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Araştırma Makalesi/ Research Article

INVESTIGATION OF PROCEDURAL RELATIONSHIP BETWEEN ACADEMIC ACHIEVEMENT AND PSYCHOSOCIAL FACTORS IN ALGEBRA COURSES

ALGEBRA DERSİ AKADEMİK BAŞARISI İLE PSİKOSOSYAL DEĞİŞKENLER ARASINDAKİ YORDAMSAL İLİŞKİLERİN İNCELENMESİ

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ABSTRACT: The aim of this study is to examine the procedural relationship between the psychosocial factors of mathematics learning such as attitudes, motivation and satisfaction and academic achievement in redesigned college-level algebra course sections. Evaluation reports on the redesigned courses show that they have achieved a level of academic achievement equivalent to and / or better than traditionally taught courses, including university-level mathematics introductory courses. However, the reasons for equal or higher academic achievement are not fully documented in the literature. In this context, the academic success of the university-level algebra course designed using the Emporium model was chosen as the focus of this research study. In this manuscript, in addition to the psychosocial factors of mathematics learning, mathematics achievement in the context of university algebra was also examined. The data related to the psychosocial variables were obtained from a likert scale developed by the researcher, and academic achievement data from the final exam grades of the algebra course. Hierarchical multiple regression analysis was used to analyze the collected data. The results of the study indicaed that satisfaction from mathematics teaching was the only significant predictor of mathematics achievement in college-level algebra; learner motivation and satisfaction were determined as important predictors of attitude towards mathematics, and attitude towards mathematics played the role of mediating variable in the relationship between student satisfaction and motivation in introductory level redesigned university algebra courses.

Key Words: College algebra; Math Emporium, Course redesign; Academic achievement, Psychosocial factors, Digital Transformation

ÖZ: Bu araştırmanın amacı, yeniden tasarlanan üniversite düzeyi cebir derslerinde tutumlar, motivasyon ve memnuniyet gibi matematik öğrenmenin psikososyal faktörleri ile akademik başarı arasındaki yordamsal ilişkinin incelenmesidir. Yeniden tasarlanan derslere ilişkin hazırlanan değerlendirme raporları, üniversite düzeyinde matematik giriş dersleri de dahil olmak üzere geleneksel olarak öğretilen derslerle eşdeğer ve / veya daha iyi düzeyde akademik başarı elde edildiğini göstermektedir. Ancak, elde edilen eşit düzeyde ya da daha yüksek bir akademik başarının nedenleri literatürde tam olarak belgelenmemiştir. Bu bağlamda, Emporium modeli kullanılarak tasarlanan üniversite düzeyi cebir dersinin akademik başarısı bu araştırma çalışmasının odak noktası olarak seçilmiştir. Bu araştırma

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makalesi kapsamında, matematik öğreniminin psikososyal faktörlerine ek olarak üniversite cebiri bağlamında matematik başarısı da incelenmiştir. Psikososyal değişkenlere ilişkin veriler araştırmacı tarafından geliştirilen likert tipi ölçek ile akademik başarı verileri ise cebir dersi final sınavı notlarından elde edilmiştir. Verilerin analizinde hiyerarşik çoklu regresyon analizinden yararlanılmıştır. Araştırmanın sonuçları, sadece matematik öğretiminden memnuniyetin üniversite cebirinde matematik başarısının anlamlı bir yordayıcısı olduğunu göstermiştir; öğrenen motivasyonu ve memnuniyeti matematiğe yönelik tutumun önemli yordayıcıları olarak belirlenmiş ve matematiğe yönelik tutum, giriş düzeyinde yeniden tasarlanan üniversite cebir derslerinde öğrenci memnuniyeti ve motivasyon arasındaki ilişkide aracı değişken rolünü üstlenmiştir.

Anahtar Kelimeler: Cebir; Math Emporium, Yeniden Tasarım; Akademik Başarı, Psikososyal Faktörler, Dijital Dönüşüm

1. INTRODUCTION

Regardless of the academic discipline, the common problems of college-level introductory courses are high enrollment rates, low academic achievement, and low retention rates. The National Center for Academic Transformation (NCAT) offered a new approach which extensively utilizes instructional and learning technologies to increase academic achievement and retention rates with an additional benefit of reducing costs of instruction. NCAT proposed six different course redesign models to achieve this goal: the supplemental model, the replacement model, the Emporium model, the fully online model, the buffet model and the linked workshop model (NCAT, 2015). Each model targets traditionally-taught college-level courses that suffer from the problems stated above. Redesign models propose a change in the methods of content delivery by infusing the best practices of instructional and learning technologies. They target different elements of instructional design to achieve the same goals. The math Emporium, fully online, and linked workshop course redesign models have been successfully implemented in college-level introductory mathematics (NCAT). Participating institutions choose their redesign model by considering many factors - redesign goals, student characteristics, course offerings, prior success of a specific model in a specific course or discipline, cost benefits and available resources – so it is not possible to find an example of each model in the field of mathematics, especially in college algebra.

The supplemental model offers technology-supported out-of-class activities, or suggests changes for designing active learning environments while retaining the basics of traditional lecture-based courses (NCAT, 2008). Carnegie Mellon University, for example, redesigned its introduction to a statistical reasoning course using the supplemental model that utilized an intelligent tutoring system which monitored students' learning progress through effective feedback and assessment. The institution reported improved academic achievement and retention (NCAT, 2015a).

