Effects of Human Factors in Engineering and Design for Teaching Mathematics: A Comparison Study of Online and Face–to-Face at a Technical College

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Abstract

The focus of this study was to examine four characteristics for successful and unsuccessful students enrolled in basic mathematics courses at a technical college. The characteristics, considered to be in part effects of human factors in engineering and design, examined the preferred learning styles, computer information systems competency, on-screen reading ability, and keyboarding proficiency. Students self-selected one of two course delivery formats, online and face-to-face, for a basic mathematics class. The measures of the four characteristics were collected for each combination of class format and success. The study found that the class format and success status relative to the measured characteristics individually did not produce significant differences. There was a significant interaction of the factors noted for the social preferred learning style suggesting that successful face-to-face students had a weaker preference for a social learning style than non-successful students did. Two hundred eighty-eight students participated in the study.

Abbreviations: Georgia Virtual Technical College (GVTC), Western Cooperative for Educational Telecommunications (WCET), Technical College System of Georgia (TCSG), Multiple Intelligences (MI), Readiness for Education at a Distance Indicator (READI), Analysis of Variance (ANOVA), face-to-face (ff), online (ol)

1. Introduction

1.1 Demographics

Students enrolled in the course MATH 1012: Foundations of Mathematics participated in this study. The course emphasizes the "…application of basic mathematical skills used in the solution of occupational and technical problems. Topics include fractions, decimals, percentages, ratios and proportions, measurement and conversion, formula manipulation, technical applications, and basic statistics." There are five math prerequisites with the last one prior to this course being elementary algebra. A third of participants in the study were male and two-thirds were female (figure 1). A majority of the participants were enrolled in health-related majors (figure 2). Although most majors were populated with female students, there were certain male-dominated majors such as firefighting, welding and automotive related areas as depicted in table 1.

