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High school student and teacher perceptions of an online learning experience integrating STEM and poultry science

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Abstract

Recent policy reports have demanded more effective education resources to support workforce needs and address deficiencies in STEM and agricultural literacy among U.S. citizens. This research assessed an educational program for secondary students contextualizing STEM education within poultry science. We designed seven 30-minute online modules to be integrated into existing agriculture and biology courses. Module content included basic hen management and welfare principles presented through text, videos, and interactive games. Participants were 499 students in 23 classrooms who used the modules in the Fall 2018 semester and served as a single treatment group in a mixed-methods study assessing program effectiveness. After the program, students completed an online questionnaire assessing motivation during the program. In addition, students completed ten 1-point content questions before and after the first six modules. Following the program, teachers responded to open-ended prompts. After excluding incomplete entries, data were analyzed from 169 student responses matched from pre- to post-questionnaire (34.1%) and 9 teacher respondents (56.2%). For each of the six content quizzes, significant increases in students' knowledge were observed after completing the modules. Students reported low to moderate interest and enjoyment in the modules and moderate perceived autonomy. Qualitative responses from both students and teachers indicated that the program's contextualization of STEM and interactive features enhanced student learning and interest.

Keywords: agricultural literacy; contextualized learning; integrated STEM; K-12; poultry

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Introduction

The Midwest poultry industry, like other agriculture industries, is facing heightened employment demands and a shortage of qualified candidates interested in filling career openings (U.S. Poultry & Egg). Table 1 illustrates the dismal interest in poultry careers among graduates of everal Midwest institutions in top egg-producing states.

Table 1

Undergraduate program coordinators' estimates of the number of graduates from their institution entering the poultry industry after graduation for several prominent Midwest animal sciences programs.

State	University	# of graduates who fill a job in poultry industry	Annual poultry jobs available for college graduates[1]
Iowa	Iowa State University	5	8,000 – 10,000
Indiana	Purdue University	2	
Ohio	Ohio State University	10	

[1]Annual poultry career availability was estimated based on the 2012 USDA Census of Agriculture Highlights and the U.S. Poultry and Egg Association Poultry Feeds America publication.

Specifically, the poultry workforce pipeline is acutely deficient in Indiana. Nationally, Indiana ranks first in duck production, second in egg production, and fourth in turkey production (USDA NASS, 2012). Poultry producers and processors directly contribute $4.25 billion to Indiana's economy annually and employ over 7,000 Hoosiers (USDA, 2012). Supported by advances in technology, the poultry industry continues to grow and change rapidly. Now more than ever, the industry occupies a scientific and technological space, with efficient production hinging on the coordination of both biological and engineered systems (Boyd, 2001). As commercial poultry production grows, the industry is also taking on greater agency in addressing societal concerns. Poultry industry affiliates make decisions with increasingly complex ethical implications at the intersection of efficient production, animal welfare, sustainability, and occupational safety (Kunzmann & Germany, 2011). To keep pace with projected growth in this ever-changing landscape, the poultry industry needs socially conscious employees with tractable STEM expertise.

Like many other developing industries, the poultry industry needs not only more STEM expertise, but also different types of it. As science and technology continue to transform ways of living and working, STEM expertise is in great demand. STEM professionals currently compose 20% of the U.S. workforce and the need for STEM-trained college graduates is predicted to continue to expand (PCAST, 2012). In agriculture, approximately 27% of annual career openings for college graduates require STEM expertise (Goecker et al., 2016). Still, it is clear that STEM expertise—in its traditional, intradisciplinary sense—is a necessary but insufficient for success in the modern workforce. The modern, technology-integrated society requires new, interdisciplinary and transdisciplinary forms of STEM expertise (Kelley & Knowles, 2016).