The replacement model replaces some traditionally-taught lectures with out-of-class, online and interactive learning activities, and requires significant changes in the remaining traditionally-taught sessions (NCAT, 2008). Pennsylvania State University (PSU) and the University of Wisconsin – Madison (UWM) redesigned elementary statistics, and general chemistry respectively by using the replacement model. PSU reported that students enrolled in redesigned sessions performed better than their peers in traditionally taught elementary statistics courses, and these redesign sessions had higher retention rates (NCAT, 2015b). The UWM, on the other hand, did not report a significant difference in academic achievement between redesigned and traditionally-taught general chemistry classes, but noted learner appreciation and enjoyment of the multimedia resources (NCAT, 2015c).

The Emporium model, which is the emerging trend in college-level mathematics education, replaces all the traditionally-taught sessions with interactive learning labs in which learners use an instructional software/classroom management system, get immediate/on-demand feedback, and work collaboratively with their peers (NCAT, 2008). The University of Alabama, the University of Idaho, Virginia Tech and Louisiana State University respectively redesigned intermediate algebra, pre-calculus, linear algebra, and college algebra using the Emporium model. The University of Alabama reported significantly higher academic achievement when attendance was mandatory, and increased course satisfaction in their redesigned intermediate algebra classes (NCAT, 2015d). The University of Idaho reported a higher percentage of A and B grades in redesigned sections of pre-calculus, and noted that minority students who were part of the College Assistance Migrant Program unexpectedly outperformed (NCAT, 2015e). Virginia Tech redesigned linear algebra, and reported that the percentage of students who passed the course improved although the math Emporium resulted in a non-significant marginal change in course grades, but improved performance in the overall common final exam (NCAT, 2015f). Louisiana State University redesigned college algebra, a course hosting student enrollment averages of 4900 annually, and reported better and/or equivalent academic achievement in both the redesigned and the traditionally-taught sections by emphasizing the differences between assessment procedures used in the two delivery models (NCAT, 2015g).

The fully online model combines the best practices of the previous models, eliminates all in-class meetings, and replaces those with online modules (NCAT, 2008). The model is extensively built on instructional software, and self-paced learning opportunities. The Rio Salado College redesigned introductory algebra using the fully online model, and reported increased retention rates, but not a significant difference between student performance (NCAT, 2015h). Iowa State University redesigned its discrete mathematics course using the fully online model, and reported significantly better academic achievement in redesigned sections, but such difference was attributed to the fact that online students had multiple attempts to take the tests. ISU also reported a lower retention rate, but it was attributed to the availability of both redesigned and traditional sections of the course that allowed students to switch between sections if they were not comfortable with online instruction (NCAT, 2015i).

The buffet model used by The Ohio State University to redesign its introductory statistical concepts course offered interchangeable learning paths for students to achieve each learning objective through a reduced number of lectures along with and constructive and collaborative learning strategies (NCAT, 2008). The institution reported both improved academic achievement and improved retention (NCAT, 2015j).

The linked workshop model that utilizes small group discussions supported by computer-based instruction replaces remedial/developmental courses with workshops which focus on core course competencies (NCAT, 2008). Austin Peay State University redesigned elementary algebra and intermediate algebra using the linked workshop model, and reported improved successful completion rate in these core mathematics courses, and higher retention rates after the redesign but noted that the redesign team did not have comparable data because traditionally-taught remedial/developmental courses were eliminated (NCAT, 2015k)

The course redesign efforts cited above indicated better and/or equivalent academic achievement, and retention rates in addition to a lower cost of instruction in the redesigned college-level mathematics courses. Although the outcomes of the course redesign efforts are continuous and hold promise for the future, the evaluation focus of the NCAT course redesign models is too narrow when the goals and evaluation criteria of the course redesign are considered. Little attention has been paid to psychosocial factors of learning. Final course grades are used as evidence of academic achievement whereas end of semester course evaluations considered only evidence of learner satisfaction. Demiroz (2016), examined the impact of course redesign efforts, the math Emporium, on psychosocial factors of learning in college algebra, and concluded that beliefs about being able to do mathematics, attitude towards technology-supported mathematics, and the overall attitude towards mathematics changed significantly in traditionally-taught college algebra. They reported that attitude towards mathematics, attitude towards technology-supported mathematics, extrinsic motivation to learn mathematics, satisfaction from instructional design, and overall attitudes toward mathematics, and overall learner satisfaction changed significantly in redesigned college algebra but emphasized that all the changes in the redesigned sections were negative in magnitude. Mathematics education literature indicates a positive relationship between academic success and the psychosocial factors of learning that are stated above (e.g. Bennett & Green, 2001; Chiu & Xihua, 2008; Covington, 2000;

Kloosterman, 1991; Ma, 1997; Minato, & Yanase, 1984; Papanastasiou, 2000; Peters & Kortecamp, 2010), so there is a contradiction in redesigned college-algebra classrooms because research institutions reported significantly higher academic achievement in redesigned sessions than in traditionally-taught sessions of college algebra (NCAT, 2015l) although the psychosocial factors of learning changed negatively.

The focus of this paper is to investigate this contradiction further, and examine the predictive nature of the psychosocial factors of learning on academic achievement. This quantitative study examined the predictive nature of learners' attitude towards mathematics, motivation to learn mathematics, and satisfaction from mathematics instruction in college level mathematics courses on academic achievement at a Midwest university which redesigned its college algebra courses using the math Emporium model supported by NCAT but controlled for field of study and incoming mathematics knowledge. This study specifically sought answers for the following research questions in a redesigned college algebra context.

- Do motivation to learn mathematics and satisfaction from the instructional design significantly predict attitude towards mathematics?
- Do attitude towards mathematics and satisfaction from the instructional design significantly predict motivation to learn mathematics?
- Do attitude towards mathematics and motivation to learn mathematics significantly predict satisfaction from the instructional design?
- Do attitude towards mathematics, motivation to learn mathematics and satisfaction from the instructional design significantly predict academic achievement in college algebra?

