Computational Thinking Guiding Change in Online Education

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Abstract

As enrollment in online courses increases, there is a need for faculty members trained in teaching with technology and who can design effective online learning environments. Faculty, however, may perceive barriers to successful online education programs such as: loss of personal interaction with students, technology challenges, pedagogical concerns, institutional policy issues, and potential problems related to support and compensation. Computational Thinking (CT) offers a logical, exploratory, expandable and collaborative way of solving complex problems in a state of change. This article examines and synthesizes the literature on both CT methods in teaching and perceived faculty barriers to wider adoption of online educational environments. A further aim is to offer suggestions for collaborative faculty design and development opportunities exploring online education using CT as a framework for problem-solving.

Keywords: online education; computational thinking; change management; faculty development

This article provides a review and synthesis of current literature on applications of CT in higher education, focused on how CT can guide change in online education. A further aim is to provide a framework to support faculty in higher education who are working with the challenges of transitioning from face to face (F2F) learning to online learning. This exploration may also serve as an introduction to CT for faculty integrating this style of problem-solving into existing curricula.

Ongoing change is necessary for growth and development in any system. Change is often problematic in complex systems, however, as it may create increased opportunities for error, increased barriers to success, and upheaval in psychosocial states. Over the last two decades, higher education has begun to address the challenge of adding a large number of online learning opportunities to more traditional F2F learning models. In addition to the challenge of orchestrating the many players needed to design and develop effective online courses, educators whose teaching and learning competencies were developed in a traditional classroom may find the shift to online pedagogy daunting.

Rogers' Diffusion of Innovation theory (2003), stresses that change is largely a social challenge. In order to promote learning engagement among digitally savvy students, educators must adapt to the dramatic changes brought about by the rise of the Web and mobile communication technologies (Johnson, Wisniewski, Kuhlemeyer, Isaacs, & Krzykowski, 2012). At the same time, “school cannot get ahead of society and the development of a [digital] literacy essentially requires time” (Papert, 2009, p.242). In order to meet the needs of digital-age students, face-to-face instructors must learn to incorporate the best of traditional classroom pedagogy in ways that address the needs of new online learning environments.

Complex social systems undergoing change benefit from a clear change implementation strategy. Computational Thinking (CT) can offer a framework supporting such a strategy.Computational Thinking involves “taking an approach to solving problems, designing systems and understanding human behavior that draws on concepts fundamental to computing” (Wing, 2006, p. 33). CT offers a construct for applied problem solving (Voskoglou & Buckly, 2012) related to social change through the use of algorithms, patterns, parallels and abstraction. By providing a clear articulation of the problems affecting change from one mode of pedagogy to another, CT can help educators build strategies for overcoming barriers to change.

Method

An initial set of key phrases, including “computational thinking”, “higher education”, “instructional design” and “online education” was used separately and in combination to search the full text database Academic Search Complete. This search was limited to peer-reviewed scholarly articles on higher education published after the year 2000. A second search was then performed on Academic Search Complete using the key phrases “faculty development”, “online education” and “faculty challenges/barriers” again separately and in combination. Selected secondary sources including texts, technical journalism and articles were found and added using both Google and Google Scholar.

Twenty-two articles from the literature search were categorized into two nodes using NVivo 10. The first node contained articles related to CT, the second articles on faculty barriers and solutions to online education (FBSOE). Summary tables of these nodes can be viewed in the appendix to this article. Text queries for abstraction, decomposition, algorithms, patterns, mapping and recursive thinking were then applied to the CT node. In the FBSOE node, text queries applied included social, pedagogy, technology training, support, and policy using stemmed words to expand relevance. These queries allowed a closer examination of authors’ ideas on faculty barriers and solutions for development, design and implementation, which will be elaborated on below.

Results

Faculty-perceived barriers to online education and solutions

According to Allen and Seaman (2013), student demand for online education increased over the ten-year period between 2002 and 2012, but faculty acceptance of online education remained low, at 32%. Lloyd, Byrne & McCoy (2012) performed a survey study on faculty-perceived barriers to online education and found perceptions of interpersonal relationship challenges, organizational issues, technology training and cost to be the most influential barriers. These findings are in line additional studies citing concerns about pedagogy and faculty support, as well as the relative quality of F2F vs. online course offerings (Smidt et al 2014; Alsofyani et al., 2013; Picciano, 2006).

