Research Proposal: The Impact of Cognitive Load on Learner Self-Efficacy in Multimedia Learning

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Introduction

Distance Education and Self-Efficacy

In 2016, nearly half (43.1%) of all undergraduate students in the United States were enrolled in at least one distance education course (Snyder, et. al., 2018). Furthermore, over a quarter (27.3%) of graduate students that year were pursuing their degrees completely online. This was all well before the distance-inducing pandemic, which saw enrollments in online coursework double from 2019 to 2020 (*Annual Data Reports*, 2020). With the ever-increasing popularity of distance education, it is critical that instructional content is designed to meet the needs of students.

Existing research has proven that students' confidence in their ability to succeed radically improves their likelihood of academic success (Arghode & McLean, 2021; Van Dinther & Segers, 2011). This confidence is defined as student *self-efficacy* (Bandura, 1972). While existing research has focused on improving student performance in online education (Sitzmann et. al., 2006; Shachar & Neumann, 2003), little research has sought to improve student self-efficacy. Self-efficacy has generally only been viewed as an influencing factor of success (Peiffer & Preckel, 2020; Shen et. al., 2013) rather than the goal of instructional design.

The weight of self-efficacy in online education raises an important question. Can online learning material be designed to improve learner self-efficacy?

Related Literature

Three topics reside at the core of this study: distance education, cognitive load theory, and self-efficacy. The following paragraphs explore related literature on each of these topics.

Research has shown that distance education (i.e. education in which the instructor and students are physically separated) can be just as effective as face-to-face education. Zhao and colleagues performed a meta-analysis (2005) in which they selected 1,375 highly accredited articles related to distance education. They established a coding system to help standardize "effectiveness" and found there was no notable difference between the effectiveness of distance education and face-to-face education. This implies that the quality of education isn't necessarily dictated by distance. It also suggests that existing distance education solutions may act as a baseline and adjustments to their design could lead to greater effectiveness.

Beyond Zhao et. al.'s research, some studies have found that distance education, when designed well, can actually out-perform traditional classroom instruction. In one meta-analysis, Sitzmann and colleagues (2006) hypothesized that web-based instruction (WBI) can be more effective than classroom instruction (CI) for teaching declarative knowledge. To test their hypothesis, they gathered data from 96 research reports. These reports accounted for a total of 19,331 trainees and 168 courses, all spanning a broad sample of course subjects and collegiate educational levels. In their analysis, they found that WBI was 6% more effective than CI for teaching declarative knowledge and 19% more effective when trainees were provided with more control and iterative feedback. This not only implies that WBI can outperform CI, but that the instructional design itself heavily influences the degree to which it does so.

Mayer & Moreno (2003) provide suggestions for improving instructional designs in multimedia learning. They pair the dual-channel assumption (a cognitive theory for processing pictorial and verbal material) with the concept of cognitive overload to suggest 9 ways to reduce cognitive load. These suggestions are based on their previous studies and other studies related to the field. If used to guide the design of multimedia learning solutions, they should help prevent cognitive overload in students, therefore freeing up cognitive space to more effectively learn the instructional content. This not only implies that cognitive load can be manipulated by content design, but that the subsequent effectiveness of the instruction is impacted as well.

Most existing research assumes the ultimate goal of instructional designers should be to achieve Mayer and Moreno's definition of meaningful learning. That is, students should develop a deep enough understanding of learning material to mentally organize it into a coherent cognitive structure and integrate it with what they already know. One commonly discussed driving factor in achieving this goal is self-efficacy. Self-efficacy is an individual's belief in their capacity to execute behaviors necessary to produce specific performance attainments (Bandura, 1972, 1977, 1986). In other words, self-efficacy is one's confidence in their ability to succeed.

Indeed, students who are confident in their ability to learn are more likely to achieve academic success. Write and colleagues (2013) explored the effect self-efficacy has on academic performance by observing 401 undergraduates through regression analyses. In their study, they found that individuals with higher self-efficacy in their first semester were more likely to persist into future semesters. This, in turn, led to further academic success and future patterns of persistence.