Research on the psychosocial factors of learning in college level mathematics courses is limited although such factors have been examined extensively in the K-12 educational context. Additionally, research on redesigned college-level mathematics education is also limited, and data/literature are limited to the institutional reports prepared for the NCAT, and some individual publications which do not specifically focus on mathematics education. Attention has been widely paid to the academic achievement, retention rates, and cost of instruction in NCAT's redesign efforts, and the psychosocial factors of learning have been ignored. Therefore, it is expected that the results of this study will make significant contributions to the mathematics education literature especially at the higher education level in which course redesign is an emerging trend, and it will further the discussions on the determinants of academic achievement in college-level mathematics education.

2. LITERATURE REVIEW

Predicting academic achievement has a long history in educational research. For many years, researchers have spent notable effort trying to determine the best predictors of academic success at all grade levels for many years. Despite all these efforts, there has been no precise agreement on the best predictors of academic achievement. It is very challenging to predict academic achievement without any unexplained variance because of the wide range of independent predictor variables that have a possible impact on academic success. In a literature review on determinants of academic achievement at the college level, Mouw and Khanna (1993) concluded that the predictability of the college level GPA by traditional factors such as previous academic achievement, and standardized test scores was unexpectedly low. In other words, the variance in college level GPA cannot be solely explained by the traditional predictors of academic achievement (Kaufman, Agars, and Lopez-Wagner, 2008).

As a result of extensive literature review, Robbins et al. (2004) grouped determinants of academic achievement under three categories: traditional which included standardized test-scores, GPA and high school rank etc.; demographic which included socio-economic status, gender, race etc.; and psychosocial which included motivation to learn, academic goals, and social support etc. It is possible that these psychosocial factors of learning could explicate a significant proportion of variance in academic achievement that cannot be explained by traditional predictors. This suggestion is supported by Krumrei-Mancuso, Newton, Kim, and Wilcox (2013) who wrote that the psychosocial factors of learning seem to be powerful determinants of academic achievement. The claim for the impact of psychosocial factors on achievement is further supported by Robbins, Allen, Casillas, Peterson, and Le in their 2006 study which concluded that academic achievement and retention were affected by various psychosocial factors such as academic discipline, academic self-efficacy, and academic motivation.

Cumulative grade-point average (GPA) for all academic subjects is the common indicator of academic achievement in college level research on educational outcomes although discipline-specific academic performance is also considered. Some researchers focus on predicting college performance along with retention and persistence, whereas other researchers focus on predicting field-specific academic performance. Robbins et al. (2004) determined that individual class performance and GPA were indicators of academic achievement, and predicted not only cumulative GPA, but also retention and persistence of college level learners. McKenzie and Schweitzer (2001) also looked from a general perspective, and focused on psychosocial factors to predict university grades. Predicting field-specific academic performance, on the other hand, requires field-specific achievement data rather than cumulative GPA. Mathematics achievement, for example, can be predicted through traditional predictors such as incoming mathematics knowledge, standardized-test scores, performance in high-school mathematics courses, and high school mathematics GPA; demographics such as gender, intended field of study, or socio-economic status; and psychosocial predictors such as attitude towards mathematics, beliefs about mathematics, motivation to learn mathematics or satisfaction from the mathematics instruction.

Field-specific academic achievement prediction research efforts heavily focus on K-12 education (e.g. Hemmings, Grootenboer, & Kay, 2011; Passolunghi & Lanfranchi, 2012; Sartawi, Alsawaie, Dodeen, Tibi, & Alghazo, 2012), while research in a college level mathematics learning contexts is limited. As a result of a five-year longitudinal study that focused on early first-graders through fifth graders, Geary (2011) reported that academic achievement or achievement growth in mathematics along with word reading can be predicted by traditional predictors (e.g. intelligence and processing speed). Larwin (2010) predicted 10th graders' mathematics achievement from students' learning ability, mathematics self-efficacy, teachers' expectations, and computer-based instruction. According to Larwin, computer-based instructional practices negatively predict academic achievement whereas the other factors positively explained the variance in achievement. Murray (2013), on the other hand, predicted algebra achievement at the college level through traditional and psychosocial determinants such as prior academic achievement, self-regulation, self-efficacy, academic resources and learning styles at college level. She concluded that incoming academic achievement, learning styles, and academic resources were the significant predictors of academic success. According to Hailikari, Nevgi, and Komulainen (2008), incoming domain-specific knowledge is the best predictor of academic achievement in college-level mathematics by explaining that the relationship between self-beliefs and academic achievement is mediated by the prior domain-specific knowledge.

Operational variables of students' attitudes towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction were examined as outcomes, and as determinants of academic achievement in the scope of this research paper. Each of these variables is well-studied in mathematics education literature. Mata, Monteiro, and Peixoto (2012) stated that a positive correlation between learners' attitude towards mathematics and achievement in mathematics is reported in recent studies. For example, as a result of a meta-analysis that includes 113 studies, Ma and Kishor (1997) reported a causal relationship between attitudes towards mathematics and mathematics achievement. Lipnevich, MacCann, Krumm, Burrus, and Roberts (2011) reported that attitude towards mathematics explain 25%-32% of the variance in mathematics achievement (as cited in Mata, Monteiro, and Peixoto). Muis (2004) synthesized thirty-three studies that focus on learners' epistemological beliefs about mathematics, and reported that all studies included in the synthesis indicate significant relationship between beliefs and cognition, motivation and academic achievement. House (2001) also determined learner attitude as a significant determinant of academic achievement in college-level calculus. Pyzdrowski et al. (2013) stated that "[s]tudent attitude had the strongest correlation with student performance, but these attitudes are influenced not only by previous student experiences and preparation but by underlying psychosocial variables" (p. 551). Ferren and McCafferty (1992) concluded that negative attitudes and low motivation impact academic achievement in mathematics instruction (as cited in Hatem, 2010). Along with attitudes towards subject-matter, motivation to learn mathematics is also one of the psychosocial factors studied in mathematics education.