The five top emergent faculty-perceived challenges are presented as additional research questions in Table 1, below:

Table 1.
Faculty-perceived challenges to successful adoption of online learning

Interpersonal Challenges	Technical Training	Pedagogical Concerns	Policy Concerns	Ongoing Support
How is the decreased social connection with students compensated for in successful online learning?	What is the learning curve for most faculty to adopt and adapt to the use of technology in teaching	Can online delivery offer the same educational quality as face-to-face learning?	Do the organizational policies support both faculty and students in an online delivery?	Does the organization offer support for the workload; recognize contributions (such as gaining tenure), continued faculty development?

Jonassen (2000) defined a typology of problems that can help to categorize these perceived challenges further. Jonassen's eleven problem types include: logical problems, algorithms, story problems, rule using problems, decision-making problems, troubleshooting problems, diagnosis solution problems, strategic performance, situated case policy problems, design problems, and dilemmas. A common problem example is technology implementation and training. Training many faculty members at once may compress the time needed but explode the cost of technology implementation in support of online courses. Categorizing these and similar problems can offer clarity and permit an effective strategy to emerge. In the example of a technology and training problem, at the institutional level it may be possible able to parse the problem into categories such as decision-making problems and policy problems, while at the level of smaller groups (such as academic departments) technology implementation and training may emerge as a strategic performance issue related to faculty development. Once these and similar problems are explored and defined, application of CT strategies may permit further refinement of potential solutions.

Social behavior and change processes

Human social behavior cannot always easily be categorized; heuristic (rule of thumb) approaches to problem solving may promote insecurity in linear thinkers and compound overlapping problems (Jonassen 2008; Silber, 2007). Nonetheless, conceptualizing problems as they emerge in the technology design and implementation processes can help keep all stakeholders (administrators, faculty, technologists, instructional designers, etc.) on the same page. For example, an experienced instructional designer can support both the people and technological changes through a series of well-planned introduction to processes. Project managers can also help to contain the scope of problems and processes associated with implementing online learning environments, as well as align interdisciplinary teams (Pan, 2012). DeSchryver and Yadav (2015) stress the importance of iterative thinking as both a creative skill and computational thinking process. Successfully transitioning faculty from F2F learning environments to online learning, may require several iterations at the stages of program, curriculum and course design.

Human interaction with change depends on the relative advantage, simplicity, compatibility, trialability, and observability (Rogers, 2003). Sharpe, Benfield, and Francois (2006) provided an overview of proposed strategy and leverages for change by examining both the context and culture within their organization. While this provides a high-level view of how processes can unfold, attention to human factors in the social context of change is critical (Rogers, 2103; Ali et al., 2005). Faculty members have a wealth of knowledge and experience within their own realms of expertise; they may find learning new teaching technologies and environments disconcerting. Drawing on faculty members' prior experience and knowledge, respecting their current role and placing them in autonomous but supported roles may help to minimize this effect.

Attributes of Computational thinking

Wing (2006) outlined how and why Computational Thinking (CT) is an important skill set for problem solving. According to Wing, CT is a way of conceptualizing problems to be solved by humans through integrating fundamental methods derived from computer science. In the case of change management related to adopting online learning, processes to overcome barriers can be derived by breaking down specific problems and identifying patterns in both the problems and any known solutions. Abstracting ideas that form principles can guide solutions and create algorithms or step-by-step solutions that offer logical clarity. By thinking differently about how problems are structured and solutions strategized, learning is grounded in theory but applied to a relevant and useful process.

Decomposition and Recursive Thinking By breaking problems down into smaller components, it is possible to focus attention on the type of problem and its component issues. Using decomposition to break down the interpersonal concerns cited by faculty in relation to online learning can offer clarity in sequencing and considering each as parts of the whole. Lloyd, Byrne, and McCoy (2012) determined that faculty members consider a potential loss of interpersonal interaction with students to be an important barrier to online learning adoption. They decomposed this result into into five specific categories of concern related to specific social interaction changes through a weighted factor analysis. Potentially, faculty development opportunities exploring each category individually would help faculty members discover and refine solutions to these concerns.

Patterns Human intuition drives pattern recognition. Common patterns begin to emerge in our awareness as we learn any new skill. Modinoveau (2009) discusses how recognizing patterns in problems can promote predictions and strategic solutions. For example, faculty members learning to develop online courses don't need to learn how to code each course in HTML. Rather, they should be able to recognize the patterns in the various structures that make up an online learning management system (LMS) such as Canvas, D2L, Moodle or Blackboard. While each LMS has its own unique proprietary specifics, any pedagogically sound courses content can be patterned into the system. Students also respond to repetitive patterns in course organization within a program. Human pattern recognition is the result of abstraction and recursive thinking (thinking about thinking). We think computationally in several instances each day without distinct awareness of doing so.

