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ABSTRACT

The components of complex domains have dynamic, interdependent relationships that are often unstable. A useful method for representing relationships among elements in complex systems is causal influence diagramming, often described as concept mapping. This study employs the use of software applications, traditional assessment, and case studies to support systems analysis of learning theories through the development of causal influence diagrams (CID) and seeks to determine the extent to which causal influence diagramming affects performance on traditional assessment measures. A second goal of this study is to determine whether causal influence diagramming of a case study affects student performance on case study analysis. A partnership was formed between the faculty members responsible for teaching Educational Psychology courses in the elementary and secondary undergraduate programs. The faculty worked together to select appropriate software, identify important systems covered in the course, and establish a unified curriculum for teaching the systems targeted for the study. Students in undergraduate Educational Psychology courses were taught to use Inspiration software to express their understanding of causal relationships within learning theory and classroom systems. (Contains 13 references, 7 figures, and 3 tables.) (AEF)

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Systems Analysis of Learning Theory Through Causal Influence Diagrams

Key words: learning theory, causal influence diagramming, systems analysis, instructional design, cognition, assessment

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Systems Analysis of Learning Theory Through Causal Influence Diagrams

Theoretical Framework

The components of complex domains have dynamic, interdependent relationships that are often unstable. A useful method for representing relationships among elements in complex systems is causal influence diagramming, often described as concept mapping.

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According to Jonassen, the act of concept mapping enhances the interdependence of declarative and procedural knowledge to produce structural knowledge, knowledge that provides insight into why things are the way they are (Jonassen, 1996). Theories of learning are complex systems that all teachers must be prepared to navigate in order to design instruction that is meaningful and appropriate. Educational psychology course are often the first place students are introduced to these complex systems. Modern technologies have increased awareness and understanding of how humans learn while providing new and efficient tools for expressing relationships within these complex systems. Providing a variety of methods for students to communicate their understanding of complex systems is an important goal for educators teaching courses on learning theories and developmental psychology.

Advances in technology have stimulated interest in providing methods that support learning about complex domains (Spector and Davidsen, 1997), but there is no evidence that causal influence diagramming improves ability to analyze complex domains, although measurement instruments are currently under development. Spector suggests that tools borrowed from the realm of system dynamicists be employed to assess understanding of complex and dynamic systems (Spector, 2000). Dabbagh discusses the benefits of two concept mapping software tools that support the representation of complex systems and details the successes of previous studies on concept mapping and academic achievement (Dabbagh, 2001). Instructors and instructional designers now possess the resources to facilitate representation of complex systems through the creation of causal influence diagrams. Additionally, combining causal influence diagramming with a case-based approach to the study of learning theory provides students with a complex system to analyze and a method for representing their understanding of the relationships among components within the system.

This approach uses two pedagogical techniques that have been proven effective. Presenting a complex domain in the form of a case study allows prospective teachers to experience classroom life while encouraging detection of specific issues and problems within a safe, yet complex authentic context (Harrington, 1996). Contemporary software applications provide tools that support learning and analysis of complex domains (Spector & Davidsen, 1997), and classroom cases are easily obtained. This study employs the use of software applications, traditional assessment, and case studies to support systems analysis of learning theories through the development of causal influence diagrams (CID) and seeks to determine the extent to which causal influence diagramming affects performance on traditional assessment measures. A second goal of this study is to determine whether causal influence diagramming of a case study affects student performance on case study analysis.

Methodology

A partnership was formed between the faculty members responsible for teaching Educational Psychology courses in the elementary and secondary undergraduate programs. The faculty worked together to select appropriate software, identify important systems covered in the course, and establish a unified curriculum for teaching the systems targeted for the study. Students in undergraduate Educational Psychology courses were taught to use *Inspiration* software to express their understanding of causal relationships within learning theory and classroom systems. The software application facilitates the use of directional arrows, text fields, and graphics to indicate relationships between

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components within a complex system. Enough licenses of the software permitted installation of the application on each student's laptop for the semester, and the instructors taught the students to use the program during one 75-minute class period.