Motivation to learn mathematics is also one of the well-studied variable in mathematics education, but despite extensive research, Csikszentmihalyi and Wong (2014) emphasized that little is known about the personality and motivational traits in academic achievement. Research on motivation indicates a strong relationship between motivation to learn and academic achievement (Kim, 2006; Wang, Haertel, & Walberg 1993; Weinstein, 1998; Wentzel, 1991). Al Khatib (2010) stated that "research demonstrates that students' motivational beliefs and self-regulated learning are directly related to their academic performance" (p. 57). According to Schoenfeld (1989), learners who had intrinsic motivation to study mathematics performed well in mathematics. Murayama, Pekrun, Lichtenfeld, and vom Hofe (2013) studied adolescents' development of mathematical competencies, and reported that "the initial level of achievement was strongly related to intelligence, with motivation and cognitive strategies explaining additional variance. In contrast, intelligence had no relation with the growth of achievement over years, whereas motivation and learning strategies were predictors of growth" (p. 1). Fortier, Vallerand, and Guay (1995) reported that academic motivation can be a mediator variable between perceived academic competence, perceived self-determination and academic achievement. According to them, increasing learners' autonomous academic motivation is one of the direct ways to improve school performance.

In addition to learners' attitude towards mathematics and motivation to learn mathematics, satisfaction from the instructional practices and design is an important factor that affects academic achievement. The math Emporium changes the instructional practices and instructional design of the college–level mathematics courses for improving academic achievement and retention. The Emporium moves traditionally-taught instructor-centered mathematics courses to a technology-supported constructivist learning environment. According to Lizzio, Wilsons, Simons (2002), learners' perceptions of learning environment at the college level predict learning outcomes better than prior academic achievement at school. In addition, Moody (2010) emphasized that retention rates, persistence in academics, and higher GPA are associated with higher levels of student satisfaction, whereas lower GPA and higher dropout rates are adversely associated with dissatisfaction of learners. Wince and Borden (1995) also documented that higher GPA's and lower withdrawal rates were related to satisfaction with university, and dissatisfaction from the curricula was one of the common reasons for dropping out from the university (Rickinson & Rutherford, 1996). In a survey study with college sophomores, Graunke and Woosley (2005) documented that satisfaction with faculty interactions, which dramatically change in the math Emporium, was a significant predictor of GPA. The impact of satisfaction from the elements of course design might not have a direct impact on academic success, but might serve as mediators in the interaction between psychosocial factors and academic achievement. For example, Pyzdrowski et al. (2013) emphasize that instructional strategies and practices that include facilitating the use of meta-cognition, encouraging class discussions guided by conceptual questions, and supporting collaborative learning activities impact learners' course performance via learners' attitudes.

3. THEORETICAL FRAMEWORK

This research paper was built on constructivism and social learning theory in which affective domain of learning has an important role. Although it is not well-documented, the NCAT's course redesign efforts carry many elements of constructivism. Course redesign models are supported by learner-centered instructional practices which built on students' prior knowledge, technology-supported and collaborative learning environments, and changing roles of instructors and students. Constructivist theories require active, collaborative and reflective participation of learners into the learning process in order to individually construct the scientific knowledge (Driver & Oldham, 1986; Duit & Treagust, 1986; Driver, 1989a, 1989b; Scott, Asoko & Driver, 1992 as cited in Solomonidou, 2009). The math Emporium redesigns college-level mathematics learning environments to provide such conditions to help learners constructing personal mathematical understandings with interacting through collaborative and authentic learning activities. The relationship between students' perceptions of learning settings, and cognitive and affective outcomes of learners is well-documented (McRobbie & Fraser, 1993; Pintrich, Marx, & Boyle, 1993; Pintrich & Schunk, 2002 as cited in Cetin-Dindar, 2016). In addition, Enonbun (2010) stated that learner-centered instruction is one of the core elements of constructivism which assumes that educational progress yields better learning outcomes if learners are presented with discovery-learning practices rather than being told or instructed.

The impacts of constructivist learning environments and practices on affective dynamics of learning such as attitude, achievement motivation and satisfaction are also well-documented in education literature. Zan and Di Martino (2007), for example, provide a simple definition of attitude "as the positive or negative degree of affect associated with a certain subject" (p. 158). A positive relationship between constructivist learning environments and learner attitudes is also noted in the literature (e.g. Aldridge, Fraser, Taylor, & Chen, 2000; Dethlefs, 2002; Kim, Fisher, & Fraser, 1999). Becker and Maunsaiyat (2004) compared learners' attitudes in traditional and constructivist learning environments and concluded that students in constructivist learning contexts had higher attitude scores than their peers in traditional learning settings. Individual components of constructivist learning environments such as technology integration and collaborative learning practices are also impact learner attitudes. The positive impact of technology integration on learner attitudes is also well-documented (e.g. Baker, Gearhart, & Herman, 1994; Kulik, 1994; Mann, Shakeshaft, Becker, & Kottkamp, 1999; Sivin-Kachala & Bialo, 1998). Hannula (2002) noted that one of the important elements of constructivist learning environments, collaborative activities, changes attitudes positively (e.g. Boaler, 1997a, b, 1998; Ridlon, 1999).

