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Work in Progress: Investigation of the Psychological and Demographic Characteristics that Impact Performance in Online Modules and Courses

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Dr. Spiegel is the Assistant Provost and Executive Director of the Trefny Innovative Instruction Center at the Colorado School of Mines. He previously served as Chair of the Disciplinary Literacy in Science Team at the Institute for Learning (IFL) and Associate Director of Outreach and Development for the Swanson School of Engineering's Engineering Education Research Center at the University of Pittsburgh. Prior to joining the University of Pittsburgh, he was a science educator at Biological Sciences Curriculum Study (BSCS). Dr. Spiegel also served as Director of Research & Development for a multimedia development company and as founding Director of the Center for Integrating Research & Learning (CIRL) at the National High Magnetic Field Laboratory, Florida State University. Under Dr. Spiegel's leadership, the CIRL matured into a thriving Center recognized as one of the leading National Science Foundation Laboratories for activities to promote science, mathematics, and technology (STEM) education. While at Florida State University, Dr. Spiegel also directed an award winning teacher enhancement program for middle grades science teachers, entitled Science For Early Adolescence Teachers (Science FEAT).

His extensive background in science education includes experiences as both a middle school and high school science teacher, teaching science at elementary through graduate level, developing formative assessment instruments, teaching undergraduate and graduate courses in science and science education, working with high-risk youth in alternative education centers, working in science museums, designing and facilitating online courses, multimedia curriculum development, and leading and researching professional learning for educators. The Association for the Education of Teachers of Science (AETS) honored Dr. Spiegel for his efforts in teacher education with the Innovation in Teaching Science Teachers award (1997).

Dr. Spiegel's current efforts focus on educational reform and in the innovation of teaching and learning resources and practices.

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Work-in-Progress: Investigation of the psychological and demographic characteristics that impact performance in online course modules

Abstract:

This paper describes a work-in-progress research study, being conducted for a larger project funded by the National Science Foundation. The study is investigating the relationship between learners' psychological characteristics of mindset, self-efficacy, and metacognition and performance in online learning experiences focusing on skills and topics relating to Advanced Manufacturing. The unique nature of the project is that the online course experiences is intended for learners in four different settings: industry/workplace, 2-year colleges, 4-year colleges, and informal settings. Through this project, learners will enroll in the modules with varying levels of expertise as well as beliefs, goals, and motivational factors that may impact their behaviors and performance. The study may be of interest to educational researchers of psychological influences on learning as well as practitioners who develop online learning experiences. This paper describes the overall project, the corresponding educational research study, and progress on the project to date.

Introduction

This work-in-progress research study is being conducted as part of a larger project funded by the National Science Foundation investigating online learning pathways in Advanced Manufacturing and Data Science. The focus of the overall project is to "design, develop, deploy, and study the effectiveness of online module learning experiences…that form learning pathways in data science and advanced manufacturing." The online learning experiences, consisting of assessments, modules, and courses, will connect learners with experts in four different learning settings: industry/workplace, 2-year colleges, 4-year colleges, and informal settings. These four learner settings provide an opportunity to study how the setting, structure of online learning, and the characteristics of learners could potentially affect learners' performance and behaviors. Through this project, learners will enter the learning pathways possessing different levels of expertise and having varying beliefs, goals, and motivational factors that may impact their behaviors and performance. This study focuses on the psychological and demographic characteristics that may impact performance in the online learning experiences. These characteristics include growth/fixed mindset, self-efficacy, metacognition, and various demographic variables.

Literature Review and Background

Literature from educational psychology posits several constructs that can potentially impact academic performance and course behaviors. One variable includes the learner's beliefs about the malleability of human traits (such as ability or intelligence), also known as growth vs. fixed mindset. According to Dweck (2008), learners with growth mindsets have the belief that human traits are incremental and can be changed with practice and training. Learners with fixed mindsets believe that traits are immutable and cannot be changed, regardless of practice or training. Research has supported that having a growth mindset positively relates to academic performance (Blackwell, Trzesniewski, & Dweck, 2007), self-efficacy (Komarraju and Nadler, 2013), and motivational beliefs (Dinger, Dickhäuser, Spinath, & Steinmayr, 2013). Additionally, research has suggested that messaging from instructors can trigger a fixed mindset in students, resulting in learners making choices to select easier rather than more challenging tasks (Aguilar, Walton, & Wieman, 2014).

