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Identifying Sources of Anxiety in an Introductory Online Undergraduate Chemistry Course

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Abstract

Learning chemistry in an online environment may have multiple sources of anxiety for students, including chemistry anxiety, math anxiety, computer anxiety, and trait anxiety (personality attribute of proneness to experience anxiety). While previous research has explored relationships between math and chemistry anxiety in a traditional setting, no studies have explored these anxieties in the online modality. Survey data were collected using existing scales (some with minor modifications), with a response rate of 31%. The scales used in this study demonstrated strong reliability. Highest sources of anxiety for each scale were presented. The perceived ease of use scale score was used as the dependent variable. As perceived ease of use increased chemistry anxiety decreased. Furthermore, as chemistry anxiety increased, math, computer, and trait anxiety increased. As computer anxiety increased, perceived ease of use decreased. However, math and trait anxiety did not demonstrate this association. Demographic variables did not influence relationships in this study. To confirm these relationships, future research will explore the influence of these anxieties in online chemistry on learner outcomes, including final course grade and course persistence. The results of this study offer new evidence regarding the influence of multiple sources of anxiety in learning undergraduate chemistry in an online setting. By integrating this knowledge with online course design best practices, educators can provide students with a lower-anxiety learning environment.

Keywords: chemistry, anxiety, online courses, online learning, computer self-efficacy, perceived ease of use

Introduction

Anxiety - an emotional reaction to a perceived situation associated with feelings of helplessness and uncertainty – is an often-explored concept in higher education. External and environmental factors such as employment status (Yan, 2007, Mounsey, Vandehey & Diekhoff, 2013)) can influence anxiety. Internal factors that impact anxiety in higher education include self-esteem (Yan, 2007), social anxiety (Russell, 2012), beliefs about learning (Young, 1991), motivation (Young, 1991, Yan. J.X., Horwitz, 2008), previous subject area experience (Townsend et al., 1998), learning strategies (Yan. J.X., Horwitz, 2008), learning interest (Yan. J.X., Horwitz, 2008), degree progress (Stanley, 2016), academic major (Brown, Strange, 1981), and gender (Yan. J.X., Horwitz, 2008). Institution and classroom level factors can influence learner anxiety, including instructor-learner interactions (Young, 1991), teaching methodology (Young, 1991, S. L. Eddy, Converse & Wenderoth, 2015), assessment design including evaluated group work (Yan. J.X., Horwitz, 2008, Khanna, 2015, Strauss, 2011), and classroom procedures like verbal communication (Young, 1991, Broeckelman-Post, Johnson & Schwebach, 2016). Student anxiety can have benefits (Keeley, Zayac & Correia, 2008) and drawbacks (Zeidner, Matthews, 2005, Zoller, Ben-Chaim, 1989, Yan. J.X., Horwitz, 2008, Ashcraft, 2002), though the literature seems to support the idea that the drawbacks outweigh the benefits as many studies seek to reduce anxiety.

Certain disciplines in higher education have prominent concerns regarding student anxiety. Chemistry anxiety is a well-explored phenomenon in the literature, with high anxiety typically present at the beginning of the course (Abendroth, Friedman, 1983, Oludipe, Awokoy, 2010). Moderating variables for chemistry anxiety include gender (with females correlating to higher anxiety) (Cooper, 1994, R. M. Eddy, 2000, McCarthy, Widanski, 2009) and chemistry experience (with low experience correlating to higher anxiety) (R. M. Eddy, 2000, McCarthy, Widanski, 2009). Academic major may be a moderating variable, but the literature is inconclusive at this time (R. M. Eddy, 2000, McCarthy, Widanski, 2009).