Researchers and policymakers began to call for STEM educational reform with more intensity in the 1980s when reports such as "A Nation at Risk" (NCEE, 1983) showed the U.S.

falling behind in STEM skill development compared to other developed nations. In subsequent decades, educational reformers began piecing together a conceptual model for "integrated STEM" learning (Ostler, 2012). Integrated STEM learning involves synthesizing concepts from multiple STEM domains through application to real-world contexts (NRC, 2014). Research suggests that integrated STEM learning has the potential to create more robust, durable forms of STEM expertise (Deming & Noray, 2015; Wang & Knobloch, 2018). Integrated STEM offers the additional benefit of offering opportunities to enhance early exposure to careers. Because integrated STEM learning must base problems in realistic contexts, educators can select and personalize contexts that are relevant to students' employability needs (Ostler, 2012; Wang & Knobloch, 2018). Preliminary work shows promise that providing high school youth opportunities and exposure within target disciplines can support the pipeline of graduates interested in pursuing related careers (Feller, 2011; Scherer, 2016) and learning academic knowledge and skills in career-oriented contexts increases high school students' academic performances (Park et al., 2017).

With its abundance of STEM career tracks, ubiquitous relevance, and conceptual richness, agriculture can serve as an ideal context for career-oriented integrated STEM programs (NRC, 2014). However, research on integrated STEM contextualized in agriculture (hereafter referred to as integrated STEM-Ag) is emerging, with limited empirical evidence extant (Pauley & McKim, 2019). Few studies document coordinated efforts to implement programs in high school classrooms (Blickenstaff, 2005; Chumbley et al., 2015; Stubbs & Myers, 2015). As nationwide efforts shift K-12 education toward integrated STEM instruction methods, more research is needed to refine this approach (NRC, 2014).

The present study examined an online learning experience contextualizing STEM within poultry science and designed to increase Indiana high school students' awareness of the poultry industry. To support students in developing interdisciplinary expertise, the program contextualized STEM within real-world poultry management and welfare issues. As such, STEM learning in our program not only served state and national educational needs, but also occurred within a context relevant to societal concerns and students' career training needs online program was designed to bring students into learning with the community of the poultry industry while circumventing the biosecurity issues associated with bringing visitors onto poultry farms. This study examined an online learning experience contextualizing STEM within poultry science and designed to increase Indiana high school students' awareness of the poultry industry. The online learning experience assessed was part of a larger initiative addressing poultry workforce pipeline issues by increasing Indiana high school students' exposure to related educational and career opportunities. Through the development, assessment, refinement, and reporting of this program, we sought to address national and statewide educational needs and contribute to the literature on integrated STEM-Agriculture efforts.

Theoretical Framework

This study focused on developments in declarative knowledge, motivation, and self-efficacy associated with an integrated STEM-poultry experience. Poultry science knowledge was understood, through Krathwohl's (2002) taxonomy, as factual knowledge of terminology and specific details. Krathwohl's (2002) revision of Benjamin Bloom's (1956) famous taxonomy of educational objectives expands the framework into two dimensions, encapsulating both knowledge and the associated cognitive processes.

To consider the motivational aspects of the program, we adopted a self-determination theory (SDT) perspective (Deci & Ryan, 1985). Ryan and Deci (2000) suggest that self-determined motivational states, in which interest and personal identification drive behavior, precipitate the development of trait-like predispositions to re-engage with a particular subject area. Because a long-term goal of our program was to enhance students' interest and identification with STEM and poultry science, we evaluated components of their intrinsic motivation during the program including interest, enjoyment, relevance, and perceived autonomy (Ryan & Deci, 2000). Although relatedness is a central component of intrinsic motivation, it was not a target outcome of our online program and was not a focus of our study. Additionally, in keeping with Sweet, Fortier, Strachan, and Blanchard (2012), we integrated self-determination theory with elements of self-efficacy theory (SET) to design and evaluate our program (Bandura, 1989). According to Bandura (1997), self-efficacy is a task-specific belief in one's own ability that predicts motivation and performance. Sweet et al. (2012) and other recent studies (e.g. Thøgersen-Ntoumani & Ntoumanis, 2006) have provided empirical and conceptual support for combining SDT and SET constructs into a single, comprehensive motivational model. Our study thus sought to understand components of motivation from a holistic, SDT- and SET-based interpretive lens.

