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Addressing Complexity in IS/IT Teaching and Research

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Abstract

This paper addresses the need to integrate research and teaching in IS/IT programs to address growing complexities in information systems. Engaging undergraduate students with industry in data collection allows a structured environment for the collection of useful datasets. The process of engaging undergraduate students in data collection is also a useful mechanism to getting them started in basic elements of research. The use of these datasets in subsequent research offers the IS discipline a pathway to rich datasets, collected longitudinally, which will empower research outcomes while also increasing the relevance of IS research to our students and industry. This experience will also help students as they move into industry or graduate education as they will have hands-on experience that empowers their future endeavors. These activities also carry the potential to empower workforce initiatives such as internships, coops, and apprenticeships. Finally, students who are trained in simple research techniques in an undergraduate program will be better prepared for the workforce as well as graduate programs. Workforce agencies and grants would potentially be valuable partners to such an initiative.

Keywords: Complexity, Teaching, Research, PBL, SRL, LCP

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1. INTRODUCTION

Information Systems (IS) literature is filled with examples of change in IS-related technology. In fact, IS-related technologies have become synonymous with change which is not only anticipated, but expected or even demanded. The pace of change was evidenced by Moore's Law which predicted (accurately) the shrinking of silicon and the related doubling of computing power every 18 months which carried on for decades. In fact, the world-wide production of transistors exceeded rice by 2010 and at a lower price point, also the global number of computers is climbing into the trillions (Lucas et al., 2012). Increasing computing power, along with constant innovations adding new capabilities, are an expectation that the economy and society at large have come to rely upon. Recent advances and investments, including direct support from nation states for AI development (*Fact Sheet: President Donald J. Trump Takes Action to Enhance America's AI Leadership*, 2025), and greenlighting a growing number of nuclear power plants to power related data centers shows that grow in IS platforms will remain strong for the foreseeable future (Crownhart, 2025).

At the same time, information systems change due to their appropriation (and misappropriation) by businesses, governments, and other consumers. These organizations look to information systems to address existing problems or realize new capabilities. While constantly-improving technologies are at the heart of these capabilities, it is an information system that effectively ties these technologies together to achieve a significant purpose which raises complexity sharply. A sobering example is the Danish Navy frigate Iver Huitfeldt, which was one of their three newest ships sharing the same class. The Iver Huitfeldt's systems failed in combat in the Red Sea in 2024 due to an IS integration issue when responding to an attack. A year later, the Danish Navy announced the problem is not solvable, and the nation's three newest ships will instead be abandoned (Sharpe, 2025).

Information systems continue to grow and evolve at a staggering rate, and failures can be excruciatingly costly. In the failure of the Iver Huitfeldt, there were fortunately warships from other nations nearby, which stopped the attack in the Red Sea, but not all IS failures have this safety net. While most IS researchers are not working on weapons systems, the systems we work with share many of the issues of complexity that were present in the failure of the Iver Huitfeldt. This paper focuses on potentially fruitful paths in IS teaching and research to help address the ever-increasing complexity of IS systems.

There have been many articles in IS research addressing the growing complexities which are presented in this paper. Of particular interest is the process of drawing students into IS research to enhance both teaching and research in the IS domain, which is the focus of this paper. This paper is being written as the authors embark on the creation of an entirely new undergraduate and graduate program in IS/IT with a focus on enhanced learning techniques. The programs are undertaken with a desire to consume IS research in courses and to make research a component of the teaching/learning process in advanced courses in both the undergraduate and graduate programs.

Complexity in information systems in this paper is defined as the growth in systems interactions required to achieve an outcome. This paper focuses on the growing complexities within information systems and how they necessitate the use of a different set of learning theories and practices to address their growing complexities. The integration of IS research into academic programs, along with greater student autonomy and partnerships with industry in graduate courses and advanced undergraduate courses, is a key to this effort and the purpose of this paper. This paper contributes to the IS literature by leveraging learning theories from extant literature and exploring improvements in IS education to empower research and partnerships with industry extending the impact of academic programs.