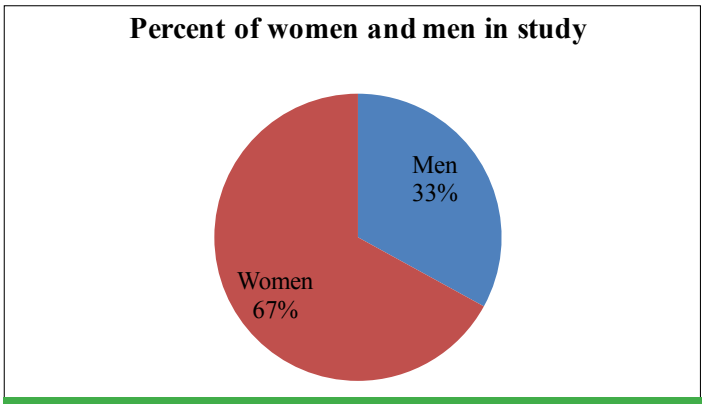

Figure 1: Gender distribution participants

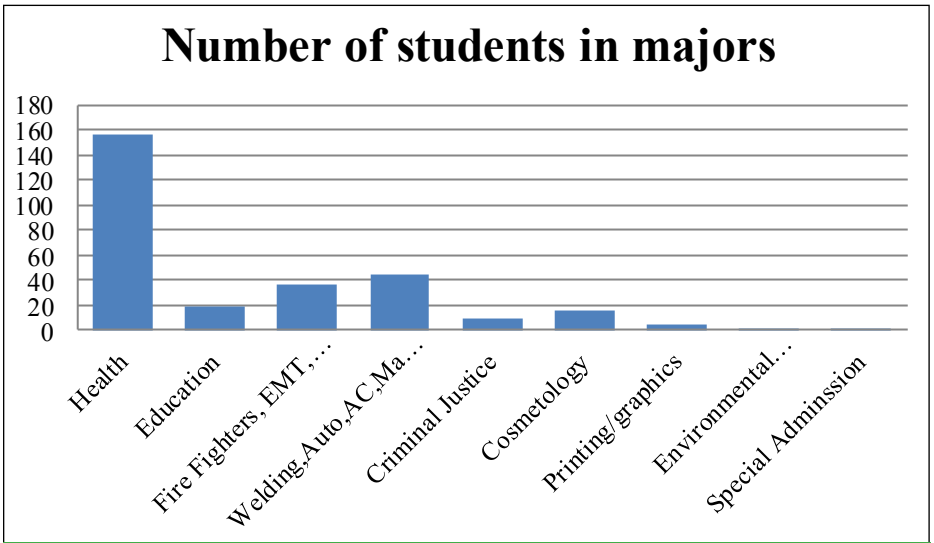

Figure 2: Participant enrollment in majors

1.2 Background

Although no short catch phrase can adequately characterize the scope of the human factors field, such expression as designing for human use and optimizing working and living conditions would give partial impression of what human factors is about (Sanders & McCormick, 1993). In this study, the effects of learning styles, computer information systems competency, on-screen reading ability, and keyboarding proficiency are partly influenced by the design of the medium used. The medium here includes the on-line devices and face-to-face devices or tools that make learning accessible. Although the words 'human factors' or 'engineering design' will not be used throughout the paper, it

Major (total enrolled)	Female	Male
Health (156)	133	23
Education (19)	16	3
Firefighters, EMT, Paramedic Tech (37)	10	27
Welding/Automotive/Air Conditioning/Machine tool/ Electrical Construction (44)	5	39
Criminal Justice (10)	7	3
Cosmetology (16)	15	1
Printing/Graphics (4)	2	2
Environmental Horticulture (1)	1	0
Special Admission (1)	1	0

Table 1 Gender Distribution in Majors

should be noted that they do have a significant contribution towards improving learning.

The Georgia Virtual Technical College (GVTC) has identified three categories of Internet use in connection with classes: online, hybrid, and Web-enhanced (GVTC, 2002). The online category courses are delivered entirely over the internet while the hybrid and web-enhanced categories use predominantly the traditional face-to-face format for instruction. While hybrid courses use a face-to-face format with some class sessions conducted online, the web-enhanced courses on the other hand are face-to-face for every contact hour but use online resources to enhance learning.

There are two schools of thought on how students learn over the Internet. One maintains that no difference exists in student learning whether set in an online-type class or a face-to-face type class, while the other suggests student learning in online classes differs from that of face-to-face. Regardless of the approach taken, the Western Cooperative for Educational Telecommunications (WCET) found most studies to date reflected no significant difference in constructs being analyzed between face-to-face and online classes (2006). Specific comparisons of online and face-to-face classes in mathematics have come to the same conclusion of there being no significant difference as identified above (Mascuilli, 2004).

The Technical College System of Georgia (TCSG) identified mathematics as one of the essential content areas within the technical college programs of study known as numeracy. "Virtually everyone uses quantitative tools in some way in relation to their work, if only to calculate their wages and benefits" (Steen, p. 1). All TCSG students in career diploma programs must take a basic mathematics course in order to complete the program successfully. She or he can choose to learn mathematics exclusively in face-to-face classes. However, with the growing use of online classes in technical colleges, many technical college students can be expected to learn mathematics in online courses. The workforce education establishment relies more and more on these online mathematics classes.

Intelligence may arguably be the primary factor in a student's ability to learn mathematics. Gardner's (1983) work in multiple intelligences (MIs) provided a theoretical foundation underlying a portion of this study. Research has indicated that people have different preferred learning styles based on these MIs (Gardner, 1999; Aragon, Johnson, & Shaik, 2001; Engelbrecht & Harding, 2005). Thus, in understanding how technical college students learn mathematics online, one critical factor to be assessed was the students' preferred learning styles. However, there is a dearth of quantitative research relating this and other student characteristics to their success or lack of it in online and face-to-face mathematics classes. This made a quantitative study relating the characteristics required for technical college students to achieve success in basic mathematics within either format valuable.

The TCSG routinely uses an evaluation instrument known as the *Readiness for Education at a Distance Indicator* (READI) (GVTC, 2009). Preferred learning styles are assessed by this instrument. Hence, the use of the READI was practicable for this study. In addition, the READI also assesses computer information systems competency, on-screen reading ability, and keyboarding proficiency as factors that indicate a student is ready for online classes.

1.3 Theoretical Framework

Readiness for Education at a Distance Indicator (READI) is the instrument that was used in this study. The instrument is based on two principal learning theories: learning styles theory and the theory of MIs (Decade Consulting, 2009a). While these two theories are different, in application, they are learner-centered and their outcomes are similar (Katzowitz, 2002).