Extensive technology integration into the math Emporium and other constructivist design features could also impact learner motivation. Waugh (2002) defined motivation as "the internal processes that give behaviour its energy and direction" (p.66). Palmer (2005) also noted that the term motivation refers to processes that activate and maintain learning behavior. According to Palmer, motivation is a necessary prerequisite and co-requisite for learning in constructivist learning theory. Keller (2008) listed five principles of motivation in educational settings as (a) learners' curiosity which comes with attention and engagement; (b) link between content and learners' goals; (c) learners' beliefs in being successful; (d) expecting and experiencing satisfying learning outcomes; and (e) self-regulation. Classroom context can significantly impact learners' motivational beliefs, so learner motivation can be optimized through effective classroom strategies (Pintrich & Schunk, 1996; Palmer, 2005). Also, as cited in Ryser, Beeler, and McKenzie (1995), researchers (e.g. Chung, 1991; Scardamalia & Bereiter, 1991; Guthrie & Richardson, 1995) claimed that technology-infused constructivist learning environments positively influence learner motivation. Fok and Watkins (2008) examined the impact of a constructivist learning environment in a Chinese secondary school context through a comparative study, and reported significant difference between traditional and constructivist learning environments in which achievement motivation was higher.

Learners tend to report improved satisfaction in constructivist learning environments supported by extensive technology integration perhaps because of the flexibility and convenience that educational technology offers. Sinclaire (2011) noted that research on student satisfaction lacks providing a clear definition of learner satisfaction in an educational context although the term satisfaction is an important factor and is well-defined in marketing literature. Elliott and Healy (2001) explained that instructional performance that meets or exceeds the student's expectations results in improved learner satisfaction which was defined as “a short-term attitude resulting from an evaluation of a student's educational experience” (p. 2). The math Emporium provides great flexibility and convenience in terms of content delivery, assessment and feedback mechanisms, collaboration and interaction, to the learners through extensive technology integration. Positive communication and interaction with the faculty and between learners, clarity and relevance of instructional tasks and assignments, course design and technology use, access to campus-based resources are some of the predictors of learner satisfaction (Douglas, Douglas, & Barnes , 2006; Johnston, Killion, and Oomen 2005; Lorenzo, 2012; Martinez-Caro and Campuzano-Bolarin, 2011). Martinez-Caro and Campuzano-Bolarin evaluated learner satisfaction in the learning environment as an “inherently desirable goal and a benefit of teaching” (p. 475). Bolliger (2004) also noted that a positive relationship is evident between quality of learning outcomes and student satisfaction.

The impacts of constructivist learning practices on the psychosocial factors of learning are evident in the literature. This study assumes that dramatic changes from a traditional lecture-based format to a technology-supported constructivist learning environment in college algebra impact academic achievement of learners through learner attitudes, achievement motivation, and learner satisfaction. The results of the study not only contribute to the mathematics education literature, but also to the constructivism, constructivist learning environments, and their impacts on mathematics achievement through psychosocial factors of learning.

4. METHOD

4.1. Research Model

The study was built on predictive research with correlational survey model. Karasar (2018) defines the correlational survey model as a “research model aiming to determine the existence and/or degree of change between two or more variables”. Cohen, Manion and Manison (2002) list predictive correlational suvey model as a type of correlational survey model that analyzes if there is change between two or more varibles and level of this change. Hierarchical regression analysis was performed to analyze predictive nature of the collected data. Newton and Rudestam (1999) stated that multiple regression is used for analyzing data if there is a need for exploring the relationship between multiple continuously distributed independent variables and single dependent variable. In this regard, final exam score was single dependent variable whereas motivation, satisfaction and attitude scores were independent variables.

4.1.1. Sampling

College-level students who enroll in redesigned college algebra courses was the population of the research study. Convenient sampling was used to select cases for data collection. The sample of the study consisted of college students who were at least eighteen years-old enrolled in college algebra sessions which were redesigned through the math Emporium model at one of the Midwest research institute. Total number of participants was 265 though not all participants completed the pretest and posttest because some of them enrolled late or withdrew at the time of pretest and posttest applications. Two different samples were reproduced within 265 participants for the data analysis. The first group of participants were the students who completed the MATH 110 entrance exam scores, and Psychosocial Factors of Learning in Redesigned Introductory College Mathematics (PFL-RICM) pretest. The second group of participants were among the participants of group 1, but these participants completed the college algebra final exam and PFL-RICM pretest and posttest.

Sample A: Out of 265, 102 participants were excluded for various reasons: thirty-two participants were excluded because of incomplete pretest or entrance exam scores due to late enrollment; forty cases were removed due to missing data and responses which were not applicable; thirty cases were excluded because of control items which were embedded into the PRL-RICM scale to identify students who did not pay attention to questionnaire items. Therefore, the final sample of students who completed the college algebra entrance exam and pretest is 163. Demographic data such as gender, socioeconomic status, race, ethnicity etc. were not collected, but intended majors of learners was asked. Participants reported 35 different intended majors.

Sample B: Out of 265, 140 participants were excluded for the similar reasons: ninety of them withdrew or did not complete the posttest; sixty-three participants were excluded because of outliers, incomplete, and not applicable answers; fifteen participants were excluded because of control items embedded into the PFL-RICM scale; and two cases were excluded because of unavailable final exam scores. The total number of participants in sample B is 125. The second group of participants reported 29 different fields of study. Based on the STEM-designated degree program list prepared by the United States Immigration and Customs Enforcement (ICE) in 2012, 71 STEM fields and 59 non-STEM fields were identified, but due to unequal cell sizes, this variable was not included in the regression analysis.