2. METHODOLOGY

A systematic review of literature was used in this study to identify, evaluate, and synthesize all relevant studies. The underlying research program explored the extent to which complexity is growing in information systems and the resultant impact on academic programs. This

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research was motivated by the need to redesign an IS undergraduate program in its entirety and develop a new IS/IT related master's program. Content for the new program, as well as pedagogies and support systems, (labs etc) are all being redesigned with a focus on emergent IS/IT platforms, the use of data science and AI as well as cloud computing. Also, Davenport and Markus (1999) was used to help form the initial research design related to the use of research to create content for academic programs.

The resulting process for selecting content is as follows. The terms "information systems" AND complexity; information systems" AND rigor AND/OR relevance; and medic AND teaching AND theory were all searched for using academic search premiere. In addition, the terms medic AND teaching AND theory; were searched for in the NIH National Library of Medicine where several meta-analyses on teaching theories were available. Also, all papers cited in the NIH meta-analyses were available for download as well. The searches yielded 158 papers on complexity, 43 papers on rigor vs. relevance, and 14,205 papers on learning theories in medicine. After an initial search for medic AND teaching AND theory there was a pair of searches completed for medic AND teaching and LCP (Learner Centered Pedagogy) and medic AND theory AND PBL (Problem Based Learning) which were discovered to be prominent topics related to learning theories during the literature review process.

The papers on complexity were divided into four categories after a cursory review. Category 1 included papers that focused on the complexity of IT artifacts within the information system, category 2 included papers that were focused on complexity within the organization as a result of information systems, and category 3 included papers focused on the complexity of developing information systems. Category 4 contained papers on the complexity of the information systems themselves. Category 4 papers were retained, while the papers from categories 1 -3 were discarded, leaving 26 papers for detailed review.

There was a comprehensive search of papers on rigor vs. relevance; however, the results of the search were dropped, as the results did not contribute to the research project. One paper was retained, which was a paper that was known before starting and helped in developing this research project.

The search for theories on teaching, LCP, and PBL related to the medical field yielded an overwhelming collection of literature. A meta-synthesis of meta-analyses is cited in the paper and was used as a guide to wade through the medical literature. Significant differences were found with the use of learning theories used in other countries and cultures due to academic readiness and learning culture. Given that this paper is being used to design a program for an undergraduate and graduate program in the United States, all the papers related to foreign programs were dropped. Also, papers that focused on a subset of the medical field as opposed to papers applied to medical education generally were dropped, as they were deemed to potentially not be as well aligned to the application to information systems. The final learning theories in the medicine search yielded 107 papers that were reviewed in detail.

3. COMPLEXITY

For the purpose of this paper, complexity in information systems is defined as the growth in systems interactions required to achieve an outcome. An example of such complexity is found in one of this paper's authors drive to work this morning. After pulling out of the driveway the author tapped the car's infotainment system and asked for the fastest route to work. Two routes were offered with the shortest requiring 12 minutes and the longer route requiring 14 minutes. Given there was just over 20 minutes of time available, and the 14-minute route passing by the local Starbucks, the author asked how long it would take to prepare a favored drink. Upon learning the drink would be ready within 7 minutes it was ordered and the longer route to work selected. The ordering of the drink was automated and completed with a voice command. There were insufficient funds in the Starbucks account requiring the author to provide a thumbprint on the phone to authorize a bank transfer to the Starbucks account and the order was processed. Upon arriving at Starbucks 8 minutes later, the drink was ready and the author proceeded to work arriving on time with a drink in hand.

The linkage of the car to the author's phone then linking to navigation to discover the best routes given current traffic conditions was the first IS outcome required. The phone then linked to a navigation system that determined the car's location, as well as current traffic conditions, and offered two optimal routes. The phone then linked to Starbucks, placed a usual order and then

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provided the estimated time for completion. Finally, the phone initiated a bank transaction moving funds to Starbucks. This series of transactions would have been difficult for a nation-state actor to accomplish and would have required great expense just a decade ago. This is now "normal" for most food vendors from Jersey Mike's to McDonalds to Dominos. In only a decade simple transactions that required little or no IS support have become laden with IS interactions.

