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## Infusing Humanities in STEM Education: Student Opinions of Disciplinary Connections in an Introductory Chemistry Course

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# 1 **Infusing humanities in STEM education: student opinions of disciplinary connections in an introductory** 2 **chemistry course**

## 3 **Abstract**

4 The *Next Generation Science Standards* and other educational reforms support the formation of deep connections  
5 across the STEM disciplines. Integrated STEM is considered as a best practice by the educational communities of  
6 the disparate disciplines. However, the integration of non-STEM disciplines is understudied and generally limited to  
7 the integration of art (STEAM). Humanistic STEM *blends* the study of STEM with interest in and concern for,  
8 human affairs, welfare, values, or culture. This study looks at an infusion of the humanities into an online chemistry  
9 course to see if there is an influence on student connection between course content and cross-disciplinary  
10 perspectives. Specifically, students were asked about the course making clear connection to STEM disciplines,  
11 between science and non-science, between science and the real world, and a widened perspective of science  
12 connection other courses in their degree programs. Items on a Likert scale were presented as part of the end of  
13 course evaluations and yielded 59 responses. Although not statistically significant difference in the pre- and post-  
14 infusion agreement, it is evident that the additional perspectives did no harm. The positive movement in this pilot  
15 study encourages further investigation with stronger infusions of both STEM and humanities content.

16 **Keywords:** STEM Education, Interdisciplinary Approach, Student Attitude, Humanistic STEM, Integrated STEM

## 17 **Introduction**

18 Our world is not neatly arranged by academic disciplines and understanding complex problems requires cross-  
19 disciplinary knowledge. Concepts from any field are enriched by the theories and methods from other fields,  
20 providing context, intellectual inquiry, and multi-perspective analysis (Stember 1991). Coherence and cohesiveness  
21 of these connections combats fragmentation of knowledge (Fogarty 1991). An integrated curriculum connects a  
22 STEM discipline to one or more other disciplines in order to enhance student learning. A cohesive integration  
23 contains the following disciplinary elements: 1) *scientific inquiry* where students construct their own questions and  
24 investigations, 2) *technological literacy* where students make use of instruments, 3) *engineering design* to provide  
25 the systematic approach to problem solving, which contributes context and provides the opportunity to apply  
26 knowledge and skills while learning from failure, and 4) *mathematical thinking* (*STEM road map: A framework for*  
27 *integrated STEM education* 2015; Kelley and Knowles 2016). Integration can include cross-disciplinary,  
28 multidisciplinary, and interdisciplinary perspectives (Jensenus 2012; Stember 1991). Pedagogical elements of  
29 integrated STEM include an authentic, relevant, and engaging context, emphasis on application and integration, a  
30 student-centered approach, and development of key transferable skills in problem-solving, creativity, and higher  
31 order thinking through the use of use of real-world problems, as well as the development of teamwork and  
32 communication skills (*STEM road map: A framework for integrated STEM education* 2015; Kelley and Knowles  
33 2016; Sanders 2012).

34 The science, technology, engineering, and mathematics educational communities support integrated STEM  
35 as a best practice (Sanders 2012). According to cognition theory, knowing how to apply knowledge and skills is just  
36 as important as learning the knowledge and skills themselves (Putnam and Borko 2000). The *Next Generation*  
37 *Science Standards* and other educational reforms support the formation of deep connections across the STEM  
38 disciplines (NGSS Lead States 2013).

39 An integrated STEM curriculum has some challenges, including competing agendas, epistemological and  
40 methodological differences, varying cohesiveness and coherence, and identifying the appropriate intersections of  
41 disciplines (Honey et al. 2014; Stember 1991; Wang et al. 2011). An integrated curriculum increases the potential  
42 for knowledge gaps in faculty (Drake and Burns 2004; Stinson et al. 2009). Some argue that integration limits the  
43 content that can be covered (Kelley and Knowles 2016) while others argue that integration increases efficiency,  
44 covering multiple disciplinary concepts simultaneously (Drake and Burns 2004).