Learning styles theory clearly informs us about learning styles and the expectation of differences in styles from individual to individual that may be observed (Katzowitz, 2002). Since learning styles define the way individuals extract, process, and memorize information, they are particularly important in web-based learning (Brown, Stothers, Thorp, & Ingram, 2006). Further, the capacity of working memory is equally important in learning (Sanders & McCormick, 1993). The learning style model used by the READI instrument is based on the Memletics model (Decade Consulting, 2009b). This model provides a specific numeric measure for each of seven areas: visual (spatial), aural (auditory-musical), verbal (linguistic), physical (kinesthetic), logical (mathematical), social (interpersonal), and solitary (intrapersonal) (Advanogy, 2007). Learning style is one of several components of the READI used to determine the readiness for technical college students to succeed in an online program (GVTC, 2008).

MI theory cautions to expect that people with differing intelligences may express preference for differing styles of learning (Gardner, 2006). In addition, as described by Laughlin (1999), in detailing the characteristics of multiple intelligence and their implications for learning, and by Smith (2006), in relation to digital libraries, multiple intelligence theory informs us about differences that may be encountered in the areas of computer information system competency which is recognizable as related to logical/mathematical and bodily/kinesthetic intelligence, on-screen reading ability can be seen as related to visual/spatial and verbal/linguistic intelligence. Finally, keyboarding proficiency is clearly related to visual/spatial and bodily/kinesthetic.

The READI was used in the assessment, providing a numerical measure of the four areas identified in the research questions: preferred learning styles, computer information systems competency, on-screen reading ability, and keyboarding proficiency. The specific areas measured by READI were chosen based on a study by Atanda Research which reported a strong correlation ($p < .001$) between the areas of computer information system competency, reading ability, and keyboarding proficiency and academic success in online classes (Decade Consulting, 2007). They also found a strong correlation between the solitary and logical learning style preferences and academic success online.

The READI embodies this theoretical framework in objective measures of preferred learning styles, computer information systems competency, on-screen reading ability, and keyboarding proficiency, measuring each of these areas that touch on the preparedness for success or failure in an online learning en-

vironment. These measures can also easily be used to determine the levels of these same characteristics relative to a face-to-face environment and allow for the comparison of successful and unsuccessful students in both genres.

1.4 Motivation

The impetus of this study was to examine the differences in preferred learning styles, computer information systems competency, on-screen reading ability, and keyboarding proficiency of technical college mathematics students in a basic mathematics class (MAT 1012 Foundations of Mathematics) and ascertain the extent of differences among the successful and unsuccessful students in both face-to-face and online classes. In the context of this study, the GVTC definitions of online and face-to-face were used, where online was entirely internet-based while hybrid or web-enhanced had a face-to-face component.

Although some previous studies have demonstrated no significant differences in outcomes between online and face-to-face delivery, that research continues to be questioned (Kassop, 2003; Joy & Garcia, 2000; Sangster, 1999; Clark, 1994; Kozma, 1994). One such critique centered on the lack of consideration in the research of the individual student's characteristics and the role these characteristics played in online learning. Robinson (2004) studied student characteristics as they related to satisfaction with their online course experience and developed an objective measuring instrument to determine that satisfaction. While some studies have shown individual student characteristics can predict success in online classes, most have primarily focused on previous student grade point averages and demographic factors as predictors of success (Wojciechowski & Palmer, 2005). On the other hand, research by Dziuban, Hartman, & Moskal (2004) identified various individual attributes that are significant predictors of success in an online learning environment. Other research has identified preparation readiness as a strong predictor of success in online courses (Smith, 2005; Smith, Murphy, & Mahoney, 2003). However, a variable, largely unexamined, is the possibility of differences between the characteristics and attributes of successful and unsuccessful students in both online and face-to-face classes.

Addressing differences in preferences of online and face-to-face students, Engelbrecht and Harding (2005) reported that, "more visually inclined learners tend to prefer the use of technology, while more verbal learners preferred a face-to-face learning environment" (p. 13). Given the research showing that different people learn mathematics in the face-to-face classroom in different ways, it is reasonable to surmise that students who are successful in learning in online mathematics classes and those who are successful in learning in face-to-face mathematics classes may exhibit different characteristics and attributes (Anderson et al., 2000). In fact, at least some researchers in mathematics education have said that, "only students that are strongly motivated self-starters, intellectually mature, home-schooled, or the handicapped can successfully complete the on-line mathematics course" (Engelbrecht & Harding, 2005).