Present Study

The research design for the present study was refined after reflecting on the results of a pilot study. In the present study, students completed two descriptive causal influence diagrams and one analytical causal influence diagram. One descriptive diagram required students to demonstrate their awareness of the relationships between components of Piaget's theory and the other descriptive diagram required students to demonstrate their awareness of the relationships between major components of the Individuals with Disabilities Education Act (IDEA). These tasks were considered "descriptive" because the causal influence diagrams identified the complexity of the relationships without critical analysis of how the various components relate to classroom practice. Students completed these diagrams outside of class and submitted them on the day the class focused on the respective topics.

The analytical causal influence diagram required the students to determine motivational issues for a student case. This diagram was considered analytical because students were required to analyze the components of motivation represented in the case and show the relationship between the components and teaching strategies within a dynamic system. The instructor led students in an analysis and discussion of a motivational case prior to the deadline of the analytical diagram. Upon completion of class coverage of how motivation influences engagement and performance, students were presented with a narrative that depicted a typical classroom motivation case about a fictitious student named Wayne (See Table 1).

TABLE 1. Causal Influence Diagram Assignments and Assessment Criteria

Descriptive Causal Influence Diagrams	
Piaget (15)	Design a causal influence diagram that reveals the relationships between components in Piaget's theories. Criteria: Stages with minimum of 2 related concepts, adaptation, organization
IDEA (15)	Design a causal influence diagram that reveals the relationships between components of the IDEA. Criteria: Include components of IDEA from evaluation to due process and detail relationships between each component
Analytical Causal Influence Diagrams	
Guided practice case study – from Woolfolk, Anita. (2001) *Educational psychology, 8th edition*. Allyn and Bacon. Defensive Diana doesn't have her lab manual-again. You tell her that she may share with another student. Then Diana pretends to be working, but she spends most of her time making fun of the assignment or trying to get answers form other students when your back is turned. She wants everyone to know that she "isn't really trying." That way, if her grades are low she has an excuse. She is afraid to try because if she makes an effort and fails, she fears that everyone will know she is "dumb."	
CID assignment-Wayne's case (15) You begin class. . . . "Get out your research notes, your prewriting notes, and the current draft of your persuasive essay. We're going to continue writing and peer-editing body paragraphs today." The moaning begins and several students have questions about your expectations. A few students pull out their notes and get started, but Wayne slumps in his chair and tries to become invisible. Wayne doesn't have his research notes, but he does have a draft. He flips his papers and pretends to be editing his draft, making minor revisions and crossing out words and phrases. Wayne is unable to move forward with his essay because he has once again forgotten to bring important resources to class. Wayne always comes through in the end with a C or D quality product. Wayne doesn't keep track of his grades or his work. Instead, he relies on his "sense" of his performance and occasionally checks his current grade average, just to get his bearings. It appears that Wayne is sabotaging his chances for good grades. His grades are somewhat better in chemistry and algebra, but it's not like Wayne to try to impress anyone with his academic performance. Criteria: Design a CID that reveals the relationship between Wayne's motivational needs and teaching strategies that might help Wayne improve his academic performance. Include: type of learner, locus of control, goals, self schemas (motivational style, self-efficacy, view of ability)	
Formal assessment-Bridgett's case (5) Bridgett is usually the first student in the door for your World History class. She is an excellent student and is well liked by her peers. Helpful, prepared, and insightful, Bridgett possesses the work habits of an AP student. You've spoken to her about moving into a more advanced section of World History, but she refuses and says she doesn't want to lose her "A". Criteria: Analyze Bridgett's motivational tendencies based on the concepts we discussed in class. You may represent your analysis through narrative, listing, or diagramming. Include: type of learner, locus of control, goals, self schemas (motivational style, self-efficacy, view of ability)	

Students were asked to create a list of influential components in the motivation case and to identify the influence of each component on other components (Figure 1). Students also created a causal influence diagram that depicted their analysis of the relationships between components of the motivation system depicted in the case (Figure 2). All causal influence diagrams were evaluated based on criteria established by experts in educational psychology. Table 1 shows the three causal influence diagram topics, the case used during the class on motivation, and the criteria used to evaluate the causal influence diagrams.