Such behavior is consistent with continued success in future careers. Ballout (2009) found that self-efficacy must be present for career commitment to predict objective and subjective goals. That is, individuals with average to high self-efficacy are more likely to reach salary goals or be satisfied with their careers than those with low self-efficacy. Self-efficacy also plays a vital role in career decision-making, generating interests, and deciding career goals (Arghode & McLean, 2021).

Cognitive load may also be related to self-efficacy. One highly relevant example is found in Chow and colleagues' (2015) exploration of the impact ego-depletion has on self-efficacy. In their study, they ran three separate experiments that induced ego-depletion, then measured the impact each method had on self-efficacy. They found that a tired mind leads to lower self-control and efficacy. Ego-depletion is the notion that willpower draws upon a limited pool of mental resources (Baumeister, et. al., 1998). This notion, much like cognitive load theory, perceives mental energy as finite. A lighter cognitive load, therefore, uses less mental energy. That, in turn, should improve self-efficacy.

Margolis and Mccabe (2006) provide another relevant article. In it, they outline three methods teachers can use for improving student self-efficacy. Based on self-efficacy theory, they present enactive mastery, vicarious experiences, and verbal persuasion as ways for teachers to help improve students' confidence in their ability to succeed. Enactive mastery, the curation of situations in which people experience a "small win" to drive future performance, aligns with the benefits of decreased cognitive load. Indeed a lighter cognitive load should feel similar to an easy win.

Hypothesis

Because the design of instructional material has been shown to influence student perceptions and performance (Sitzmann et. al., 2006) and mentally taxing tasks have been shown to impact self-efficacy (Chow et. al., 2015), it is hypothesized that cognitive load would influence self-efficacy. Based on this, the current study predicts that when multimedia learning experiences are designed to reduce cognitive load, they will positively impact student self-efficacy.

Methods

This study will use a basic trickle-down randomized design comparing multiple treatments to investigate the impact of cognitive load on learner self-efficacy in multimedia learning. Self-efficacy will be measured using a variation of the 8 questions from Chen et. al.'s (2001) General Self-Efficacy Scale. Responses will follow a 6-point Likert scale ranging from strongly disagree to strongly agree (Maurer & Pierce, 1998). Each participant's answer will be aggregated into an average ranging from 1 (lowest self-efficacy) to 6 (highest self-efficacy) to provide a singular measurement. This measurement will be used to compare the results between different treatment groups.

A digital instructional module consisting of segmented instructional videos will be developed to teach participants three basic graphic design principles (alignment, repetition, and balance). 5 iterations of the module will be created by following and violating recommendations for reducing cognitive load in multimedia learning (Mayer & Moreno, 2003).

Participants

This study will collect data from Amazon Mechanical Turk (MTurk) participants using the Qualtrics survey platform. A total of 250 participants will be recruited to allow for 50 participants in each experiment group. This number was selected as a range that follows trends in similar studies related to online learning (Craig et. al., 2015; Craig et. al., 2009; Driscoll et. al. 2003). Participants will be compensated $1.81 for their time. It is expected that each individual will complete the study within 15 minutes. Participants will be limited to US MTurk users with a 95% completion rate and at least 50 completed hits. These requirements have been proven to generate high-quality data by ensuring genuine human responses (Paolacci & Chandler, 2014).

Materials

Demographics Survey

A 6-question demographics survey will be given to each participant to record their age, ethnicity, gender, highest level of education, location, and language fluency.

Knowledge Test

A knowledge test will be given to each participant to measure their existing knowledge of the three graphic design principles presented in the instructional module. This test consists of 3 open response questions:

1. In your own words, describe the graphic design principle of balance.
2. In your own words, describe the graphic design principle of repetition.
3. In your own words, describe the graphic design principle of alignment.