45 While there has been recent attention on integration of the STEM disciplines, including interest in STEAM  
46 (science, technology, engineering, *arts*, and math), humanities discipline integration into STEM has garnered much  
47 less attention (Becker and Park 2011; Hoachlander and Yanofsky 2011). When art is present, it is either not assessed

48 using appropriate learning objectives or is evaluated as a secondary criterion (Perignat and Katz-Buonincontro  
 49 2019). A modern approach is humanistic STEM, defined as “a path blending the study of science, technology,  
 50 engineering, and mathematics with interest in, and concern for, human affairs, welfare, values, or culture”  
 51 (Bourdeau and Wood 2019). As with STEM disciplines, the arts and humanities disciplines require critical thinking  
 52 habits of mind, including creativity, contextual perspective, intellectualism and curiosity, an ability and confidence  
 53 to use reason, perseverance, self-reflection, and both flexibility and adaptability in thinking in order to be open-  
 54 minded to new ideas (Hamman 2013; Paul and Binker 1990). The humanities disciplines – such as the study of  
 55 languages, philosophy, logic, and rhetoric – can offer additional perspectives for students (American Academy of  
 56 Arts and Sciences 2013). Table 1 presents skills used in problem solving across disciplines.

57 **Table 1: Comparison of Skills for Problem Solving across Disciplines** (Alkhatib 2019; Kelley and Knowles  
 58 2016; Nurdyansyah et al. 2017)

Core Skill for Problem Solving	Disciplinary Skill			
	Science	Technology & Engineering	Mathematics	Humanities Meta-Discipline
Understanding a problem by ...	making observations and generating questions	identifying criteria and constraints	creating abstractions of a situation, represented as symbols	identifying the key elements of the problem
Plan an investigation by ...	developing an explanation (hypothesize)	analyzing existing solutions	looking for solution entry points	questioning assumptions and identifying existing information
Appropriate tools ...	strategically	strategically	strategically	strategically
Perform investigation by ...	systematic experimentation and modeling	designing and running models	logic and reason	organizing information
Iteration towards ...	understanding	a good enough solution	generalized models and proof	interpretation
Analyze data ...	using logical and quantitative thinking	using quantitative thinking to locate optimal design	using quantitative thinking	looking for a pattern using mixed methods
Construct an argument from ...	evidence	evidence	evidence	evidence
Informed decision-making and justifying ...	conclusions	design decisions	potential solution paths	potential conclusions
Communication of ...	ideas, results, explanations, and implications	ideas, design decisions, explanations	potential models	ideas, explanations, and implications
Work and credit are ...	shared	shared	shared	shared

59

60 While the literature on the impacts of integrated STEM is scarce, it appears that students in integrated  
 61 curricula outperform those in fragmented curricula (Beane 1993; Becker and Park 2011; Fan and Yu 2017; Hartzler  
 62 2000). An integrated approach improves higher-level thinking skills, problem solving, and retention, likely due to  
 63 the intellectual, practical, and pedagogical implications of integration (Fan and Yu 2017; Fllis and Fouts 2001;  
 64 Furner and Kumar 2007). There is a need for further research to establish the impact of interventions, scaffolding,  
 65 and instructional designs (Becker and Park 2011; Kelley and Knowles 2016; Sanders 2012). Because student  
 66 attitudes towards STEM influence motivation (Becker and Park 2011), it is important to understand how integration  
 67 influences student attitudes and perspectives. This study explores the impact of a small-scale interdisciplinary

68 infusion into an online course on student perceptions of the connectedness of the course to other disciplines, other  
69 courses, and the real world.

70 H<sub>a1</sub> More students will agree than disagree that the course made clear connections between science, technology,  
71 engineering, and math.

72 H<sub>a2</sub> More students will agree than disagree that the course made clear connections between science and non-science  
73 topics and issues such as art, history, and the humanities.

74 H<sub>a3</sub> More students will agree than disagree that the course made clear connections between science and the world  
75 around them.

76 H<sub>a4</sub> More students will agree than disagree that the course has widened their perceptions of how science connects to  
77 other courses in their degree program.