Purpose and Objectives

The purpose of this study was to explore and describe the perceptions of high school students and teachers involved in an online integrated STEM learning experience using the context of poultry science. The following objectives guided our research:

1. Describe student declarative knowledge based on content quiz performance before and after completing each module.
2. Describe student motivation during the program in terms of perceived interest, enjoyment, relevance, and autonomy.
3. Explore teacher and student perceptions of program effects on students' STEM-learning and STEM motivation.
4. Explore differences in student motivation and declarative knowledge gains during the program among demographic groups.

Method

Instructional Design

Robinson, Westfall-Rudd, Drape, and Scherer (2018) introduced a framework to assist the integration of STEM within agriculture instruction. The authors identified five characteristics of integrated STEM education: "(1) Instruction integrates two or more subject areas within a context; (2) Students' work should be practical and/or authentic; (3) Intentionally target critical thinking and problem-solving skill development; (4) Learning is student-centered; (5) Technology is regularly used" (p. 255). To support the development of employability skills, career motivation, and content proficiency, we designed seven online modules using principles of integrated STEM-agriculture education. The following is a summary of each characteristic's incorporation into the program design.

Authentic, Problem-Based Learning. The online modules in our program incorporated science, technology, engineering, and mathematics within the context of real-world poultry science and laying hen management challenges. Context can enhance the meaningfulness and relevance of concepts for students (Knobloch, 2003; Nathan, et al., 1992). Compared with traditional instruction, learning in context can improve recall and transferability of knowledge (Driscoll, 2005; Hmelo-Silver, 2004). Integrating STEM within the context of agriculture can result in more efficient learning and deeper understanding of STEM concepts (Drake & Burns, 2004; Krathwohl, 2002). In our program, we incorporated STEM learning in practical poultry science topics including physiology, welfare, and facility design (see Table 2). Our objective was to create interest by providing students authentic problems requiring scaffolded STEM learning to advance students' knowledge of poultry science. For example, through the program, students played the role of poultry farm manager to calculate a facility's manure production in terms of annual tons, convert it to tons of nutrients, and determine appropriate manure application rates for crop production.

Table 2.

Overview of STEM-Poultry Program Content.

Module	Content
1	Introduction to the Table Egg Industry
2	Laying Hen Anatomy, Physiology, and Biology
3	Introduction to Animal Welfare
4	Laying Hen Management
5	Industry Technologies
6	Egg Processing

We targeted critical thinking and problem-solving skills through problem-based learning. Studies have shown that problem-based learning (PBL) increases employability skills such as problem-solving skills, communication skills, critical thinking skills, and adaptability (Albanese & Mitchell, 1993; Hmelo-Silver, 1998; Koray, et al., 2008). Although a variety of methods can be described as "problem-based," PBL can be defined as allowing students to self-direct their learning by working through scenarios with authentic, loosely structured problems (Savery & Duffy, 1995). Four of the seven online modules included an interactive simulation game that involved students in making management decisions and addressing issues for a poultry facility. Although the simulation game provided background information for each scenario, students were responsible for finding needed information and using it to create their own solution. For example, one module posed learners with poultry health issues related to facility design. Students learned pathology and welfare concepts to recommend and defend their solutions.

Learner-Centered, Motivating Instruction

Principles of learner-centered instruction served as the basis for module design. With problem-based, self-directed learning, learner motivation is key to success (Harun et al., 2012). We used the design framework of the ARCS motivation model to enhance learner motivation (Keller, 1987; Table 3). Many online and blended courses have based their design and assessment on the ARCS model (Keller & Suzuki, 2004). It centers on maximizing four components of motivation: attention, relevance, confidence, and satisfaction. The modules for this study employ tactics such as performance feedback, varied delivery, and localization to support the four motivation components of the ARCS model.