4.2. Instrumentation

Data on students' attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the instructional practices and design were collected through the psychosocial factors of learning in redesigned college-level mathematics courses (PFL-RICM) survey consisted of three subscales developed by Demiroz (2016). Psychometric analysis of the scale were performed as explanatory factor analysis for internal structure validity and internal replicability analyses. Internal structure validity evidences indicated 17-items attitude subscale has three-factor structure: attitude towards mathematics, attitude towards technology-supported mathematics and learners' belifs about learning mathematics; 6-item motivation subscale indicated a two-factor structure: intrinsic motivation and extrinsic motivation; and 12-item satisfaction subscale indicated three-factor structure: satisfactions from mathematics instruction, course redesign efforts and mathematics learning experiences. Reliability and validity analyses on the instrument indicated that the PFL-RICM scale is a reliable and valid data collection tool (Demiroz). The PFL-RIM scale is the combination of three sub-scales: attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the instructional design and practices (Demiroz). Learner' attitude towards mathematics was operationalized by attitudes towards mathematics (α=.92), attitude towards technology supported mathematics (α=.85), and self-beliefs about mathematics (α=.77); learners motivation to learn mathematics was operationalized by students' intrinsic motivation to learn mathematics (α=.67), and extrinsic motivation to learn mathematics (α=.50); and learner satisfaction was operationalized by satisfaction from mathematics instruction (α=.84), satisfaction from course redesign (technology-supported mathematics teaching) efforts(α=.76), and overall satisfaction from the mathematics learning experiences (α=.77). The college algebra entrance exam and common final exam were developed by the department of Statistics and Mathematics at the research institution. Reliability and validity evidences for these tools were not available nor psychometric analysis were performed over the data.

4.3. Procedure

This research study was built on a predictive research in correlational research design. The PFL-RICM scale was administered at the beginning and at the end of the fall semester in all redesigned college algebra sections. Participants who completed both pretest and posttest received 5 points extra credit as compensation. Students who were not eligible to participate in the study were given an algebra worksheet, and received 5 points extra credit added to their final exam upon completion. The institutional research and planning programs (IRAP) office of the research institution provided additional data on intended field of studies, MATH 110 entrance exam scores and final exam scores.

4.4. Data Analysis

Hierarchical multiple regression was used to predict outcome variables that include learner attitude towards mathematics, motivation to learn mathematics, satisfaction from the mathematics instruction, and college algebra final exam scores through psychosocial factors of learning. Two sets of hierarchical regression analyses were completed. The first set of regression analyses was conducted to examine the relationships and possible interaction effects between the psychosocial factors of learning: attitude towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction. The second set of analyses focused specifically on predicting college algebra final exam scores from the same psychosocial variables. After all the assumptions for hierarchical multiple regression were tested, interaction effects between the psychosocial variables were also inspected. Scores of each predictor variable were centered before calculating the interaction terms as suggested by Warner (2014).

5. RESULTS

5.1. Prediction of Psychosocial Factors

Attitude towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction were examined as psychosocial factors of learning through regression analyses for better understanding of predictive and relational nature of these variables. Each variable was included as predictor and outcome with the centered interaction terms to investigate possible interaction effects. It should be noted that the pretest scores collected from 163 participants (sample A) were analyzed, so the data refers to the prior and general mathematics attitudes, motivation to learn mathematics and satisfaction from mathematics instruction before enrolling in redesigned college algebra sessions. The results of the regression analyses along with bivariate correlations are summarized in Table 1.

Table 1: Summary of Hierarchical Regression Analyses (Part 1).

	Predictors	*Attitude*	*Motivation*	*Satisfaction*	*b*	*β*	sr^2_{unique}
Attitude	*Step 1*						
	Motivation	+.43*		+.35*	+.488*	+.434	.19
				Intercept=	+1.170		
						R^2=	.19
						$R^2_{adj.}$=	.18
						R=	.43*
	Step 2						
	Motivation	+.43*			+.282*	+.251	.05
	Satisfaction	+.60*	+.35*		+.444*	+.515	.23
				Intercept=	+.577		
						R^2=	.42
						$R^2_{adj.}$=	.41
						R=	.65*
Motivation	*Step 1*						
	Satisfaction	+.60*	+.35*		+.272	+.355	.13
				Intercept=	+1.676		
						R^2=	.13
						$R^2_{adj.}$=	.12
						R=	.35*
	Step 2						
	Satisfaction	+.60*	+.35*		+.112	+.146	.01
	Attitude		+.43*	+.60*	+.308*	+.346	.08
				Intercept=	+1.353		
						R^2=	.20
						$R^2_{adj.}$=	.19
						R=	.45*
Satisfaction	*Step 1*						
	Motivation	+.43*		+.35*	+.463	+.355	.23
				Intercept=	+1.334		
						R^2=	.13
						$R^2_{adj.}$=	.12
						R=	.13*
	Step 2						
	Motivation			+.35*	+.149	+.114	.23
	Attitude		+.43*	+.60*	+.644*	+.555	.05
				Intercept=	+.581		
						R^2=	.38
						$R^2_{adj.}$=	.37
						R=	.61*
	Means	2.31	2.33	2.41			
	SD	.52	.47	.61			
	* P<.001						

Initial examination of multiple regression assumptions indicated no violations of normality and linearity, and regression analyses for predicting attitudes from motivation and satisfaction; motivation from attitudes and satisfaction, and satisfaction from motivation and attitudes were conducted over data collected from sample A (N=163). Centered interaction terms were included into the regression analyses. None of them was a significant predictor of the outcome variables, and R^2 changes were less than .004, so they were excluded from the regression models. The first regression model ($R=.65$, $R^2=.42$, $R^2adj=.41$, $F(2,160)=58.033$, $p<.001$) that predicted attitudes from motivation and satisfaction indicated that about 42% of the variance in learner attitudes could be explained by learners' motivation to learn mathematics ($b=.282$, $t(163)=3.903$, $p<.001$, $sr^2=.05$), and learners' satisfaction from the mathematics learning experiences ($b=.444$, $t(163)=8.002$, $p<.001$, $sr^2=.23$). About 5% of the variance in learners' attitudes towards mathematics was uniquely predictable from motivation to learn mathematics whereas satisfaction from previous mathematics experiences uniquely explains about 23% of the variability in learner attitudes towards mathematics. Increase in learner satisfaction and motivation in college level mathematics courses supports positive changes in learner attitudes towards mathematics as expected.