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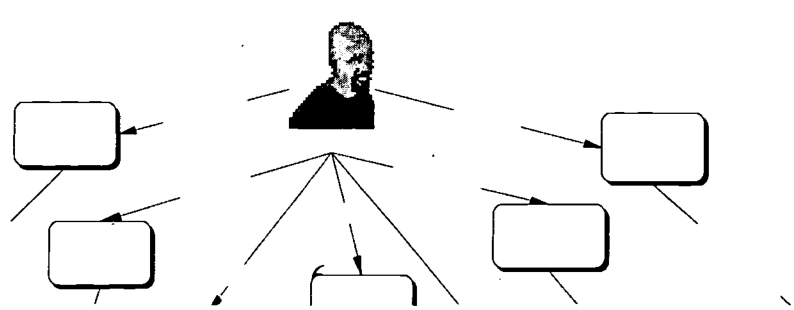
Figure 1. Chart outlining components and relationships for the analytical CID

DIRECTIONS:
Use the table to identify the variables associated with motivation theory in this scenario. Then, use this data to create a causal influence diagram that reflects your understanding of the theoretical and practical implications of the scenario

Name of the Concept/Variable	Value/Meaning of the Concept	Concepts Influenced	Teaching Strategy
Type of Learner: Work-avoidant	Doesn't work to look smart; wants to avoid work	Pays little attention; difficulty focusing; does work simply to finish – not to learn; low level of engagement; surface processing	Engaging activities; show the value of learning; connect materials to meaningful experiences; authentic tasks; autonomy and responsibility; high teacher expectations
Type of Motivation: Extrinsic Motivation	Caused by external factors such as rewards and punishments	Learning for rewards, not for the sake of learning itself; surface processing	Show value of tasks; authentic tasks; high teacher expectations; autonomy and responsibility
Motivational Style: Failure-accepting	Avoids failure by "sticking to what they know," not taking risks, and claiming to not care	Performance goals or no goals; external locus of causality; entity view of ability; learned helplessness; gives up easily; low self-esteem and self-concept	Recognition – authentic praise that focuses on progress, growing competence and independence; cooperative learning; de-emphasis on grades – emphasis on learning; set high (but obtainable) teacher expectations
View of Ability: Entity-fixed	Belief that ability is a fixed characteristic and cannot be changed	Set performance goals, if any at all; surface processing; low self-esteem or self-concept	Problem-based learning; autonomy; recognize progress and ability; encourage deep processing
Self-Efficacy: ??			
Type of Goal: Performance Goals (if any)	[illegible]	Surface processing; [illegible] – not for learning	Authentic tasks and problem-based learning; autonomy; recognize progress and challenge-seeking; de-emphasize grades and focus on learning
Locus of Causality: External	Something outside of the learner is causing behavior	[illegible] performance goals	Recognize effort and progress; autonomy and responsibility; high teacher expectations
Motivational Style: Learned Helplessness	Expectation, based on past failure, that all one's efforts will result in failure	Little motivation; external locus of causality; entity view of ability; work-avoidant; failure-accepting; pessimistic view of learning; low self-esteem and self-concept	Recognition; high teacher expectations; cooperative learning; comparing progress to self-best, not others; encourage student participation in evaluation

In an effort to determine the extent to which causal influence diagramming affects performance on traditional assessment measures, multiple-choice questions not related to the causal influence diagramming activities were identified for two tests. Multiple-choice questions on subjects included in the causal influence diagramming activities were identified and labeled as lower and higher level cognitive processing based on Bloom's taxonomy (Bloom, 1956). Multiple choice test items were also identified for the causal influence diagramming topics of Piaget, IDEA, and theories of motivation.