Abstraction Czerkawski and Lyman (2015) describe abstraction as "a tool that permits the creation of large and complex systems of information by defining and generalizing from simpler components" (p.57). This can be a useful when one encounters the challenges described by Silber (2007) in designing educational environments and methods when the design is guided by "ill-structured" or poorly defined problems at the outset. Abstraction allows us to examine the structure and complexity of problems before focusing on the details. "The most important and high level thought the process in CT is the abstraction process. Abstraction is used in defining patterns, generalizing from instances and parameterization" (Wing, 2010, p. 1). A common process in academic course development the use of curriculum mapping. Komenda et al. (2015) discuss the use of curriculum mapping through spatial representations of the curriculum so that interconnections can be visualized graphically using learning analytics, algorithms, and models to fully understand learning outcomes. While higher education curriculum is viewed at the university, program and course level, faculty at all ranks can engage with the curriculum at each level of abstraction, by viewing a map or web of interconnectivity. Voskoglou and Buckley (2012, p. 33) describe abstraction as a way of mapping from a complex representation to a simpler one.

Lu and Fletecher (2009) assert that problems can be understood and resolved more effectively by encouraging multiple levels of abstraction. For example, if the policy concerns are viewed from both the top-down and bottom-up perspectives, then organizational administrative and student concerns can be addressed. Focusing on a specific level of abstraction within a problem can yield clarity and more efficient solutions.

Parallels In computer science, parallel processing is used to accomplish many computing tasks synchronously; parallel thinking lends itself to further defining problems and making sense of them cognitively. Instructional design projects often use both sequential and parallel approaches. For example, Alsofyani, Aris, and Enyon (2013) described their experiences guiding faculty through change using the Technological, Pedagogical, and Content Knowledge (TPACK) model for building competencies in online education. They found that though prior studies have explored a hybrid model of online learning in teaching with technology, participants rated a fully online faculty development experience favorably. Similarly, Rienties et al. (2013) examined the impact of collaborative teacher training across different institutions and disciplines outside of their own in a parallel teacher training in technology course.

Algorithm Design Basic algorithms are step-by-step processes for resolving a specific challenge. We use algorithms each day in our thinking in simple human interchanges such as driving. If the light is red, I must stop, if it is yellow, I have choices. With respect to faculty forming algorithms to solve problems, Moldonoveau (2009) discusses how algorithms can provide logical steps, and also several different models in choosing a viable solution. For example, with regard to technical training, not all participants learn technology at the same pace. Offering a self-paced step-by-step approach in an online learning forum can promote faculty awareness of how students may perceive learning in an online format and build comfort with their own experience in a learning management system.

Change Management

Change management using CT can guide transitions by patterning human decision points using computer logic, abstraction, recursive thinking, and algorithms. The advantage of using a CT model to guide and promote change in higher education is a clarification of the complexity of the impact that change will have on educational systems. The shift from F2F courses to an online format creates uncertainty. Lack of professional development funding and opportunities compound this uncertainty among faculty members. Online learning and teaching with technology savvy students requires new pedagogical methods that incorporate technology. There are at least three emerging trends in development of new pedagogy for online education:

1. A move towards opening up learning, making it more accessible and flexible. The classroom is no longer the unique center of learning, based on information delivery through a lecture.

2. An increased sharing of power between the professor and the learner. This is manifested as a changing professorial role, towards more support and negotiation over content and methods, and a focus on developing and supporting learner autonomy. On the student side, this can mean an emphasis on learners supporting each other through new social media, peer assessment, discussion groups, and online study groups with guidance, support, and feedback from content experts.