Students leave our programs going into an industry that expects these capabilities which include applications, high speed mobile telecom, databases, API's, cybersecurity controls etc, just to order a sandwich. Or, the process of ordering a drink or a sandwich requires significant IS complexity and our graduates must be able to build and manage these systems.

The medical field is an excellent exemplar for IS as it managed complexity and the development of subdomains of learning/research/practice a century before IS and documented the learning theories developed to train students. The medical field did not identify complexity as a cause for the need for specialization early on, as the field of science around complexity had not yet been born. Weisz (2003) notes the rise of specialization growing in the medical field in the latter nineteenth century due to the growing base of information needed for practitioners and the large populations needing medical support. The idea was the population needed to be divided into categories based on their medical need.

Practitioners then can be more specialized on a small amount of medical knowledge, and practitioners would see many similar cases, allowing the development of heightened expertise that would be documented and increase medical knowledge. The solution to the complexity problem, by design increased the complexity and exacerbated the problem. Of course, this increase in complexity brought fantastic advances in medical science. This was a sociotechnical system gaining complexity through the discovery of new knowledge about the human body, coupled with increasing medical technologies, and a growing population. A century later IS practitioners face a similar challenge as our discipline faces rapid growth and specialization.

Meyer and Curley (1991) define complexity in information systems based on the uncertainty of doing business using information systems. There are myriad other definitions, but this is the definition used in this project with several caveats described in the methodology. Specifically, complexity that is specific to an IT artifact within the information system, complexity created within the organization as a result of the use of an information system, or the complexity involved in developing the information system (categories 1-3 in the methodology section above) are not included. Only complexity brought about by the use of the information system is considered.

Merali (2006) offered an early paper addressing complexity issues in information systems, articulating a number of the drivers of complexity in information systems and, also, introducing complexity theory and complexity science. This paper identifies many of the causes of complexity and the emerging constructs around complexity science and offers researchers a starting point in investigating information systems through the lens of complexity. Particular insight is drawn from the conclusion where the authors note the difficulty in simplifying the world with high level generalizations, rather there is a need to build multi-level representations of the world. The authors call for exploratory modeling to discover how the world works.

Benbya et al., (2020, p. 3) cites Holland (Holland, 1995) and argues that "complexity is made up of large numbers of diverse and interdependent agents that influence each other in a nonlinear way and are constantly adapting to internal or external tensions." The diverse and interdependent agents are human agency, symbol-based computation, and physical artifacts interacting within an information system. These elements create a sociotechnical entanglement that drives complexity and limits generalizability in research. This is particularly true when drawing sources from physical (non-digital) sources along with digital.

Meyer and Curly's paper predates Merali, and Benbya and views uncertainty in terms of the ability (or lack thereof) to do business using an IS platform. Merali and Benbya look at complexity as either a collection of many components adding complexity or the nonlinear impact that components have on one another. A point of agreement with Merali and Benbya is they treat IS complexity as a construct seemingly acknowledging that complexity in information systems cannot be measured directly. This paper likewise offers no measures of complexity other than anecdotal evidence such as ordering a drink or designing a warship that demonstrate challenges in modern systems.

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4. TEACHING

We believe the integration of teaching and research can address complexity in the IS field. As students engage in industry-relevant activities they inevitably reach the end of what they were taught in their academic program and begin to improvise. Whether googling or engaging AI for a solution, or turning to practitioners or fellow students for help, students expand their learning. Students not only gain specific information on the topic at hand but they gain skills and confidence in the process of engaging and mastering new skills and competencies which is perhaps the best way to take on growing complexity. Furthermore, students who develop the ability to share their newfound skills and competencies through the application of research principles and producing written reports or conference presentations can extend their ability in ways that the medical field has enjoyed for decades and the IS field needs.