Mathematics is another subject that may trigger anxiety (Bradstreet, 1996, Nunez-Pena, Suarez & Bono, 2013, Jain, Dowson, 2009, Kesici, Erdogan, 2009). Introductory chemistry courses include mathematics. Student performance has been linked to math anxiety even in non-mathematics courses (Wahid, Yusof & Razak, 2013, Nunez-Pena et al., 2013, Flanagan, Einarson, 2017, Pourmoslemi, Erfani & Firoozfar, 2013). Math anxiety has been shown to be related to gender, with females showing higher anxiety (Maloney et al., 2012, Hembree, 1990, Pourmoslemi et al., 2013). Academic major may not be a significant moderating variable in math anxiety (Helal, Hamza & Hagstrom, 2011, Pourmoslemi et al., 2013). Self efficacy and a positive math attitude predict math anxiety

(Akin, Kurbanogly, 2011). Previous negative math-related class experiences are related to math anxiety (Ramirez, Shaw & Maloney, 2018).

In a study of anxiety in the traditional chemistry classroom, a significant relationship was reported between chemistry anxiety and math anxiety (R. M. Eddy, 2000). In this study, the chemistry anxiety correlated with chemistry experience but chemistry anxiety did not correlate with math experience (R. M. Eddy, 2000). Students enrolled in online chemistry lecture reported slightly higher chemistry anxiety than those enrolled in traditional chemistry lecture, though this difference was not statistically significant (removed for blind review).

An increasing number of courses in higher education, including chemistry, are being offered asynchronously online. Students report anxiety when starting a new online course, even if they have prior online learning experience (Conrad, 2002). This previous experience may increase motivation, which in turn may increase course satisfaction and final course grade (Wang, Shannon & Ross, 2013). Self-efficacy may mediate computer anxiety (Saade, Kira, 2009). Gender may moderate computer anxiety, with more females reporting computer anxiety (Stoilescu, McDougall, 2011). Computer ownership, perceived computer skills, and computer experience negatively correlate with anxiety (Korobili, Malliari, 2010). Computer anxiety can be reduced in an online course through reduction in transactional distance and degree of autonomy (Hauser, Paul & Bradley, 2012). Computer anxiety and attitudes may improve throughout the term (DeVaney, 2010). While distance learning may be a source of anxiety for some, it may reduce anxiety for other students due to the ability to self-pace, practice privately, and reduced peer pressure (Hurd, 2007). To date, there is no existing literature exploring computer anxiety in online chemistry courses, though computer anxiety may be a contributing factor in the student preference of face-to-face (traditional) modality for chemistry lecture. In one study, 75% of students reported a preference for the traditional modality (Thirunarayanan, Bayo & Slater, 2010).

In this study, we analyze anxiety in an online chemistry course, determining the relative prevalence of chemistry, math, computer, and trait anxiety (the tendency of a person to experience anxiety) (Figure 1) and their impact on perceived ease of use of the LMS. Specifically, we pose the following alternative hypotheses:

H1a: Chemistry anxiety is negatively correlated with students' perceived ease of use of the learning management system (LMS).

H2a: Chemistry and math anxiety will have a significant positive association.

H3a: Chemistry and computer anxiety will have a significant positive association.

H4a: Chemistry and trait anxiety will have a significant positive association.

H5a: Computer anxiety is negatively correlated with students' perceived ease of use of the LMS

H6a: Math anxiety is negatively correlated with students' perceived ease of use of the LMS

H7a: Trait anxiety is negatively correlated with students' perceived ease of use of the LMS

H8a: Math, computer, and trait anxiety moderate the association between chemistry anxiety and perceived ease of use.

[insert figure 1 near here; Figure 1: Research Model of Mediation of Relationship Between Chemistry Anxiety and Perceived Ease of Use]

Experimental

Participants

The study participants were undergraduate students enrolled in online sections of an introductory general chemistry course from a medium-sized private institution (Table 1). As is typical in online courses, the student population was non-traditional, with an average age of 34 (traditional students who take college courses right after high school are typically aged 18-22). Additionally, 50% of the student population had an active duty or reserve military affiliation

and most had full time work commitments. Military student demographics in higher education are similar to non-traditional students (Ford, Vignare, 2015).