While the lack of differences in outcomes of face-to-face and online mathematics classes have been touted, whether there are differences in characteristics of the successful and unsuccessful students in both formats has not been ascertained. In a preliminary analysis of the influence of learning-style preferences on student success, Aragon, Johnson, and Shaik (2002) concluded that there were significant variances in the learning style preferences of face-to-face and online students. As cited above, some believe these differences must also exist between successful and unsuccessful students. The problem is that there has been no determination as to whether these differences in characteristics of successful and unsuccessful students in both online and face-to-face basic mathematics classes actually do exist.

1.5 Research Questions

The following questions guided this research: (a) Are there statistically significant differences in the preferred learning styles of successful and unsuccessful face-to-face and online students in a basic mathematics course? (b) Is there a statistically significant difference in the computer information system competency of successful and unsuccessful face-to-face and online students in a basic mathematics course? (c) Is there a statistically significant difference in the on-screen reading ability of successful and unsuccessful face-to-face and online students in a basic mathematics course? and (d) Is there a statistically significant difference in the keyboarding proficiency of successful and unsuccessful face-to-face and online students in a basic mathematics course?

2. Methods and Procedures

This research study used quantitative methods for data collection and analysis obtained from the READI along with the grade results obtained from mathematics students in face-to-face and online mathematics classes. READI is an inventory instrument used as a student self-diagnostic tool. Atanda Research conducted a study in 2007 concerning the relationship of READI scores and measures of academic success and goodness fit for distance education as a measure of construct validity (Decade Consulting, 2008). A replicate study conducted in 2008 involved 2,622 students representing 300 schools showed that READI is an indicator of goodness fit for distance learning as evidenced by multiple correlations that are statistically significant at the .01 level. The use of of READI, an accepted evaluation instrument, minimized threats to internal validity. Applied Measurement found high reliability for areas measured.

Two hundred eighty-eight subjects participated fully in this study. All participants were students at a technical college in the state of Georgia in the United States. All students were enrolled in the basic mathematics course, MAT 1012 Foundations of Mathematics, during the fall quarter of 2008 or the winter quarter of 2009. All student participants were tasked to complete the online READI assessment at the beginning of the classes.

Overall, there were 191 students who took the class face-to-face and 97 who took the class online. Of these, there were 75 (77 percent) successful online students and 154 (81 percent) successful face-to-face students. The groups in this study were based on class formats and the levels based on student success. This study compared the two format-based groups (independent variables), each with two result levels (successful and unsuccessful), for the characteristics identified in the research questions.

A causal comparative approach was used in the study to ascertain whether there were significant differences in the characteristics of preferred learning styles, computer information systems competency, on-screen reading, and keyboarding proficiency among technical college mathematics students. Each of these areas of the READI was based on previous research. The method of analysis of each of these areas paralled those of this research.

Each of the seven learning styles were measured (Decade Consulting, 2009a). Each learning style is assigned a numerical value between a low of one to a high of 20 to indicate its relative dominance.

Computer information systems competency, a combination of technical, computer and internet competency combined with technical knowledge, is a second area assessed. Students answer various questions relating to computer information systems competence and receive an overall numerical score for computer information systems competency ranging from a low of zero to a high of 100.

The next area of assessment is on-screen reading ability. To measure reading comprehension, students answer questions based on a text they have been given to read within a specified time. READI then calculates a percent score based on the speed and accuracy of answers. The final area measured is keyboarding proficiency. The student is provided a passage to type, and READI calculates typing speed and errors.

The students fell into one of four groups: successful in online classes, un-

successful in online classes, successful in face-to-face classes, and unsuccessful in face-to-face classes. An arithmetic mean was calculated on each of the groups for each of the measured elements within these characteristics. A two-way ANOVA was performed on each of these to determine whether there were significant differences. The Bonferroni correction procedure was available to compensate for a potential increase in false positive difference errors because of the performance of multiple tests with significant differences discovered. Groups and outcomes were evaluated in-situ and variables in the study were not controlled by the researcher. As a result, evidence for causation is weaker than in an experimental design where groups and factors are controlled.