3. An increased use of technology not only to deliver teaching but also to support and assist students and to provide new forms of student assessment. (teachingonline.ca, 2012, para.2)

Shifting to a more collaborative teaching-learning model can be especially effective with adult learners. Faculty members serve as facilitators and guides through new data, information, and knowledge. In learning to become online educators, faculty must view themselves as filling an emerging role. Figure 1 offers suggested uses of CT as solutions to some of the barriers they may perceive or encounter, based on this review of the literature:

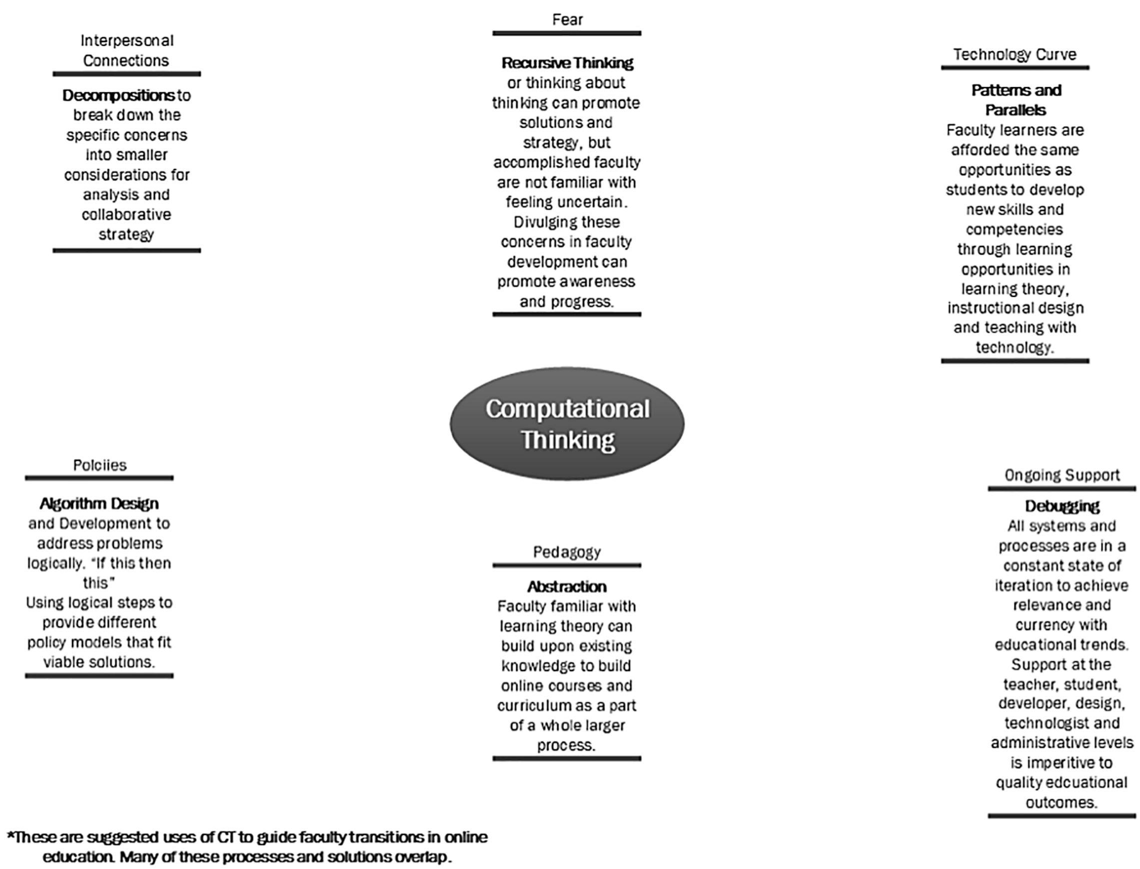

Figure 1. *Computational Thinking to Guide Faculty through Change*

Discussion

Vouskoglou and Buckley (2013) observed, "CT develops a variety of skills (logic, creativity, algorithmic thinking, and modeling/simulations), involves the use of scientific methodologies and helps to develop both inventiveness and innovative thinking" (Vouskoglou & Buckley, 2013 p. 29). CT offers faculty not only the opportunity to explore new problem-solving processes but also to unleash their own creativity in designing courses, research and policies within their areas of specialization. One way to offer faculty members a chance to learn CT would be to provide an opportunity to undertake online course development, using CT as a model. Faculty would be able to choose any subject of interest; participatory design and development of online course content would both promote an understanding of new course technology and allow faculty to apply their expertise in course content areas.

Institutions and departments can find one model in Soh, Shell, Ingraham, Ramsay, and Moore (2015), who created a series of courses that supported both analysis (decomposition, pattern recognition) and reflection (abstraction, algorithm design), but used simple description exercises to promote collaborative problem solving. Smidt, McDyre, Bunk, Li and Gatenby (2014) also offered a possible framework for development starting with face-to-face conversation and then transferring communications to an online discussion board.