This test will be administered before participants watch the instructional content, then administered again afterward to measure learning. The coding system used to grade responses will be generated based on the content in the video. Grades will be determined by how many of the key points shown in the video are included in the responses. The pre-test may also be used to control for the impact that existing knowledge can have on cognitive load and self-efficacy.

Instructional Modules

5 instructional modules will be randomly and evenly distributed to participants. Each module is based on one template in which 5 instructional video segments are presented in sequence; the design of which is dependent on the manipulation. Table 1 outlines these module iterations in their relation to Mayer and Moreno's recommendations.

Table 1

Instructional Module Iterations Designed to Manipulate Cognitive Load

Module Iteration	Technique for Reducing Cognitive Load		
	Off-Loading	Segmenting and Pre-instruction	Weeding and Signaling
A			
B	Violated		
C		Violated	
D			Violated
E	Violated	Violated	Violated

Self-efficacy Questions

After viewing the instructional material, participants will be given 8 questions to measure their resulting self-efficacy. A variation of Chen et. al.'s (2001) General Self-Efficacy scale will be used to administer the following questions:

1. I can achieve most of the goals for applying alignment, repetition, and balance principles that I set for myself.
2. When facing difficult tasks related to alignment, repetition, and balance principles, I am certain that I can accomplish them.
3. In general, I think that I can obtain outcomes related to alignment, repetition, and balance principles that are important to me.
4. I believe I can succeed at most any endeavor related to alignment, repetition, and balance principles to which I set my mind.
5. I can successfully overcome many challenges related to applying alignment, repetition, and balance principles.

6. I am confident that I can perform effectively on many different tasks related to applying alignment, repetition, and balance principles.
7. I am confident that I can perform effectively on many different tasks related to alignment, repetition, and balance principles.
8. Compared to other people, I can do most tasks related to alignment, repetition, and balance principles very well.

Responses will follow a 6-point Likert scale ranging from strongly disagree to strongly agree (Maurer & Pierce, 1998).

Knowledge Transfer Test

A 7-question test will be given to participants to measure their ability to transfer the knowledge they learned in the instructional material to novel situations. Questions in this test will require participants to apply graphic design techniques to visuals not presented in the instructional videos. The following multiple-choice questions will be used:

1. Which of the following designs best follows the principle of alignment?
2. Which principle is violated in this design? Why?
3. Is the principle of repetition used well in this design? Why or why not?
4. Which principle is violated in this design? Why?
5. Which of the following designs best follows the principle of balance?
6. Is the principle of alignment used well in this design? Why or why not?
7. Which of the following designs best follows the principle of repetition?

Each question response will be flagged as correct or incorrect, then used to calculate an overall test percent grade.

Mental Effort Question

A single question measuring mental effort (Paas, 1992) will be given intermittently to participants to record the cognitive load associated with different tasks performed during the study. This question will be given after the instructional module, recall post-test, and knowledge transfer test. The question is as follows: How much mental effort did you have to use to answer the previous questions? Responses will follow a 9-point scale from “very, very low mental effort” to “very, very high mental effort.”

Inattentiveness Filter Questions

Following recommendations from Kennedy et. al. (2020), participants will be given two additional questions at the end of the study to confirm attentiveness. One question will ask for the year they were born to confirm it matches the age they listed in the demographic survey. The other will ask for their city of residence to confirm it is in the state they previously listed in the demographic questions.

Procedure

Upon recruitment from MTurk, participants will receive the consent form. They will then answer the demographic questions, after which they will be randomly assigned to one of the 5 experimental conditions. Each participant will then watch the instructional videos assigned to their group. After completing the instructional videos, participants will answer self-efficacy questions, take a recall test, and take a knowledge transfer test. Mental effort questions will be included between each test to measure cognitive load. At the close of the study, participants will answer two questions designed to flag inattentive responses.

Conclusion

Self-efficacy is an important element of student success in online learning. By manipulating the design of an instructional video to adjust cognitive load, this experiment will seek to understand if a decrease in cognitive load has a positive influence on self-efficacy. If so, the value of well-designed multimedia learning material extends beyond immediate performance as it influences the critical measurement of self-efficacy.