The second regression model ($R=.45$, $R^2=.20$, $R^2adj=.19$, $F(2,160)=20.246$, $p<.001$) that predicted learner motivation from attitudes and satisfaction indicated that about 20% of the variance in learner motivation could be explained by learners' attitudes towards mathematics ($b=.308$, $t(163)=3.903$, $p<.001$, $sr^2=.08$), and learners' satisfaction from the mathematics learning experiences ($b=.112$, $t(163)1.645$, $p>.001$, $sr^2=.01$). However, only attitude towards mathematics was significant predictor of leaner motivation, and about 8% of the variance in learners' motivation to learn mathematics was uniquely predictable from attitudes towards mathematics. Only 1% of the variability in learner motivation was explained by learners' previous satisfactions from mathematics learning experiences. When learner motivation was predicted solely by learner satisfaction from mathematics learning experiences ($R=.35$, $R^2=.13$, $R^2adj=.12$, $F(1,161)=23.207$, $p<.001$), the variance uniquely explained by the learner satisfaction ($b=.272$, $t(163)=4.817$, $p<.001$, $sr^2=.13$) increased to 13%.

The third regression model ($R=.61$, $R^2=.38$, $R^2adj=.37$, $F(2,160)=48.167$, $p<.001$) that predicted learner satisfaction from attitudes and motivation indicated that about 38% of the variance in learner satisfaction could be explained by learners' attitudes towards mathematics ($b=.644$, $t(163)=8.002$, $p<.001$, $sr^2=.25$), and motivation to learn mathematics ($b=.149$, $t(163)=1.645$, $p<.001$, $sr^2=.01$).

However, only attitude towards mathematics was a significant predictor of learner satisfaction, and about 25% of the variance in learners' satisfaction from mathematics instruction was uniquely predictable from attitudes towards mathematics. Motivation explained 1% of the variance in learner satisfaction. The model which only included motivation to learn mathematics as predictor of learner satisfaction ($R=.35$, $R^2=.13$, $R^2adj=.12$, $F(1,161)=23.207$, $p<.001$) indicated that the variance uniquely explained by the learner motivation ($b=.463$, $t(163)=4.817$, $p<.001$, $sr^2=.13$) increased to 13%.

It should be noted that learner satisfaction from mathematics instruction became a non-significant predictor of learner motivation, and likewise learner motivation became non-significant predictor of learner satisfaction when attitude towards mathematics was included in the models. That indicates a possible mediation effect. A Sobel test ($z = .044$, $p = .000$) and path analysis confirmed that attitude towards mathematics partially and significantly mediates the relationship between learner motivation to learn mathematics, and learners' satisfaction from the mathematics instruction.

5.2. Prediction of academic achievement from psychosocial factors of learning.

College algebra final exam scores were predicted by attitude towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction via hierarchical multiple regression in redesigned college algebra context. All of the participants in Sample B (N=125) were included in the regression analysis. Predictors were entered the regression in different orders by considering all possibilities. This revealed that the order of predictors impacted model statistics and significance of regression coefficients specifically in step 2. This situation might be attributed to possible interactions between independent variables. The summary of regression models that include prediction of final exam scores by each predictor individually, and by all three predictors is presented in Table 2.

Table 2: Summary of hierarchical regression analysis (Part 2).

	Predictors	*Final*	*Attitude*	*Motivation*	*Satisfaction*	*b*	*β*	sr^2_{unique}
	Attitude	+.25		+.59	+.57	+.081*	+.254	.06
					Intercept=	+.508		
							R^2=	.06
							$R^2_{adj.}$=	.06
							R=	.25*
	Motivation	+.22	+59		+.44	+.082*	+.219	.05
					Intercept=	+.492		
							R^2=	.05
							$R^2_{adj.}$=	.04
							R=	.22*
	Satisfaction	+.29	+57	+.44		+.081*	+.295	.29
					Intercept=	+.501		
							R^2=	.08
							$R^2_{adj.}$=	.09
							R=	.29*
Step 1	Satisfaction	+.29	+57	+.44		+.081*	+.295	.29
					Intercept=	+.501		
							R^2=	.08
							$R^2_{adj.}$=	.09
							R=	.29*
Step 2	Satisfaction	+.29	+.57	+.44		+.061*	+.222	.03
	Attitude	+.25		+.59	+.57	+.040	+.127	.01
					Intercept=	+.459		
							R^2=	.10
							$R^2_{adj.}$=	.08
							R=	.31*
Step 3	Satisfaction	+.29	+.57	+.44		+.058*	+.211	.03
	Attitude	+.25		+.59	+.57	+.029	+.091	.00
	Motivation	+.22	+.59		+.44	+.027	+.073	.00
					Intercept=	+.429		
							R^2=	.10
							$R^2_{adj.}$=	.08
							R=	.32*
	Means	.68	2.09	2.25	2.18			
	SD	.19	.60	.51	.69			

* $p<.05$

Initial examination of multiple regression assumptions indicated no violations of normality and linearity, and regression analyses for predicting college algebra final exam scores from attitudes towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction were conducted over data collected from sample B (N=125).