Survey data were collected using SurveyMonkey, with participation solicited through a recruitment announcement in the learning management system. Research participants were provided a survey that included specific demographic and learning characteristic questions, including age, gender, ethnicity, GPA, academic major, and previous math, computer, and chemistry experience. The survey was administered once at the start of the term. This study was deemed exempt by the Institutional Review Board (approval #20-110). The sample size was relatively small (n=26) however we tried to compensate for the lower n through thorough survey questioning where multiple scales were used to gauge student perceptions.

Table 1: Research Participants

Term Date	Section ID	Students Enrolled (#)	Responses (#)	Response Rate (%)
October 2020	A	31	26	31
	B	18		
November 2020	C	11		
January 2021	D	12		
	E	11		

Measures and Data Analysis

Anxiety measures. The Derived Chemistry Anxiety Rating Scale (DCARS) is a common instrument for measuring chemistry anxiety (R. M. Eddy, 2000, Rotairo, Avilla & Aranes, 2015, Huey, 2013, McCarthy, Widanski, 2009). However, this instrument uses language that is specific to the traditional modality. This study modified the DCARS survey to use language inclusive of the online modality (Appendix 1). Additionally, only the first two subscales were used in this study (Chemistry-Learning Anxiety and Chemistry-Evaluation Anxiety), resulting in 26 items. The third factor, Chemical-Handling Anxiety, is not relevant to anxiety in a chemistry lecture course. Each subscale has a demonstrated high level of reliability indicated by Cronbach's alpha coefficients (R. M. Eddy, 2000), including other adaptations to the scale (Senocak, Baloglu, 2014).

The 9-item Abbreviated Math Anxiety Scale (AMAS) is a Likert-format scale that shows strong internal consistency for the whole instrument as well as both subscales (learning math anxiety and math evaluation anxiety), indicated by Cronbach's alpha coefficients and other measures of reliability (Primi et al., 2014, Cipora et al., 2015, Hopko, 2003). This instrument was modified minimally to use language inclusive of the online modality (Appendix 1).

The Anxiety instrument (ANX) is a 4-item Likert-format scale with demonstrated validity and reliability, indicated by Cronbach' alpha (Saade, Kira, 2006, Saade, Kira, 2009).

To determine trait anxiety – or proneness to anxiety – this study employed the Trait Anxiety Scale from the State-Trait Anxiety Inventory (STAI) (Spielberger, 2010). This is a 20-item instrument using a Likert-format scale. This subscale asks respondents to rate their feelings "in general", from "almost never" to "almost always".

For the DCARS, AMAS, and ANX instruments, a higher rating from students indicated higher anxiety. For the STAI instrument, questions included both positive and negative anxiety statements. For positive questions, a higher student rating indicated a stronger positive emotion and thus less anxiety; for negative questions, a higher student rating indicated a stronger negative emotion and thus more anxiety.

Perceived ease of use measure. While anxiety can have a variety of effects including impacts to performance, this study used a self-reported "perceived ease of use of the LMS" variable to explore the relationship between the anxieties studies to preserve anonymity. This study implemented the Perceived Ease of Use (PEU) instrument, which explores student perceptions regarding navigation of online courses (Saade, Kira, 2009). The 4-item

instrument used positive language to measure the degree to which students expect the LMS to have low cognitive effort and minimal usage difficulties. Higher ratings from students indicate easier perceived use.

Data Analysis. Hypotheses were evaluated using correlation analysis. Alpha levels for all testing were set at .05 (Sharpe et al., 2019). Data were coded using Microsoft Excel and evaluated using StatCrunch software (Pearson Education, 2021). Data obtained from anxiety scales were treated as a continuous variable (Ramirez et al., 2018). In this case, 26 surveys were evaluated, which comprised the use of all five scales by survey respondents. Demographic data were compared to assess differences between groups based on age, ethnicity, GPA, and gender using Mann-Whitney U and Kruskal-Wallis statistics as appropriate. Reliability of all scales used in this study were evaluated for reliability using Cronbach's Alpha (Sharpe et al., 2019).