References

Annual Data Reports. (2020). Retrieved February 19, 2022, from https://nc-sara.org/annual-data-reports

Arghode, Heminger, S., & McLean, G. N. (2021). Career self-efficacy and education abroad: implications for future global workforce. *European Journal of Training and Development,* 45(1), 1–13. https://doi.org/10.1108/EJTD-02-2020-0034

Ballout. (2009). Career commitment and career success: moderating role of self-efficacy. *Career Development International,* 14(7), 655–670. https://doi.org/10.1108/13620430911005708

Bandura, A. (1972). *Self-efficacy: The Exercise of Control*.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. In *Psychological Review* (Vol. 84, Issue 2, pp. 191–215). https://doi.org/10.1037/0033-295x.84.2.191

Bandura, A. (1986). The Explanatory and Predictive Scope of Self-Efficacy Theory. In *Journal of Social and Clinical Psychology* (Vol. 4, Issue 3, pp. 359–373). https://doi.org/10.1521/jscp.1986.4.3.359

Bandura, A. (2006). Guide for constructing self-efficacy scales. *Self-efficacy beliefs of adolescents*, 5(1), 307-337.

Baumeister, Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego Depletion: Is the Active Self a Limited Resource? *Journal of Personality and Social Psychology*, 74(5), 1252–1265. https://doi.org/10.1037/0022-3514.74.5.1252

Broadhead-Fearn, D., & White, K. M. (2006). The role of self-efficacy in predicting rule-following behaviors in shelters for homeless youth: A test of the theory of planned behavior. *The Journal of Social Psychology,* 146, 307-325.

doi:10.3200/SOCP.146.3.307-325

Casey, Logan S., Jesse Chandler, Adam Seth Levine, Andrew Proctor, & Dara Z. Strolovitch. (2017). Intertemporal Differences Among MTurk Workers: Time-Based Sample Variations and Implications for Online Data Collection. *SAGE Open*, 7. https://doi.org/10.1177/2158244017712774

Chen, G., Gully, S. M., & Eden, D. (2001). Validation of a new general self-efficacy scale. *Organizational research methods, 4*(1), 62-83.

Chow, Hui, C. M., & Lau, S. (2015). A depleted mind feels inefficacious: Ego-depletion reduces self-efficacy to exert further self-control. *European Journal of Social Psychology*, 45(6), 754–768. https://doi.org/10.1002/ejsp.2120

Copperman, A. (2020). *8 basic design principles to help you create better graphics.* Adobe Blog. Retrieved February 25, 2022, from https://blog.adobe.com/en/publish/2016/08/11/8-basic-design-principles-to-help-you-create-better-graphics

Craig, Chi, M. T. H., & VanLehn, K. (2009). Improving Classroom Learning by Collaboratively Observing Human Tutoring Videos While Problem Solving. *Journal of Educational Psychology, 101*(4), 779–789. https://doi.org/10.1037/a0016601

Craig, S. D., Twyford, J., Irigoyen, N., & Zipp, S. A. (2015). A Test of Spatial Contiguity for Virtual Human's Gestures in Multimedia Learning Environments. *Journal of Educational Computing Research, 53*(1), 3–14. https://doi.org/10.1177/0735633115585927

Driscoll, D. M., Craig, S. D., Gholson, B., Ventura, M., Hu, X., & Graesser, A. C. (2003). Vicarious Learning: Effects of Overhearing Dialog and Monologue-like Discourse in a Virtual Tutoring Session. *Journal of Educational Computing Research, 29*(4), 431–450.

https://doi.org/10.2190/Q8CM-FH7L-6HJU-DT9W

Fleischer, Mead, A. D., & Huang, J. (2015). Inattentive Responding in MTurk and Other Online Samples. *Industrial and Organizational Psychology*, 8(2), 196–202. https://doi.org/10.1017/iop.2015.25