A spirited debate played out among IS researchers in the latter 1990s related to rigor vs. relevance in IS research. An argument was made during that debate that IS research should not follow the lead of other business disciplines, but instead should emulate the fields of medicine and law as reference disciplines (Davenport & Markus, 1999). The authors arguments focused on the notion of practice in law and medicine informing research and then coming full circle with research informing practice. Of particular interest for this paper, the authors called for publishing in trade journals and using research in the classroom setting to teach and train students. (Davenport & Markus, 1999).

Davenport and Markus’ (1999) paper did not focus on teaching; however, it did recommend using the fields of law and medicine as reference disciplines to guide IS research and then bring that research back into the classroom. For this paper, the decision was made to use the field of medicine as a reference discipline due to similarities with IS. The medical field continues to grow in complexity and create new sub disciplines as the field increases the level of capabilities due to that knowledge, along with advances in medical practices and technologies.

The IS field started with simpler computers and information systems. However, the information systems field has become more complex, and roles are increasingly specialized as systems grow increasingly complex. Davenport and Markus (1999) did not mention how teaching needs to change to integrate with research but this paper posits a syllogism:

> If the information systems field is to use the medical field as a reference discipline for research. And the information systems field wishes to mimic the success of the field of medicine in integrating research and teaching. Then the information systems field must use the medical field as a reference discipline for teaching.

Table 1

Aspect of LCP	Overview
Active Participation	Learners are actively engaged in learning which may include a learn-by-doing or hands-on approach
Adapting to Needs	Learning is flexible and adapted to learners’ needs
Autonomy	Learners work by themselves taking responsibility for their own learning; learners are focused on both the content but also the long-term learning skills
Relevant Skills	Content is relevant to learners’ lives outside of the course; there is a focus on lifelong learning
Power Sharing	Learner has some measure of autonomy and is involved in decision making in the learning process
Formative Assessment	At least some assessment is student driven with students having the ability to repeat, alter and negotiate some elements of the assessment process

Numerous learning orientations, philosophies, theories, and methodologies in the medical field were examined to determine which may have a positive impact on developing an integration between teaching and research in IS programs.

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Many of the insights gleaned from the medical literature on teaching theories and techniques are have been adopted across academia. The use of active learning with techniques, such as the flipped classroom, is an example of a technique that has benefitted many, perhaps all disciplines.

There was a clear distinction that divided the theories, techniques or orientations from one another namely learner centered vs teacher center instruction. Learner Centered Pedagogy (LCP) focuses on the learner being responsible for learning with at least some measure of autonomy. Bremner (2021) offers six aspects of LCP shown in Table 1.

There has been considerable debate regarding the efficacy of LCP-(Learner Centered Pedagogy) related pedagogies with largely mixed outcomes (Bremner et al., 2022). While Bremner et al. (2022) found little objective evidence for LCP yielding superior outcomes to traditional approaches to learning, there was non-objective evidence (learner and teacher survey data) of a growing acceptance and appreciation for LCP. Rovers et al. (2018) studied why students use learning strategies with a focus on Self-Regulated Learning (SRL). While SRL differs from LCP, the underlying concept of students taking responsibility for their learning is similar. In fact, the active participation, relevant skills, power sharing and formative assessment aspects identified in Table 1 for LCP can also be found in SRL. An interesting element of the study is that the university in which the study was conducted incorporates the Problem-Based Learning (PBL) format into its programs which may influence students' acceptance of SRL. PBL is an underlying learning format used broadly within medical schools and is shown to improve performance after graduation (Prince et al., 2005).

PBL has been the focus of a great deal of literature denoting both positive and negative outcomes. There are not only meta-analyses of PBL but also a meta synthesis of meta analyses (Strobel & van Barneveld, 2009). PBL has taken on a number of definitions in part because of programs developing their own approaches that can influence outcomes (Barrows, 1996). For the purpose of this paper, PBL is defined as "an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2006, p. 9).