## 78 **Methods**

### 79 *Participants*

80 This study was performed at a medium-sized private university in the United States. The pilot study was run in an  
81 online introductory chemistry course, available to both STEM and non-STEM majors. End of course evaluations  
82 provided data between August 2018 and October 2019. The response rate to the survey pre-intervention averaged  
83 66.1% ( $\pm 10.7\%$ ), with an  $n$  of 35 respondents. The response rate to the survey post-intervention averaged 67.5%  
84 ( $\pm 9.2\%$ ), with an  $n$  of 24 respondents. For this study, each section of the course was taught in the asynchronous  
85 online modality. While demographic data was not collected, the majority of students enrolled in the studied sections  
86 were non-traditional students.

### 87 *Interventions*

88 With the goal of infusing small integrations across the online course, a multi-disciplinary team collaborated on  
89 modifications to the course that did not impact assessments, assignment design, or core content (Table 2). For  
90 example, the first module's original title of "Introduction to Chemistry" was changed to "Bacon and Gunpowder".  
91 The overview for the module opens with a quote from Roger Bacon regarding the connection between mathematics  
92 and science. Bacon was an English philosopher who first detailed the production of gunpowder, thus the inspiration  
93 for the module title. This overview also includes the added video on the math used in chemistry - dimensional  
94 analysis. The module ended with a quote from Democritus (an ancient Greek philosopher who put forward an  
95 atomic model in 442 BCE), "We think there is color, we think there is sweet, we think there is bitter, but in reality  
96 there are atoms and a void."

97 **Table 2: Integrated STEM infusions**

Cross-disciplinary changes	humanistic STEM module titles
	add alchemy videos in two discussion prompts
	embed quotes from philosopher scientists into overview/wrap-up for each module
Interdisciplinary changes	add video on the math used in chemistry
	edit two discussion prompts to include technology and engineering perspectives
	add video on interdisciplinary applications of specific chemistry content

98

### 99 *Measuring Impact*

100 The impact of these interventions on student perceptions of course connections was measured by adding customized  
101 end of course evaluation questions. Using a 5-point Likert scale, respondents were asked to state their level of  
102 agreement with the following statements:

- 103
- This course made clear connections between science, technology, engineering, and/or mathematics.

- 104 • This course made clear connections between science and non-science topics and issues, like art, history,
- 105 and the humanities.
- 106 • This course made clear connections between science and the world around me.
- 107 • This course has widened my perceptions of how science connects to other courses in my degree program.

108 The surveys were completed anonymously; all data were aggregated with no individual identifiers. The Institutional  
 109 Review Board deemed this study exempt, therefore informed consent was not obtained.

110 As an additional measure of impact, student final course grades were collected for the terms studied. Data was  
 111 collected after conclusion of the courses and was provided to the researchers in aggregate with personal identifiers  
 112 removed.

113 **Statistical Analysis**

114 Cross sectional survey research was used to evaluate student perceptions on if the course made a clear connection to  
 115 STEM fields, Humanities, the world around them and how science connects to other courses in their degree  
 116 program. Students did not realize that they were involved in a research study avoiding any “John Henry or  
 117 Hawthorne” effect. A total of 59 student survey responses were examined. All data were viewed as nominal and  
 118 evaluated using the appropriate  $\chi^2$  (chi-square) test using StatDisk 13. Although a 5 point Likert scale was used, the  
 119 “Strongly Agree” and “Agree” answers were grouped into the “Agree” category. “Neutral”, “Disagree” and  
 120 “Strongly Disagree” answers were grouped into the “Disagree” category. Since all four questions involved science  
 121 and student’s perception of science, a Bonferroni corrected alpha was used ( $\alpha = .0125$ ) (Gay et al. 2006).

122 Final course grades between the pre-intervention and post-intervention groups were compared using an independent  
 123 samples t-test.

124 **Results & Discussion**

125 The four research questions were evaluated using two different Chi-square tests (Table 3). Pre and post intervention  
 126 data were examined using a Chi-square goodness-of-fit test for each question. Pre and post-intervention perceptions  
 127 were also evaluated using Chi-square contingency tables to test for a difference of proportions.