Results and Discussion

Reliability Analysis

The instruments used in this study (DCARS, AMAS, ANX, and STAI) all had high reliability (Table 2). When reporting science education research, a Cronbach's alpha of at least 0.7 indicates acceptable internal consistency, with values over 0.9 being very strong (Taber, 2018). The reliability reported for all scales used in this study aligns with previously reported values. It is important to note that the DCARS and AMAS scales were modified slightly to include language appropriate for the online learning classroom environment. These results suggest the modification did not reduce the reliability.

Table 2: Reliability Assessment of Instruments

Scale	Scale Items (*N*)	Average Total Score	Scale *SD* (avg.)	Cronbach's α
DCARS Factor 1: Learning Chemistry	17	38.31	15.66	.958
DCARS Factor 2: Chemistry Evaluation	9	30.85	8.98	.953
AMAS: Learning Anxiety Subscale	5	9.89	4.74	.930
AMAS: Testing Anxiety Subscale	4	11.42	4.46	.886
ANX	4	6.35	3.65	.886
STAI	20	49.15	14.01	.960
PEU	4	14.12	4.67	.956

Sources of Anxiety

By ranking the anxiety instrument items by their means, the sources associated with the highest anxiety in an online undergraduate chemistry course can be evaluated. The top anxiety responses for each scale are presented in Table 3.

Table 3: Sources of Highest Anxiety for Each Scale

Source of Anxiety	Mean Anxiety Level
DCARS – Factor 1: Learning Chemistry Anxiety	2.26
Signing up for a Chemistry Course	2.77
Thinking about a Chemistry Course	2.58
Thinking about a Chemistry Lab	2.54

DCARS – Factor 2: Chemistry Evaluation Anxiety	3.34
Thinking about an upcoming Chemistry Test 1 day before	3.77
Taking an examination (Quiz) in a Chemistry class	3.54
Being given a "pop" quiz in a Chemistry class	3.50
AMAS: Math Anxiety – Learning Anxiety Subscale	1.98
Starting a new chapter in a math book	2.16
Having to use the tables in the back of a book	2.12
Listening to a mathematics lecture	2.04
AMAS: Math Anxiety – Testing Anxiety Subscale	2.86
Being given a "pop" quiz with mathematics problems	3.15
Being given a homework assignment of many difficult mathematics problems that is due the next class meeting	3.00
Taking an examination with mathematics questions	2.69
ANX: Computer Anxiety	1.59
It scares me to think that I could cause the computer to destroy a large amount of information by hitting the wrong key.	1.96
I feel apprehensive about using computers.	1.54
Computers are somewhat intimidating to me.	1.46
STAI: Trait Anxiety	2.46
I (do not) feel at ease	2.77
I (do not) feel calm	2.73
I (do not) feel content	2.72

In regard to chemistry anxiety, previous studies have reported mean anxiety for learning chemistry ranging from 1.78 to 2.3 (McCarthy, Widanski, 2009, R. M. Eddy, 2000). This aligns with the reported average for online chemistry learners from this study. Similarly, previous studies reported mean anxiety for the chemistry evaluation subscale ranging from 2.72 to 3.29 (McCarthy, Widanski, 2009, R. M. Eddy, 2000), which is slightly lower than the average reported for online learners of 3.34 as reported under the DCARS Factor 2 Scale. In this study, chemistry quizzes and exams tended to be the most anxiety provoking events. A recent study reported no significant differences in chemistry anxiety between online and in-person students (removed for blind review).

In regards to math anxiety, previous studies reported an average AMAS total score ranging from 21.9 to 23.6 (Cipora et al., 2015, Primi et al., 2014), which aligned with the value of 21.23 reported here, with similar weighting in the subscales of math learning and math evaluation. Currently, there is a gap in the literature comparing math anxiety between online and in-person students using the AMAS instrument. In the past, online students tended to have a different demographics from in-person students. A recent study reported that adult learners reported higher anxiety than traditional students (Jameson, Fusco, 2014).