PBL (Problem Based Learning) utilizes real-world cases which already incorporate the relevant skills aspect of Learner Centered Pedagogy (LCP) as noted in Table 1. PBL also includes teams of students working together to come up with their own solutions to the problems posed with an ability to identify the items of interest that cover active participation, power sharing and formative assessment in addition to relevant skills (Moust et al., 2005; Rovers et al., 2018). PBL addresses four of the six aspects of LCP shown in Table 1.

5. DISCUSSION

The purpose of this paper is to consider learning theories that leverage student research and offer learning improvements in an undergraduate and graduate IS/IT program. The issue of complexity was studied as it has a growing impact on the IS field and is driving the specialization of roles in the IS field which are following a similar path to roles in the medical field a century earlier. The hope is that the IS field can learn valuable lessons from the medical field and bring about changes in our programs more quickly as a result.

The greatest revelation so far in this project is the role that Problem Based Learning (PBL) played in the early stages of the medical field grappling with changes to manage the specialization of the field and the broadening base of content students required. In addition to a broadening base of content, there was also an explosion of new technologies and specializations that medical schools either needed to teach, or at least provide learning pathways toward.

A significant goal of the new program is the development of a research program that is woven through the undergraduate and graduate degree programs. Benbya et. Al (2020) noted that complexity limits generalizability in research and requires multi-level representations of the world in research. This process necessitates a dramatic increase in research activities. A potential path forward is a call for applied research where undergraduates, including community college students, work with industry to examine questions relevant to their programs and collect data in formats useful to researchers. Theoretical researchers can consume datasets from applied research and use it in their work and perhaps issue calls for datasets with particular properties to which undergraduate programs can engage their efforts.

Such programs could constitute a win-win between undergraduate programs and researchers who consume their data.

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Undergraduate programs also have research requirements in many cases, and as long as there are outlets where their research can be published, this relationship would help faculty at the undergraduate level. Also, by establishing relationships with industry, undergraduate programs connect their students with industry opening doors for internships, apprenticeships and employment. As graduates with research experience enter the workforce there is an opportunity to link with professional associations to perpetuate the research cycle.

We contend that researchers who consume data from undergraduate applied research teams win, as they have datasets at their disposal that are collected under controlled conditions from industry. The fact that researchers can also describe the datasets they need, would lead to an even greater opportunity where researchers get exactly the data they were wanting. The availability of such datasets would allow exciting new topics to be explored.

Finally, we contend that the IS discipline and industry win as the data being collected via undergraduate programs could be repeated each semester with the next batch of students in the class, collecting data continuously or at intervals. In either case, IS academics get real-world data collected in a longitudinal format leading to rigor and relevance in research that has been sought for decades. Industry in turn receives research insight that is valued and actionable. This seems to be the goal laid out by Davenport & Markus (1999) when they called for emulating medicine or law. However, the growth in size, scale, complexity, and velocity of change in IS makes this change more necessary now than ever.

6. CONCLUSIONS

The authors of this paper are currently working with companies to determine willingness to participate in a second phase of this research project. Two of five firms contacted so far, have indicated a willingness to try to develop a relationship that will lead to undergraduate students working with the companies to develop a data collection. There will need to be legal agreements developed, and each company so far is requiring that datasets will need to be reviewed by IT audit teams at each collection interval to ensure the security parameters in the agreement were enforced, and that the parameters still protect the interests of the firms.

Assuming all of this works, there will also be a need to find a journal that will publish the data collections, and the IS field needs to find a way to value these contributions. Undergraduate faculty will need both publication credit that their school acknowledges and values, as well as student service credit to make this endeavor worthwhile for undergraduate faculty. It seems that some sort of academic speed-dating type of tool may also become necessary to help undergraduate programs wanting to participate to connect with research teams needing data and companies that want to provide data in exchange for potential future insights that can help the firm drive success.

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