The first regression model ($R=.25$, $R^2=.06$, $R^2adj=.06$, $F(1,123)=8.497$, $p<.005$) that predicted college algebra final exam scores from attitudes towards mathematics indicated that about 6% of the variance in final exam scores could be explained by learners' attitudes towards mathematics ($b=.081$, $t(125)=2.915$, $p<.005$, $sr^2=.06$). The second regression model ($R=.22$, $R^2=.05$, $R^2adj=.04$, $F(1,123)=6.169$, $p<.05$) that predicted college algebra final exam scores from motivation to learn mathematics indicated that about 5% of the variance in final exam scores could be explained by learners' motivation to learn mathematics ($b=.082$, $t(125)=2.484$, $p<.05$, $sr^2=.05$). The third regression model ($R=.29$, $R^2=.09$, $R^2adj=.08$, $F(1,123)=11.699$, $p<.001$) that predicted college algebra final exam scores from learner satisfaction from mathematics instruction indicated that about 9% of the variance in final exam scores could be explained by learners' satisfaction from mathematics instruction ($b=.081$, $t(125)=3.420$, $p<.001$, $sr^2=.09$).

The predictors were entered based on the correlation coefficients between dependent and independent variables in the final regression analysis. As presented in Table-2, Model 1 indicated that satisfaction from mathematics instruction ($R=.29$, $R^2=.09$, $R^2adj=.08$, $F(1,123)=11.699$, $p<.001$) significantly predicts ($b=.081$, $t(125)=3.420$, $p<.001$, $sr^2=.09$) final exam scores in college algebra. Model 2 ($R=.31$, $R^2=.10$, $R^2adj=.08$, $F(2,122)=6.608$, $p<.005$) explained that satisfaction from mathematics instruction significantly predicts ($b=.061$, $t(125)=2.116$, $p<.05$, $sr^2=.03$) final exam scores, whereas attitudes toward mathematics ($b=.040$, $t(125)=1.213$, $p>.05$, $sr^2=.01$) was not a significant predictor of college algebra final exam scores. Model 3 ($R=.32$, $R^2=.10$, $R^2adj=.08$, $F(3,121)=4.538$, $p<.005$) indicated that satisfaction from mathematics instruction significantly predicts ($b=.058$, $t(125)=1.981$, $p<.05$, $sr^2=.03$) final exam scores, whereas attitudes toward mathematics ($b=.029$, $t(125)=.771$, $p>.05$, $sr^2=.00$), and motivation to learn mathematics ($b=.027$, $t(125)=.677$, $p>.05$, $sr^2=.00$) were not a significant predictor of college algebra final exam scores. All of the regression models indicated that positive changes in learner attitudes towards mathematics, increased student motivation to learn mathematics, and increased learner satisfaction in mathematics learning were all associated with higher final exam scores in college algebra.

6. FINDINGS

The predictive nature of psychosocial factors of learning mathematics, such as attitude towards mathematics, motivation to learn mathematics, satisfaction from the mathematics instruction and college algebra final exam scores was examined under the scope of this research paper. The first set of hierarchical multiple regression analyses was used to predict attitude from motivation and satisfaction; motivation from attitude and satisfaction; and satisfaction from the motivation and attitude. The results indicated that motivation to learn mathematics and learner satisfaction from the mathematics instruction were significant predictors of learners' attitude towards mathematics, and positive attitude associated with higher learner motivation and increased satisfaction in the concept of college algebra. Learner motivation and learner satisfaction significantly predicted each other, but attitude had a significant mediator effect between these two. In other words, motivation predicts satisfaction and satisfaction predicts motivation through learners' attitude towards mathematics. The second set of regression analyses was completed to predict college algebra final exam scores as indicator of academic achievement from attitude towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction. The final regression model explained that about 10% of the variance in final exam scores could be predicted by learners' attitude towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction. However, only learners' satisfaction with mathematics instruction, which explained 3% of the variance in final exam scores, was a significant predictor of academic achievement in college algebra context. The difference between the variance explained by the model, and the variance explained by the satisfaction from mathematics instruction could be attributed to the possible interaction effects between psychosocial factors of learning and their relations with the final exam scores. However, such interaction effects were not examined under the scope of this research paper. Finally, this study proved that the contradiction between increased academic achievement and negative changes in psychosocial factors of learning in college algebra is valid. Research results revealed that positive changes in psychosocial factors of learning associated with increased academic achievement, but Demiroz (2016) concluded that changes in psychosocial factors of learning in redesigned college algebra were negative when compared to a traditional way of teaching, although the research institution reported higher academic achievement in redesigned sessions.

6.1. Limitations

This research study is limited by the three psychosocial factors of learning: attitude towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction. The data was collected in college algebra settings, and might not be generalized to other mathematics teaching/learning contexts. A single indicator of academic achievement, final exam scores, was used as the dependent variable, and it might not be a strong indicator of mathematics achievement in college algebra. It was planned to include entrance exam scores as indicator of incoming mathematics knowledge into the regression model. However, there was not a sufficient variability in the entrance exam scores. All students in the sample (N=163) scored either 15, 16, 17, 18, 19, or 20. Therefore, the reliability and validity of the entrance exam scores, and also final exam scores were another concern.

This research study shed light on the contradiction between changes in psychosocial factors of learning in redesigned college algebra settings and academic achievement, but did not fully explain it, so further research is highly encouraged. Future research that focuses on a broad range of psychosocial factors that include socio-cultural and socio-economic variables could be very informative to understand the role of these variables in mathematics achievement at college level. A model tested through path analysis could be considered for better understanding of the interaction effects between psychosocial factors of learning in college level mathematics context. Finally, instead of using a single indicator of mathematics achievement, an operational variable that includes final grades in different college level mathematics courses as well as high school mathematics courses should also be considered.

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