3. Results

This study examined differences in preferred learning styles, computer information systems competency, on-screen reading ability, and keyboarding proficiency of technical college mathematics students in a basic mathematics course (MAT 1012 Foundations of Mathematics). It examined successful and unsuccessful face-to-face and online students in a basic mathematics course. The combinations of class format and success formed four groups for the analyses. This study identified no significant differences in the main effects of characteristics of the students in any group.

Format	Success	*M*	*SD*
Online	Unsuccessful	6.95	2.149
	Successful	7.24	1.815
Face-to-face	Unsuccessful	7.92	1.498
	Successful	6.92	1.980

Table 2 Descriptive Statistics for the Dependent Variable Social Learning Style

The ANOVA indicated a significant interaction between format and success, although the partial eta squared value was relatively low, $F(3, 284) = 5.004$, $p = .026$, partial $\eta^2 = .017$. However, there were no significant main effects for format, $F(3, 284) = 1.234$, $p = .268$, partial $\eta^2 = .004$, and success, $F(3, 284) = 1.552$, $p = .214$, partial $\eta^2 = .006$.

Source	*df*	*F*	*p*	η^2
Format	1	1.234	.268	.004
Success	1	1.552	.214	.005
Format * Success	1	5.004	.026	.017

Table 3 Analysis of Variance for Dependent Variable Social Learning Style

*p < .05

(I) Group	(J) Group	Mean Difference	Std. Error	*p*	95% CI
ff_unsuccess	ol_unsuccess	.96	.511	.314	[-.47, 2.40]
	ol_success	.68	.381	.367	[-.39, 1.75]
	ff_success	1.00	.347	.041	[.03, 1.98]
ff_success	ol_unsuccess	-.04	.432	1.000	[-1.25, 1.18]
	ol_success	-.32	.267	.688	[-1.08, .43]
	ff_success	-1.00	.347	.041	[-1.98, -.03]

Table 4 Scheffé Post Hoc Social Learning Style

*p < .05

Format	Success	*M*	*SD*
Online	Unsuccessful	5.45	1.945
	Successful	6.31	2.348
Face-to-face	Unsuccessful	6.89	2.145
	Successful	5.97	2.269

Table 5 Descriptive Statistics for the Dependent Variable Verbal Learning Style

Source	df	F	*p*	η^2
Format	1	2.606	.108	.009
Success	1	.009	.924	.000
Format * Success	1	6.690	.010	.023

Table 6 Analysis of Variance for Dependent Variable Verbal Learning Style

The ANOVA indicated a significant interaction between venue and success, $F(3, 284) = 6.690$, $p = .010$, partial $\eta^2 = .023$. However, there were no significant main effects for venue, $F(3, 284) = 2.606$, $p = .108$, partial $\eta^2 = .009$, and success, $F(3, 284) = .009$, $p = .924$, partial $\eta^2 < .001$.

(I) Group	(J) Group	Mean Difference	Std. Error	*p*	95% CI
ff_unsuccess	ol_unsuccess	1.44	.546	.488	[-2.39, .68]
	ol_success	.58	.606	.134	[-3.14, .27]
	ff_success	.92	.513	.795	[-1.96, .92]
ff_success	ol_unsuccess	.52	.546	.488	[-.68, 2.39]
	ol_success	-.34	.453	.643	[-1.86, .69]
	ff_success	-.92	.317	.777	[-.56, 1.22]

Table 7 Scheffé Post Hoc Verbal Learning Style

*$p < .05$

The first research question that guided this study sought to ascertain if there were statistically significant differences among these groups of successful and unsuccessful face-to-face and online students in the visual, social, physical, aural, verbal, solitary, and logical preferred learning styles. Previous research suggested differences should be expected (Aragon, Johnson, & Shaik, 2002). Nevertheless, in all of the two-way ANOVA analyses performed, no significant differences were found in the main effects for any of the seven learning styles analyzed.

However, there was a significant interaction effect found for students selecting a social learning style preference in face-to-face classes. Students with greater preference for a social learning style were significantly less successful in face-to-face classes than those who had a lesser preference for the social learning style. The READI measure of social learning style is related to Gardner's theory of multiple intelligences and his interpersonal intelligence type. People who are strong in this area are capable of gauging other people's feelings and are good at relating and getting along with other persons.

