational forms create occupational shifts. The question is how to assess the relative importance of the two explanations. Data used in this case study are the one percent Public Use Sample of the 1980 and 1990 Censuses. The principal software tool used is Excel.

A.3. Exploring structures of organic molecules by computational methods

This case study examines methods for correlating measured physical properties of simple organic molecules with their structures. Students use the laws of physics and appropriate computational methods to predict the structures and properties of simple molecules (the answers being "checked" by reference to suitable data bases, e.g., NIST, Beilstein, etc.). The calculations are performed with the aid of commercially available software (e.g., Alchemy, HyperChem, Spartan, Gaussian 94). The calculations explore paths permitted by the physical constraints to produce a minimum energy arrangement of the nuclei within the molecule and thus generate a global minimum structure. Comparison of the energies of structures so produced allow predictions of (at least relative) physical properties which can then be compared to those found in databases of chemical and physical properties.

Appendix B. Questions used

The question statements and questions below were taken from a data collection instrument developed and validated by Kock et al. (2002). The quantitative question statements were answered on a five-point scale going from "Strongly disagree" to "Strongly agree". The values assigned to these answers ranged from 0 ("Strongly disagree") to 4 ("Strongly agree").

Quantitative question statements

- The case study improved my perception of IT's potential for solving complex problems.
- The case study improved my general perception of IT.
- I learned a lot from this case study about specialized IT applications.
- I learned a lot from this case study about IT issues in general.

Qualitative questions

- What were the main positive aspects of this case study?
- What were the main negative aspects of this case study?

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