In both resident and online courses, the instructional environment should be deliberately created to encourage learners to engage in effortful and engaging activities and to utilize cognitive and metacognitive strategies that will help ensure the fruitfulness of their efforts. Mindset, self-efficacy, and motivation have each been shown to positively impact student performance. However, little research has been done to explore the interaction among these constructs. Exploring the interaction among these different constructs across multiple learning contexts will allow the researchers to further explore these relationships to find ways to encourage improved learner performance. In addition, exploring these constructs across four populations of learners can shed light on the interaction between various demographic and psychological constructs.

Context of larger grant

In addition to developing online learning experiences to enhance current and future workforce members in manufacturing, the call for proposals required an in-depth engineering education component. We are using the Engineering Learning framework (Spiegel, 2016) to design, develop, deploy, evaluate, and disseminate self-assessment tools, modules, and courses that align to form learning pathways that empower diverse learners to reskill or enhance their skills to tackle advanced manufacturing problems through data science. The Engineering Learning framework uses cognitive principles in the development of online courses (Spiegel, Sanders, & Sherer, 2018a; Spiegel, Sanders, & Sherer 2018b). As the framework states, "Engineering Learning is an intentional design process that positions students to cognitively engage with content and data using professional tools, while interacting and collaborating with peers to develop their content expertise, skills, and professional practices. The end goal is to create the richest opportunities for students to become innovative STEM leaders." Principles included in the framework include alignment with student learning outcomes, engagement with active learning, reflecting on learning, among other constructs and principles. The study of the constructs of growth/fixed mindset, self-efficacy, and metacognition align well with Engineering Learning and the design of the modules.

In addition to the general approach being used to develop the modules, learners will complete a module specifically dedicated to growth/fixed mindset. This module explains growth/fixed mindset, assesses participants' current mindset about the subject area, guides participants through two activities around growth/fixed mindset, and talks about strategies to have a growth mindset when going through the modules. There will be reminders throughout the module pathway for learners to consider mindset when completing their work. This research study will find out what connects best with learners at various skill levels, predictive aspects of the users regarding their learning and pathways, as well as different learning format designs.

Research Questions

Five research questions are being studied for this project, which are listed here:

1) How do psychological characteristics of learners, including mindset, self-efficacy, and metacognition affect performance in the online course modules?
2) How do the learners' demographic characteristics, such as gender, prior knowledge, and educational background affect performance?
3) What is the interaction among the psychological characteristics and demographic characteristics of learners that affect performance?
4) How do the psychological characteristics and their inter-relationships (mindset, self-efficacy, and metacognition) differ across the four learning settings?
5) How do the learners' demographic and psychological characteristics affect their preferences and navigation patterns (i.e., preferences for specific types of assignments and course behaviors) with the various course design elements (i.e., less challenging versus more challenging assignments, reflection activities)?