In regard to computer anxiety, previous studies reported a mean anxiety score ranging from 2.34 to 2.65 (Saade, Kira, 2009, Saade, Kira, 2006). Here, mean computer anxiety was 1.59, notably lower. Computers have

been ubiquitous in American society. It is unknown what impacts the presence and availability of computers have had on reducing computer anxiety in online learning though the connection is logical.

In regard to trait anxiety, previous studies within higher education reported an average total trait anxiety score of 45.39 (Mojgan, Kadir & Soheil, 2011), which aligned with the average reported in this study. It is unclear at this time how trait anxiety may differ between online and in person students.

Except for Computer Anxiety, all of the scale results reported in this study align with previous research within higher education.

Who Experiences Anxiety

This study also sought to explore the influence of various moderating variables on anxiety in an online undergraduate chemistry course. Due to the non-parametric shapes of the distributions, data were evaluated using a Mann-Whitney U (gender) and Kruskal-Wallis (age, ethnicity, GPA, and major) comparing median ranks between the groups. Data for the 26 survey respondents yielded no statistically significant differences ($\alpha = .05$) for any of the scales used in this study although future studies could gain statistical power by increasing sample size. Although demographics did not seem to play a role in this study, variables such as age, ethnicity, GPA, and gender should be examined in any future study replications.

Correlation Analysis

The first hypothesis (H1a) explored in this study predicted a negative correlation between chemistry anxiety and perceived ease of use of the learning management system. An understanding of this association will be the basis of exploring mediation of other types of anxiety (computer, math, and trait anxiety). Correlation analysis resulted in a significant negative correlation ($r = -3739$, $r^2 = .1398$, $p = .0299$). Analysis showed enough evidence to reject the null hypothesis of no association. As chemistry anxiety decreased, perceived ease of use increased.

Next, the association between each potential mediating variable and chemistry anxiety was explored (H2a – H4a). It was predicted that computer, math, and trait anxiety would respectively each have a positive correlation with chemistry anxiety (Table 4). We found significant positive correlations between math and chemistry anxiety, computer and chemistry anxiety and trait and chemistry anxiety. As chemistry anxiety increased, math anxiety, computer anxiety, and trait anxiety also increased.

Table 4: Comparisons of Chemistry Anxiety and Three Potential Mediating Variables

Correlation	(*r*)	r^2	*p*
Math & Chemistry	0.725	.526	<.001
Computer & Chemistry	0.529	.280	.0027
Trait & Chemistry	0.386	.149	.0258

Furthermore, the association between each potential mediating variable and perceived ease of use was explored (H5a – H7a). It was predicted that computer, math, and trait anxiety would respectively each have a negative correlation with perceived ease of use (Table 5). While our analysis did not support a significant negative correlation between math or trait anxiety and perceived ease of use of the LMS, there was support for a significant negative correlation between computer anxiety and perceived ease of use. As computer anxiety increased, perceived ease of use decreased.

Table 5: Potential Mediating Variables and Perceived Ease of Use of the Learning Management System

Correlation	(*r*)	r^2	*p*

Math & PEU	-0.298	0.089	.0696
Computer & PEU	-0.339	0.115	.0452
Trait & PEU	-.0163	.0002	.468

204

205 ***Assessment of Mediation***

206 The proposed hypothesis on moderation (H8a) stated that math, computer, and trait anxiety moderate the association
207 between chemistry anxiety and perceived ease of use. The correlation between chemistry and perceived ease of use
208 was (r = -3739, r^2 = .1398, p = .0299). However, it was not possible to determine which were casual variables. It
209 was not possible to tell if less chemistry anxiety would cause improved perceived ease of use or vice versa.
210 Additionally, the relatively low Pearson's r would lead an observer to believe other variables may be at work. We
211 noted significant associations between chemistry anxiety and math, computer, and trait anxiety respectively (Table
212 4). However, perceived ease of use only showed significant associations with computer anxiety (Table 5) and
213 chemistry anxiety (reported above). Although no casual factors can be identified in this analysis, the results can still
214 be instructive in course design and reducing the number of surveys students need to take to determine anxiety.