Figure 2. Causal Influence Diagram Analyzing Motivation Theory in a Case Study



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Upon conclusion of the final causal influence diagram, students were asked to respond anonymously to questions about causal influence diagramming and their perceptions of the effects on test performance. Data used to determine the extent to which causal influence diagramming influenced the ability to analyze complex systems came from causal influence diagrams created by the students, performance on multiple-choice test items, and anonymous student responses to open-ended questions.

Results

High performance on causal influence diagramming and accuracy on multiple-choice test items were common for students in this study. The causal influence diagram on Piaget was used to assess student knowledge of Piaget's theories as well as student ability to manipulate the software. It was evident by the quality of the products that the students had no difficulties manipulating the software. Student performance on causal influence diagrams was measured by comparing performance to expectations established by experts (see Table 1). Each causal influence diagram was worth fifteen points and full credit was earned if specific criteria were represented accurately on the diagram. Students were expected to demonstrate awareness of the relationships between components by using directional arrows labeled with text descriptors of the relationship. Mean, median, mode, and standard deviation were determined for performance on each diagram (see Table 2). The difference between the means of the diagrams is minimal and the standard deviation is the greatest on the analytical diagram. The large deviation and the high mode on the analytical causal influence diagram indicate that a few members of the group had poor performance while the majority earned high scores.

TABLE 2. Descriptive Statistics for Performance on Causal Influence Diagrams

	Piaget	IDEA	Motivation
Mean	12.6	11.4	11.8
Median	12	11	13
Mode	12	11	14
Std. Dev.	1.9	2.1	3.6

Student responses to multiple-choice questions on unit tests were also totaled and compared. Performance on each test item was assessed and a "1" was recorded for correct responses and a "0" was recorded for incorrect responses. Each set of questions yielded the same total points enabling easy comparison of question sets.

On the first test, frequency of responses on three questions not related to Piaget, three questions on Piaget's theory at the application level, and three questions on Piaget's theory at the knowledge/comprehension level was determined, total point value for each question set was 45. Figure 3 shows the total scores on the three sets of questions from the first test. Frequency of correct responses was the highest for knowledge level questions about Piaget's theory. The score for the control set of questions was lower than the knowledge level set of questions and only 1 point higher than the total score for the application level questions. Frequency of responses to multiple-choice questions was also calculated for the test on motivation. Student responses to two questions on topics other than motivation, two questions on motivation at the knowledge level, and two questions on motivation at the application level were tabulated and Figure 4 shows the results of those calculations. Total scores for each set of questions was 30 points. Total points earned on the control questions was 23, total points earned on analysis level questions was 29, and total points earned by the students on the identification/knowledge level