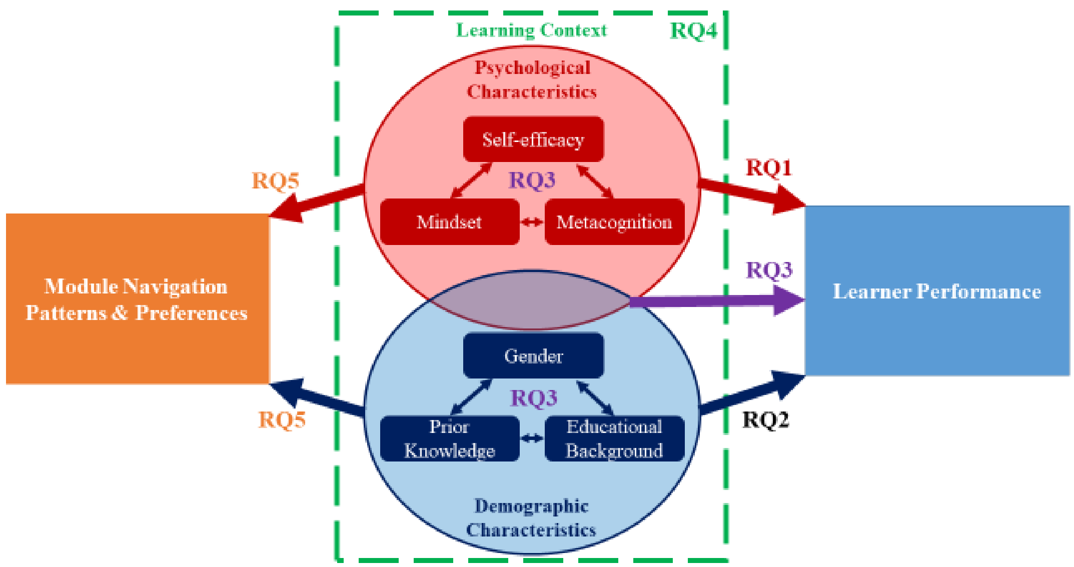

Figure 1: Illustration of research questions and the relationship of learners' characteristics to performance and navigation patterns and preferences

Research Methods

The proposed research method for this study is primarily survey based, with both existing instruments and newly developed instruments used to measure each construct of interest. Table 1 lists the instruments, measure, source (if using an existing instrument), and the timeline for when each instrument would be administered.

Growth versus fixed mindset will be measured using Dweck's (1999) Implicit Theories of Intelligence Scale. Because mindset can differ based on different domains, the research team acknowledged that an additional instrument needed to be created to measure learners' beliefs in the domains included in the online learning experiences- namely engineering, manufacturing, and data science related fields. Therefore, a set of different measurements were created relating to growth mindset. These included a measure we call the Implicit Theories of Engineering Ability scale, which is an 8-item Likert-type scale measuring the degree that engineering ability is more of an innate, fixed trait, or consisting of skills that can be improved with training and practice. We also created a measure, which we call the Implicit Theories of Advanced Manufacturing Competencies scale, that is intended to measure learners' beliefs about the malleability of the competencies associated with advanced manufacturing.

Self-efficacy within the course modules will be measured by the self-efficacy scale on Pintrich and colleagues' (1991) Motivated Strategies for Learning Questionnaire (MSLQ). An additional scale that was developed by the authors of this paper includes a domain-specific measure of self-efficacy: Self-Efficacy for Advanced Manufacturing Competencies. The competencies that were included in this scale, as well as the Implicit Theories of Advanced Manufacturing Competencies Scale, stemmed from prior grant-related work of industry professionals (described in the following section).

Current Progress on Research Study

Because of the COVID-19 pandemic, some of the research tasks were delayed as the researchers involved had to focus on helping faculty at their respective institutions shift to remote teaching. The development plan was refined at the program launch and again after the impact of COVID-19 to readjust the timeline and working parameters (i.e., working fully-remotely). We are on track to accomplish all goals by the end of the project.

As of February 2021, we have conducted site visits and interviews with our five industry partners (Microbial Pulse, Kong, Adaptive Innovations Corporation, EMP, and Stratasys). The 23 interview transcripts were analyzed to identify key module topics and learning outcomes for development. We have held virtual meetings with our advisory team which include our industry partners. Our development team have developed 14 modules/courses to date. We are currently piloting instruments and learning experiences with Colorado School of Mines and Red Rocks Community College students. After initial revisions we will begin piloting with our industry partners.

Regarding the data collection for this study, the focus to date has been on the development and piloting of instruments. A set of instruments, consisting of general growth mindset, domain specific mindset, and domain-specific self-efficacy, were piloted in the Fall 2020 semester with a group of industry professionals who participated in a virtual training on advanced manufacturing. A larger pilot with students who are majoring in either advanced manufacturing, smart manufacturing, or mechanical engineering is currently being planned for Spring 2021. The instrument was revised for the student population and data collection has begun.