In face-to-face classes, subjects had a lower social score when successful than when unsuccessful. In online classes, the effect was just the opposite. The effect of the four experimental conditions (face-to-face – successful (ff_success), face-to-face – unsuccessful (ff_unsuccess), online – successful (ol_success), and online – unsuccessful (ol_unsuccess)) on the social score differed significantly. However, performance of the post hoc procedure for a 2 x 2 factorial required some data manipulation. The four experimental conditions were converted into four levels of the same grouping variable. These four levels were compared using the Scheffé post-hoc test with ONE-WAY ANOVA analysis and significant results were obtained for the face-to-face successful and unsuccessful groups.

These results from the Scheffé comparisons indicated that the significant FORMAT* SUCCESS interaction was primarily because of the subjects scoring significantly lower on the social scale for successful face-to-face students than for unsuccessful face-to-face students. None of the other conditions were significantly different from each other.

At least one previous researcher found a similar difference. Keast (1999), in his studies of the relationship of learning styles and gender differences to performance in mathematics classrooms, found traditional mathematics classrooms as not suited to a learning style characterized as connected knowers. Similar to a person with a social preferred learning style, for a connected knower, "their knowledge of truth develops through care for others and their relationships with others" (p. 53). He found this learning style to be gender related and that, "most girls favored the connected mode of learning" (p. 55). This connected mode of learning is enhanced by environments where people can converse freely, take in nonverbal cues, and interact with other people in a relatively open manner. Constraints of a rigid classroom- management structure could impede this mode of learning.

A similar significant interaction effect was found when analyzing the results for the verbal learning style. However, further analysis revealed there was no identifiable causation. Additional studies focusing specifically on this learning style may be needed to uncover specific causative factors that may exist.

In face-to-face classes, subjects had a lower verbal score when successful than when unsuccessful. In online classes, the effect was the opposite. The verbal score differed among the four format and success combinations (face-to-face - successful, face-to-face - unsuccessful, online - successful, online - unsuccessful) Again, the nature of the differences and between which factors were not identified by the interaction effect. Thus, the Scheffé post-hoc comparisons were used again following the detailed procedures for data preparation identified by Ho (2006).

The results from the Scheffé post hoc indicated that none of the six format and success combination comparisons were significantly different.

For computer information system competency the expectation was for successful online students to have a significantly higher competency scores than unsuccessful online students based on the requirement to use computer technology more extensively in online course than in face-to-face course. However, as the results showed, successful and unsuccessful online students did not differ significantly in this competency.

In the on-screen reading ability comparison, the study found no significant differences among the groups. As the subject matter of mathematics does not consist of large amounts of material that must be read, this may explain why there were no significant differences in outcomes among the groups. For subjects requiring extensive reading materials, such as literature courses or social science courses, the significance of the differences in student ability may have

Format	Success	*M*	*SD*
Online	Unsuccessful	66.73	13.871
	Successful	66.92	14.553
Face-to-face	Unsuccessful	70.38	11.209
	Successful	65.69	13.762

Table 8 Descriptive Statistics for the Dependent Variable Computer Information System Competency

Source	df	F	*p*	η^2
Format	1	.338	.561	.001
Success	1	1.169	.280	.004
Format * Success	1	1.379	.241	.005

Table 9 Analysis of Variance for Dependent Variable Computer Information System Competency

*p < .05

The ANOVA indicated no significant interaction between format and success, $F(3, 284) = 1.379$, $p = .241$, partial $\eta^2 = .005$. In addition, there were no significant main effects for format, $F(3, 284) = .338$, $p = .561$, $\eta^2 = .001$, and success, $F(3, 284) = 1.169$, $p = .280$, partial $\eta^2 = .004$.

Format	Success	*M*	*SD*
Online	Unsuccessful	60.18	20.857
	Successful	63.99	17.199
Face-to-face	Unsuccessful	62.49	18.144
	Successful	64.76	17.312

Table 10 Descriptive Statistics for the Dependent Variable On-screen Reading Ability

Source	df	F	*p.*	$\eta^{\angle}$
Format	1	.328	.567	.001
Success	1	1.281	.259	.004
Format * Success	1	.081	.776	.000

Table 11 Ability Analysis of Variance for Dependent Variable On-screen Reading Ability

*p < .05

The ANOVA indicated no significant interaction between format and success. $F(3, 284) = .081$, $p = .776$, partial $\eta^2 < .001$. There were no significant main effects for format, $F(3, 284) = .328$, $p = .567$, partial $\eta^2 = .001$, and success, $F(3, 284) = 1.281$, $p = .259$, partial $\eta^2 = .004$.