Figure 3. Frequency scores for multiple-choice questions on Piaget, N=15

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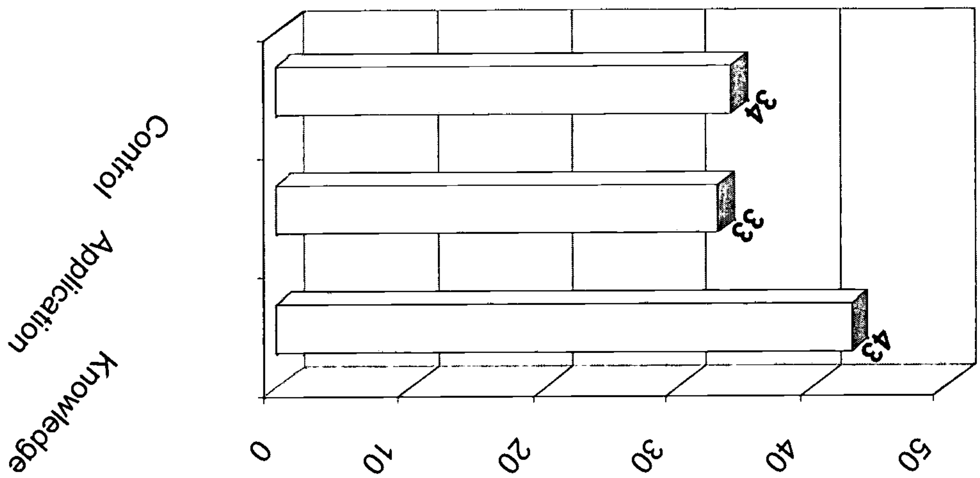
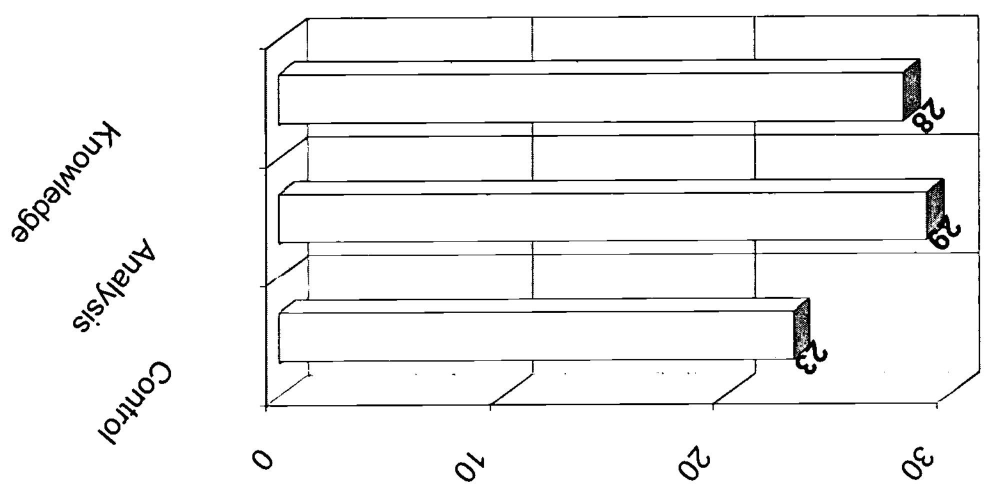


questions was 28. Results indicate that students performed better on the questions related to the topic of motivation than they did on the questions about topics not addressed with causal influence diagrams.

Figure 4. Frequency scores for multiple choice questions on motivation, N=15



Student performance on the analytical CID and a case analysis on a test were compared to determine the relationship between causal influence diagramming activities and performance on the case analysis. Table 4 presents the mean, median, mode, and standard deviation for both the diagram and the case analysis from the test. Higher modes for both measures indicate that most students performed well on the diagram and on the case analysis. The decrease in the standard deviation and high mean on the case analysis indicate that even more students were successful on that assessment item.

TABLE 3. Comparison of performance on CID to performance on motivation case analysis, N=15

13	Median	4
Causal Influence Diagram (1-15)		Motivation Case Analysis (1-5)
11.87	Mean	4.26
14	Mode	4
3.642	Standard Deviation	0.593

Student responses to questions about their perceived value of causal influence diagramming were also collected and analyzed. Student perceptions of how causal influence diagramming activities affected their understanding of the complex systems of Piaget's theory, IDEA, and motivation were measured by responses to three questions. The students responded anonymously to the following questions:

1. To what extent did causal influence diagramming affect your understanding of Piaget's theory, IDEA, and motivation theories?

2. To what extent did causal influence diagramming improve your understanding of the relationship between motivation theory and teaching practice?

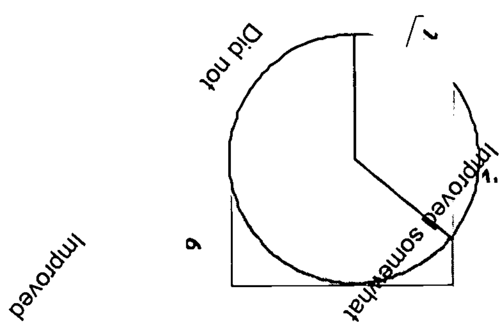
3. Did you use *Inspiration* for other classes? If yes, briefly describe how and why you used the software.

For question 1, student responses were categorized at three levels, did not affect, affected somewhat, and did affect. Figure 5 presents the frequency of student responses to question 1 and reveals that the majority of students believed that causal influence diagramming activities had a positive affect on their performance.