Table 1: Variables and measures to be explored in the research study

Variable	Measure	Source	Timeline
General growth mindset	Implicit Theories of Intelligence Scale	Dweck (1999)	Pre-module
Domain specific mindset (beliefs about nature of ability relating to course content)	Implicit Theories of Engineering Ability Scale; Implicit Theories of Advanced Manufacturing Competencies Scale	Created by Authors	Pre-module
Self-efficacy Scale	(MSLQ) – Self-Efficacy Subscale;	Pintrich, et al. (1991)	Pre-module
Domain specific self-efficacy	Self-Efficacy for Advanced Manufacturing Competencies	Created by Authors	Pre-module
Course preference scale	Survey about specific module activities and learner preferences	To be created	Post-module
Module navigation patterns	Course analytics (number of times engaging in certain tasks)	Course analytics and course survey	During and post-module
Course performance	Self-Assessments	To be created	Pre- and Post-module
Metacognition	Judgment precision (confidence on self-assessments)	Schraw (2009)	Pre- and post-module

Next Steps and Future Work

After a large enough sample of the instrument data has been collected, we plan to conduct psychometric analyses and conduct validity studies. Psychometric analyses will be conducted in the form of either classical item analysis, or item response theory (IRT) analysis if the sample size is sufficient. Appropriate reliability indices such as Cronbach's alpha will also be calculated. Validity evidence based on internal structure will be collected through the use of factor analysis. Additional validity evidence will concern relationships among the different scales being measured. Additional data collection will take place in the Fall 2021 semester.

Courses and modules will continue to be piloted with Colorado School of Mines' students this spring and summer. We will expand pilots to our industry partners in Fall 2021. The revised timeline is illustrated in Table 2.

The work-in-progress format of this paper will allow the authors to receive feedback from the community on what direction to take the next steps in the study. Specifically, the authors hope to receive feedback on the appropriateness of the research questions, ideas on how to improve the study, and interpretation of preliminary data, which will be available by the conference date. We also hope to learn about other initiatives relating to advanced manufacturing and studies about the constructs of growth/fixed mindset, self-efficacy, and metacognition.

Table 2: Revised Timeline

	Year 1				Year 2				Year 3			
	October 2019 - September 2020				October 2020 - September 2021				October 2021 - September 2022			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Advisory Board	Meeting			Update Report	Meeting	Update Report	Meeting	Update Report	Meeting	Update Report		Update Report
Survey & Feedback from Industry Partners	Design & Initiate	Site Visits			Survey		Focus Groups		Survey		Focus Groups	
Self-assessments	Design & Pilot (Industry, Self-study, & Mines)				Refine	Data Altering	Analysis	Ongoing use, Data gathering and Anlysis (Industry, Self-study, RRCC, & Mines)				Analysis Report
Self-study modules		Design & Pilot (Industry, Self-study, & RRCC)				Ongoing use, Data gathering and Anlysis (Industry, Self-study, RRCC, & Mines)			Refine	Test	Analysis	Analysis Report
Moderated modules			Design & Pilot (Industry, Self-study, & RRCC)			Revise	Ongoing use, Data gathering and Anlysis (Industry, Self-study, RRCC, & Mines)			Refine	Test	Analysis Report
Facilitated modules			Design & Pilot (RRCC & Mines)				Revise	Ongoing use, Data gathering and Anlysis (RRCC & Mines)				Analysis Report
Courses				Design & Pilot (RRCC & Mines)				Ongoing use, Data gathering and Analysis (RRCC & Mines)				Analysis Report

Revised Development Timeline: Note that settings are marked in [brackets: I = industry, RRCC = Red Rocks Community College, M = Mines, S = student/personal] –assessments and modules will initially be piloted in industry, then additional resources will be rolled out to all four settings.

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