215

216 [insert figure 2 near here; Figure 2: Influence of Mediating Variables on the Association between Chemistry Anxiety
217 and Perceived Ease of Use]

218 ***Limitations***

219 It is possible that the results in this study were impacted by the relatively small sample size. The small sample size
220 should be considered when examining the results and recommendations of this study. Future researchers could use
221 the methodology of this study with a larger sample size to determine if results could be replicated.

222 Nonresponse error is often a concern in survey research. This survey was non-incentivized and voluntary, which
223 could introduce bias, over-representing strong opinions (either positive or negative). Because this study explored
224 various sources of anxiety, it is reasonable to assume that some students opted out of participation due to the topic of
225 inquiry. The response rate fell below ideal sample size parameters, given the population size, response rate and
226 confidence level. With a 95% confidence level, the response rate resulted in a margin of error of 16.5%.

227 The total drop/withdrawal rate was 2.35% (n=2) The two withdrawals along with the small sample may
228 have influenced the statistical outcomes possibly skewing data as those with high anxiety may not have persisted.

229 The goal of this study was to establish the co-presence of various sources of anxiety in an asynchronous
230 online introductory chemistry course. Data were collected anonymously via survey. Future work will collect
231 confidential data in order to explore the influence of the anxieties confirmed to be experienced by online learners on
232 learner outcomes, including final course grade and course persistence. This future work will also explore self-
233 efficacy and how anxiety changes across the term.

234 **Conclusions**

235 This study demonstrates that undergraduate students enrolled in introductory chemistry online are likely to face
236 multiple sources of anxiety, including chemistry, math, computer, and trait anxiety. In this study, the Chemistry and
237 Computer Anxiety scales were both associated with perceived ease of use with the learning management system.
238 Math and Trait anxiety all had non-statistically significant associations with Perceived Ease of Use, but all three of
239 those scales were positively correlated with the Chemistry Anxiety scale.

240 Potential moderating variables of gender, age, GPA and major did not show enough evidence to conclude
241 subgroups in these areas responded in significantly different ways. This study used anonymous data due to the

sensitive nature of discussing anxiety. With the associations between anxieties more clearly established, future work can proceed with confidential data exploring how anxieties influence student performance in the course, aiming for a higher sample size and thus a more robust analysis of possible moderators.

Due to the small sample size, the results of this work may have limited generalizability. However, this work addresses critical gaps in the literature, specifically regarding co-occurrence of anxieties in learning chemistry and the presence of these anxieties within an online learning environment. Furthermore, this study establishes tentative associations between anxieties that are worthy of deeper exploration.

This study presents a new understanding regarding the co-occurrence of anxieties within an online undergraduate chemistry course. With a stronger understanding of these anxieties, course designers can implement strategies to mitigate specific sources of anxiety and thus limit certain negative effects. For example, online course designers can include effectively placed videos demonstrating step-by-step procedures on how to run specific computer operations pertinent to the course. Formative assessment in the form of a "feedback session" for a class may reduce math anxiety in a course that uses math but is not a math course (Nunez-Pena et al., 2015). Educational researchers can explore the impact of implementing strategies for these co-present sources of anxiety that are shown to be effective in existing literature or they can test new strategies and targeted interventions to reduce sources of anxiety. Any chemistry course can be stressful due to a variety of reasons. Learning chemistry online introduces new sources of anxiety. The more instructors and instructional designers can understand what students are experiencing, the better.

Conflicts of interest

There are no conflicts to declare.

Ethical and Consent Statements

This study was reviewed by the Institutional Review Board (IRB) of [removed for anonymous review] (approval #20-110). The study was deemed exempt by the Institutional Review Board. Therefore, informed consent was not obtained.

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