Format	Success	*M*	*SD*
Online	Unsuccessful	22.23	7.994
	Successful	21.88	10.993
Face-to-face	Unsuccessful	21.92	10.032
	Successful	22.10	10.730

Table 12 Descriptive Statistics for the Keyboarding Competency

Source	df	F	*p*	$\eta^{\angle}$
Format	1	.001	.977	.000
Success	1	.003	.958	.000
Format * Success	1	.027	.870	.000

Table 13 Analysis of Variance for Dependent Variable Keyboarding Competency

*p < .05

The ANOVA indicated no significant interaction between format and success. $F(3, 284) = .027$, $p = .870$, partial $\eta^2 < .001$. There were also no significant main effects for format, $F(3, 284) = .001$, $p = .977$, partial $\eta^2 < .001$, and success, $F(3, 284) = .003$, $p = .958$, partial $\eta^2 < .001$.

a more significant impact on group differences.

Keyboarding proficiency results were also not significantly different. As with reading, the requirement for extensive keyboard entry for mathematics courses is not normally large. For this reason, differences in student capabilities among the groups in this area may not have been measurably significant.

For these three questions guiding this study concerning group differences in computer information systems competency, on-screen reading ability, and keyboarding proficiency, the analyses of the data provided by the READI did not reveal significant differences among successful and unsuccessful technical college students in face-to-face and online basic mathematics classes. These results suggested that these characteristics may not be predictors of success in online technical college mathematics classes, nor may they be indicators of which format for learning mathematics a technical college student should employ.

In viewing the no significant differences finding relating to the inverse relationship of a social preferred learning style and success in a face-to-face basic mathematics class, perhaps the differing interests and limited interaction time students who had a strong social preferred learning style had in the class were a detriment to their learning mathematics. Perhaps the gender composition of the sample explains the interaction difference found. These are both interesting observations for future research.

4. Discussion

Based on the results obtained in this study, the delivery of classes in basic mathematics in technical college is format independent. If similar results are obtained in other disciplines, then it can be concluded that the delivery of classes in these disciplines is format independent. Thus, technical college students can expect the same outcome whether their classes are taken over the Internet or in a face-to-face environment, and this would validate the commitment by the TCSG to offer occupational classes in both formats (significance of research).

5. Conclusion

The principal implication of this study was that there were no significant differences in the characteristics measured for successful face-to-face versus online technical college students in a basic mathematics class. This tended to conflict with some research, such as that by Engelbrecht and Harding (2004) that found visual learners preferred technology, while verbal learners preferred a face-to-face interaction. However, it supported the more prevalent no significant difference conclusions regarding all face-to-face and online classes. In addition, it validated the decision to offer this class in both formats for the technical college student to acquire the numeracy skills needed for their occupational program of study.

The single significance, that of a tendency for students with stronger orientation toward preference for social learning to be less successful in face-to-face classes than the success of those with a lesser preference for social learning, seemed to imply that strong social learning preference may lead to less success in these classes. However, more research, focused specifically on this characteristic, may be needed to establish a degree of confidence in the predictive ability of this learning characteristic (implication of research).

6. Recommendation

Based upon the research results, limitations, and implications, the following recommendations for additional study were developed: (a) repetition of this study at other technical colleges is suggested to provide results that are more generalizable; (b) similar research should also be conducted for other academic disciplines such as English or psychology; (c) similar research in the occupational disciplines, which are being offered more and more in both formats, is warranted since these disciplines have components that extend past problem- solving and require a different form of action and interaction than mathematics in either a face-to-face or online class format; (d) further investigation of the role student interaction or gender may play in the success of students with a social-preferred learning style in mathematics classes may be warranted; (e) examine the role of instructor (pedagogy) in leading students towards a systematic progression of thinking over time; (f) seek to understand student capacity to retain information and use new skill if correlated to age; and (g) further review the uniqueness of human factors engineering and design, if any, that contribute to learning.

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