Masterman, Walker and Bower (2013) also aimed to promote opportunities in using technology tools to guide and support pedagogy while also promoting collaborative faculty learning in designing online courses. They concluded "[the] challenge to embedding computational support for teachers' thinking in a manner that takes into account all these factors is to position it within the design of a program, department, and faculty where it is used by academics on a regular basis." (Masterman, Walker & Bower, 2013, p. 23).

Conclusion

Fear of risk and unfamiliarity with new possibilities impedes social change such as adoption of online learning. Innovation must have observable benefits, be compatible with the learner's current schema, combined with a scalable scaffold to build competency and overcome complexity through repeated experience. (Kaminski, 2011). CT offers a scaffold for breaking down problems related to adopting online learning into smaller pieces for analysis (decomposition), constructing solid pedagogy (recursion), simplifying problems (abstraction, parallels, and patterns), and planning applicable solutions and policies (algorithm design and automation). Additionally, CT is a logical approach to problem exploration and resolution that does not cut off creativity or collaboration. According to Mishra and Koehler, "learning is most effective when teachers have appropriate awareness of the complex interplay between pedagogy, technology and discipline knowledge, and integrate these when designing teaching" (as cited in Rienties et al., 2013, p. 482). By maintaining currency and relevance in pedagogy, including online learning, educators will be able to share knowledge using the methods that are most meaningful to current students.

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Appendix

Table A1

Articles on Computational Thinking

Authors	Type of article or population studied	Indicator	Comparator	Outcome
Barr, Harrison & Conery (2011)	Survey of PK-12 Teachers (N= 697)	To introduce concepts of CT and ascertain a working definition of relevance to teaching	Current curriculum, vocabulary, tools and applications for various disciplines at various levels	Development of a working definition of CT and a framework for application of skills acquired through CT educational opportunities
Berland & Duncan (2016)	Coded CT of students turns playing the game *Pandemic* (N= 23)	To learn if CT occurs naturally in cognitive processes and how they might be applied to educational opportunities	One control group and three research groups to explore scaffolding development, rule following, and algorithm design	Students innately used CT strategies with and without intervention. CT could be fostered in learning environments to promote problem-solving skills
Czerkawski & Lyman (2015)	Literature review	To explore the reasons why CT is not yet at fundamental educational opportunity in higher education and suggestions about how CT could be integrated	Comparison of current K-12 integrations of CT	Establishing partnerships, strategies, resources and research initiatives to support the integration of CT in the various disciplines in higher education will benefit all students in this computer oriented era
DeSchryver & Yadav (2015)	Literature Review Course Design	Can computational thinking promote creative thinking?	Creativity, creative thinking and computational thinking with applications for both faculty and student development.	Creative thinking interwoven into teachable technology at the design and delivery points. Computational and creative literacies promote students prepared for the complexities of future challenges

Table A1 Continued

Authors	Type of article or population studied	Indicator	Comparator	Outcome
Guzdial (2008)	Literature Review	Can non-computer science students benefit from CT processes?	Computer science and non-computer science students	CT is necessary for students of computer science and other disciplines because it is a necessary skill for 21st-century academics and professions
Kostadiov (2013)	Simulation	Can the usefulness of CT be simulated and illustrated for common problem-solving situations?	Statistical computation software application "R"	"R" allows for the visualization of CT for analysis of problems with random or non-linear solutions. The simulation supports the application of CT processes beyond science and math
Masterman, Walker & Bower (2013)	Feasibility Study	Can digital technology tools support faculty in learning design with determinative support?	Four different approaches to three computational design applications	Faculty assessment of the digital tools yielded the need for a deeper view of pedagogical design. The authors offer thinking using modeling, mapping abstraction, as suggestions to refine and align faculty development opportunities
Moldoveanu (2009)	Analysis of cognitive processes in managers	Can the analysis of the strategic thinking of managers foster new ways of thinking and predicting decision making?	Cognitively challenging problems vs. cognitively easy problems and computational thinking processes	Adjusting ways of thinking strategically through training and awareness can result in improved problem-solving opportunities
Soh, Shell, Ingraham, Ramsay, & Moore(2015	Undergraduate computer science students (N=15)	Can computational thinking and creative thinking combined promote expanded problem-solving skills?	Computational creative exercises (CCE) and control group	Higher test scores were correlated with students who completed the CCE courses
Voskoglou & Buckley (2012)	Literature Review Classroom experiment (N=90)	Can computational thinking skills support students in problem-solving?	Problem-solving experimental group supported with computers/ technology and control group	Critical thinking tools using computation and technology-enhanced student as evidenced by the better problem-solving skill