Figure 5. Frequency of responses to open-ended question 1, N=14

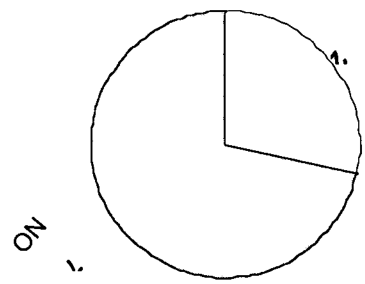
Figure 6 shows the frequency of responses to the second open-ended question. Student responses were categorized in three areas, did not improve, improved somewhat, and improved. Results of frequency analysis revealed that the majority of students perceived the causal influence diagramming activities as helpful.

Figure 6. Frequency of responses to open-ended question 2, N=14



Students were also asked if they used the software application for the causal influence diagramming activities in other classes. Figure 7 presents the frequency of responses to question 3 and reveals that most students did not use this application to support work in other classes.

Figure 7. Frequency of student responses to question 3, N=14



It is evident that this group of students perceived their experiences with causal influence diagramming as helpful on the study of complex educational systems. Students perceived descriptive causal influence diagramming as an effective tool to support understanding of complex systems. Fewer students indicated that analytical causal influence diagramming helped them recognize the relationships between theories of motivation and classroom practice. Slightly less than 1/3 of the students reported that they used the software application to help them in another class.

Discussion

Most students performed well on the causal influence diagrams and the test items. Comparison of student performance on multiple choice test questions related to both types of causal influence diagramming activities and multiple choice questions not related to the causal influence diagramming reveals that the activities affected student performance in a positive way. Student performance on the first test showed that correct responses to questions at the knowledge/comprehension level exceeded correct responses to the set of control questions. Accuracy on the application/analysis/synthesis level questions almost equaled the accuracy of responses to the set of control questions. Additionally, student self-reports show that attitudes toward the activities were positive.

Comparison of performance on multiple-choice test items on motivation revealed that scores for both sets of motivation questions exceeded the total group scores for the set of control questions and performance on analysis/application level questions was slightly higher than performance on knowledge/comprehension level questions. The majority of students felt that the activities were beneficial in helping identify relationships between theory and practice, and the performance on the test items supports their perceptions. The comparison of performance on the analytical causal influence diagram and analysis of a case on a test support the idea that critical analysis skills transfer. Students who performed well on the diagram performed well on the test. Although causality between performance on diagramming activities and test performance cannot be substantiated by this study, it can be assumed that the activities had some influence on student performance. The results of multiple-choice test questions on motivation theories indicate that the combination of a case study and a causal influence diagramming activity affected student performance more than descriptive causal influence diagramming. Student experience with the software, the activities, and more guided practice complicate interpretation of these results. It appears, however, that the combination of a case study and a causal influence diagramming activity had more impact on student performance than descriptive diagramming assignments.

Implications for Teacher Educators

The results of this study provide a starting point for a more controlled investigation of the effects of causal influence diagramming on the analysis of complex educational systems. Since student performance was consistently high on the diagrams and the multiple choice test questions on the diagrams, performance at causal influence diagramming can be a strong indicator of performance on traditional evaluation measures. Student self-reports indicate positive attitudes toward the activities, most likely facilitated by unlimited access to a computer and the software throughout the course.

A case study approach to an analytical causal influence diagramming activity has the potential to improve student performance beyond that descriptive diagramming alone. Integrating a systems analysis approach and computer software to facilitate the representation of complex systems in an educational psychology course is an excellent method for improving test performance, helping novice teachers recognize the value of non-traditional computer-based approaches to assessment, and modeling methods for addressing diverse learning styles. Engaging future teachers in such experiences throughout all phases of their preparation can only increase the likelihood that these methods will be integrated into their instructional design repertoire in the future. Meanwhile, causal influence diagramming activities prepare them to move into a closer study of the complex domain of teaching and learning in their professional preparation courses.

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