128 **Table 3. Survey Results: Pre and Post-Treatment**

	Pre Treatment				Post-treatment				Pre and post treatment comparison	
	Agree	Disagree	$\chi^2$	p	Agree	Disagree	$\chi^2$	p	$\chi^2$	p
Clear connections between science, technology, engineering and mathematics	31 (89%)	4 (11%)	20.829	<.001*	23 (96%)	1 (4%)	20.167	<.001*	.968	.325
Clear connections between science and non-science topic and issues such as art, history and the humanities	26 (74%)	9 (26%)	8.257	.004*	21 (88%)	3 (12%)	13.5	<.001*	1.534	.216
Clear connections between science	33 (94%)	2 (6%)	27.457	<.001*	23 (96%)	1 (4%)	20.167	<.001*	.071	.79

and the world around them										
Widened their perceptions of how science connects to other courses in their degree program	30 (86%)	5 (14%)	17.857	<.001*	20 (84%)	4 (16%)	10.667	.001*	.062	.803

129 *Note:* p values identified with an asterisk are statistically significant using a Bonferroni corrected alpha ( $\alpha = .0125$ ).  
130 Percent values shown are rounded to the nearest whole number.

131 Significantly more students agreed than disagreed that the course made a clear connection to STEM fields,  
132 Humanities, the world around them, and improved their understanding of how science connects to other courses in  
133 their degree programs. This was evident in both traditional (pre-intervention) and interdisciplinary (post-  
134 intervention) methods. The changes making the course more interdisciplinary appeared to be just as successful at  
135 making these connections as the course with fewer disciplinary infusions.

136 While the difference between pre-intervention (traditional) and post-intervention (interdisciplinary) were  
137 not statistically different from each other, the positive movement on first two measures is encouraging. STEM  
138 discipline connectedness moved from 88.6% agreement pre-intervention to 95.8% post-intervention. STEM and  
139 humanities connectedness moved from 74.3% to 87.5% post-intervention. The intervention in this study used a  
140 small-scale cross-disciplinary infusion of perspectives. It is possible that with further course modifications to  
141 emphasize humanities disciplines, a statistically significant change in student perceptions could be seen here. Real-  
142 world connectedness was already very high, at 94.3%, leaving very little room for a statistically significant impact  
143 of an intervention.

144 Final course grades were compared between the pre-intervention (mean = 72.31) and post-intervention  
145 (mean = 70.39) groups. With a t Stat of 0.36 (df = 70, P = 0.72), the difference between the two groups is not  
146 statistically significant. The infusions did not statistically influence student content mastery as measured through  
147 final course grades, which is a desirable outcome because the small infusions did not interfere with the learning of  
148 the chemistry concepts.

149 Several key limitations of this study influence must be analyzed. A primary limitation of this survey is  
150 sample size. This pilot study was performed to ensure that an infusion of cross-disciplinary perspectives would not  
151 negatively impact student perceptions prior to a larger scale investigation of the student impacts on this type of  
152 intervention. A second limitation is nonresponse error. While census data was sought, survey completion was not  
153 mandatory nor was it incentivized, resulting in a response rate ranging from 57.1% - 83.3%. Voluntary survey  
154 responses can introduce bias, with over-representation of strong opinions, both positive and negative. This limitation  
155 is challenging to overcome in survey research, but due to the benign nature of the questions, is unlikely to have  
156 significantly impacted results.

## 157 **Conclusions**

158 In this study, the data supported the idea of infusing interdisciplinary perspectives in an introductory chemistry  
159 course. It can be argued that we live in a very interdisciplinary world yet our academic courses are structured along  
160 strict disciplinary lines. One would think an interdisciplinary approach would better prepare our students to  
161 understand the world around them and effectively work with people who have different backgrounds and  
162 disciplines.

163 Aligned with design-based research, future work will ramp up the presence of humanities perspective in the  
164 course to see if a stronger infusion can achieve statistically significant results. In the next iteration, validated  
165 instruments to measure student attitudes will be used (e.g. learning attitudes about science (Adams et al. 2006)) and  
166 data collection will include assessment of content mastery with and without infusions.

167 **Ethical Approval:** All procedures performed in studies involving human participants were in accordance with the  
168 ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later  
169 amendments or comparable ethical standards.

170 **Informed Consent:** The research was deemed exempt, therefore informed consent was not obtained.

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