Kennedy, Clifford, S., Burleigh, T., Waggoner, P. D., Jewell, R., & Winter, N. J. G. (2020). The shape of and solutions to the MTurk quality crisis. *Political Science Research and Methods*, 8(4), 614–629. https://doi.org/10.1017/psrm.2020.6

Margolis, & Mccabe, P. P. (2006). Improving Self-Efficacy and Motivation: What to Do, What to Say. *Intervention in School and Clinic*, 41(4), 218–227. https://doi.org/10.1177/10534512060410040401

Mayer, R. E., & Moreno, R. (2003). Nine Ways to Reduce Cognitive Load in Multimedia Learning. In *Educational Psychologist* (Vol. 38, Issue 1, pp. 43–52). https://doi.org/10.1207/s15326985ep3801_6

Maurer, T. J., & Pierce, H. R. (1998). A comparison of Likert scale and traditional measures of self-efficacy. *Journal of Applied Psychology, 83*(2), 324–329. https://doi.org/10.1037/0021-9010.83.2.324

Najafi, M. & Foladjang, M. (2007). The Relationship Between Self-Efficacy and Mental Health Among High School Students. روانشناسی بالینی و شخصیت, 1(22), 69–83.

Paas, F. G. W. C. (1992). Training strategies for attaining transfer of problem-solving skills in statistics: A cognitive-load approach. *Journal of Educational Psychology, 84*(4), 429-434. doi:http://dx.doi.org/10.1037/0022-0663.84.4.429

Paolacci, G., & Chandler, J. (2014). Inside the Turk: Understanding Mechanical Turk as a participant pool. *Current directions in psychological science, 23*(3), 184-188.

Peiffer, Ellwart, T., & Preckel, F. (2020). Ability self-concept and self-efficacy in higher education: An empirical differentiation based on their factorial structure. *PloS One, 15(7)*, e0234604–e0234604. https://doi.org/10.1371/journal.pone.0234604

Shachar, & Neumann, Y. (2003). Differences Between Traditional and Distance Education Academic Performances: A Meta-Analytic Approach. *International Review of Research in Open and Distance Learning*, 4(2), 1–20. https://doi.org/10.19173/irrodl.v4i2.153

Shadish, W. S., Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and Quasi-experimental Designs for Generalized Causal Inference*. Wadsworth Publishing Company.

Shen, Cho, M.-H., Tsai, C.-L., & Marra, R. (2013). Unpacking online learning experiences: Online learning self-efficacy and learning satisfaction. *The Internet and Higher Education*, 19, 10–17. https://doi.org/10.1016/j.iheduc.2013.04.001

Simonson, Smaldino, S. E., & Zvacek, S. (2015). T*eaching and learning at a distance : foundations of distance education* (6th ed.). Information Age Publishing, Inc.

Sitzmann, Kraiger, K., Stewart, D., & Wisher, R. (2006). The Comparative Effectiveness of Web-based and Classroom Instruction: A Meta-analysis. Personnel Psychology, 59(3), 623–664. https://doi.org/10.1111/j.1744-6570.2006.00049.x

Snyder, T., Brey, C., & Dillow, S. (2018). Digest of Education Statistics 2018. https://nces.ed.gov/pubs2020/2020009.pdf

Van Dinther, Dochy, F., & Segers, M. (2011). Factors affecting students' self-efficacy in higher education. Educational Research Review, 6(2), 95–108. https://doi.org/10.1016/j.edurev.2010.10.003

Wright, Stephen, L., Jenkins-Guarnieri, M. A., & Murdock, J. L. (2013). Career Development Among First-Year College Students: College Self-Efficacy, Student Persistence, and Academic Success. *Journal of Career Development, 40(4)*, 292–310. https://doi.org/10.1177/0894845312455509

Zhao Y, Lei J, Lai BYC, Tan HS. (2005). What makes the difference? A practical analysis of research on the effectiveness of distance education. *Teachers College Record, 107*, 1836–1884.