Table A1 Continued

Authors	Type of article or population studied	Indicator	Comparator	Outcome
Wing (2006)	Perspective	CT provides a "universally applicable" process that supports learners in all disciplines of all ages	CT to critical thinking and computer science	CT promotes a human focused process for generating new ways of thinking using abstraction, decomposition, algorithms and heuristics that can be applied to all disciplines, not just computer science
Wing (2008)	Perspective	CT is driven by both societal and technological progress as we increasingly rely on computers for everything we do	A fundamental understanding of CT is critical to students of the technological era we live in	As computers become ubiquitous in all human interactions, our relationship with computers will allow us to solve complex problems in all disciplines. CT will be a mainstream educational requirement of all students thriving in the age of technology and innovation

Table A2
Faculty-perceived barriers and solutions for online education

Author	Type of article or population studied	Indicator	Comparator	Outcomes
Ali et al. (2005)	Surveyed Faculty N=65)	To ascertain faculty perceptions of competency and assess future needs in teaching online	Benner's Novice to Expert Continuum.	Faculty rated highly in concerns for ongoing support. Faculty who had taken online courses had a higher level of perceived competence with online education
Allen &, Seaman (2012)	Surveyed faculty (N= 4564) Academic administrators (N= 591)	Growth of online education Increased push for online education	Faculty to Administrators	Faculty have more pessimism than optimism regarding quality and organizational commitment. Administrators have more optimism than pessimism

Table A2 continued

Author	Type of article or population studied	Indicator	Comparator	Outcomes
Hoffman and Dudyiak (2011)	Experiential review of process	Faculty professional development to address a gap in the knowledge of faculty transitioning to online education and subsequent technology	Traditional faculty roles, responsibilities, and skills with those required for teaching online.	Faculty transitioning from traditional didactic structure need initial and ongoing support in the design, development, administration to meet the professional, organizational and student needs of online education
Johnson, Wisniewski, Kuhlemeyer, Isaacs, & Krzykowski (2012)	Experiential review of process	Faculty development boot camp focused on guiding faculty through transitions to online learning	Knowles andragogy in support of adult learners	Faculty anxiety about implementing online education and using technology can be mitigated by faculty development programs. Faculty would benefit from having an introduction to learning theories as well as the technology that can support them
Lloyd, Byrne & McCoy (2012)	Literature Review and Survey (N=75)	A disproportionate number of faculty are prepared to meet the increasing demand for online education	Perceived barriers to faculty development and implementation of online learning and teaching	Perceived barriers include organizational, fiscal, technological, pedagogical and workload related challenges. These perceptions vary dependent upon rank, gender, and experience
Ortagus & Stedrak (2013)	Perspectives	How can the demand for online education be met with existing and/or “contingent” faculty	The current state of tenured faculty aligned with the “academic ratchet” of conflicting academic goals	Participation of tenured faculty through an incentivized and developed approach will be critical to providing quality educational opportunities for students seeking online education

Table A2 continued

Author	Type of article or population studied	Indicator	Comparator	Outcomes
Picciano (2015)	Conceptual framework and proposed plan for online education development focused on faculty	Careful planning of online education may promote better organizational, academic and pedagogical outcomes	Planning model vs disruptive innovation model	Perspectives on a proposed planning model for engagement with online education at the organizational level
Sahin (2006)	Literature Review	How are faculty rates of technology adoption influenced by social systems?	Faculty adoption of technology using Rogers Diffusions of Innovation Theory	Rogers's theory offers a predictable model for faculty adoption of technology but influenced by experience, training, and organizational support
Sharpe Benfield, & Francis (2006)	Contextual Analysis	What strategies promote the implementation of quality online learning for students and development by faculty?	Approaches by several academic institutions	Strategies for adopting online education include innovator champions, faculty-centered control over innovation projects and support from educational technologists
Smidt, McDyre, Bunk, Li, &Gatenby (2014)	University faculty using online discussion boards (n=21)	What are the specific attitudes of faculty toward online education and how can they be explored while developing new skills?	Qualitative review of faculty after implementation of an online educational experience	Course design and faculty training implications are offered as new opportunities to promote quality online education by faculty with an understanding of role as a facilitator