Table 3.

Sample Module Content: Laying Hen Anatomy, Physiology, and Biology

Section	Content	Features
1	Welcome	Text
2	Introduction Video	Video
3	Reproduction Introduction	Text
4	Hen Laying Cycle	Interactive chart
5	External Anatomy	Interactive diagram
6-7	Reproductive Tract Anatomy	Interactive diagram
8	Anatomy of the Egg	Interactive diagram
9-10	Development of the Egg	Interactive text slides
11	Egg Abnormalities	Interactive text slides
12	Factors of Stress in Poultry	Dialog with character
13	Stress Video	Video
14	Your Thoughts	Open-ended response
15	Better Egg Production	Pictures and character dialog
16	Genetics and the Environment	Pictures and character dialog
17	Your Thoughts	Written case study
18	Careers to Consider	Career interview video
19	Your Thoughts	Open-ended response
20	Selective Breeding	Dialog with character
21	A Hen for Each Environment	3D video
22	Improvements in Science	Interactive text slides
23	Test Your Knowledge	Drag and drop activity

To create a sense of inquiry and hold students' attention, the modules included intriguing discrepancies throughout multiple self-paced scenarios. For example, in one scenario, students responded to a sudden decrease in egg production. Students' sense of relevance was supported by the localization of content. All videos within the modules took place at Indiana poultry facilities and featured Hoosiers with careers in the poultry industry. Demonstrating the utility of content proficiency to students' career goals further served to increase the modules' perceived relevance to students (Frymier & Shulman, 1995). Finally, we supported student confidence and satisfaction through enactive mastery experiences with consistent rewards (Bandura, 1989). As students were guided through problems successfully, animated characters announced students' scores and provided encouragement.

In addition to utilizing the ARCS model for instructional design, the modules were designed to build on students' prior knowledge and prompt reflection. At various checkpoints, learners received reflection prompts and wrote several paragraphs summarizing the meaningfulness of the content. Reflecting on contextualized learning can improve self-regulated learning skills such as metacognition (Meyer & Turner, 2002). Three to five suggested prompts were also provided to teachers to facilitate discussion following the modules, although we did not design assessment to confirm their application in classrooms.

Incorporation of Technology

Robinson and colleagues (2018) suggested that technology be incorporated in integrated STEM teaching in terms of both content and content delivery. Our program content highlighted technologies used for facility management including climate control, manure management, egg collection, and egg processing. Students encountered content primarily through the program's online platform, which required students to interact with simulations of industry technology interfaces.

Population and Participants

Indiana high school teachers of junior- and senior-level agriculture and biology during the fall 2018 semester formed the population for this study. We selected a convenience sample, placing no limits on the number of enrollees. We recruited teachers with word of mouth, social media, and email listservs. A total of 16 schools enrolled in the study, resulting in participation of 499 students in 23 classrooms. Class sizes varied substantially but averaged 21 students (s = 11.14). Data were not collected for students who did not provide assent or parental consent, and those who failed to complete the post-questionnaire. In total, we matched 169 complete responses from students for pre- and post-questionnaires, representing a 34.1% response rate. Demographic information of the 169 respondents is summarized in Table 4.

Table 4

*Profile of Poultry Modules student respondents (*N *=169).*

		n	%
Gender	Female	68	40.2
	Male	96	56.8
	Non-Binary/Not Specified	5	3.0
Year in School	Freshman	47	27.8
	Sophomore	43	25.4
	Junior	22	13.0
	Senior	57	33.7
Community	Rural	48	57.4
	Urban	120	42.6
Course Type	Biology	48	28.6
	Agriculture	120	71.4

Study Design

The university institutional review board supervised all study procedures. We studied motivational variables using a quantitative single group pre-test, post-test design. Students completed the pre-questionnaire immediately prior to using the modules and both students and teachers completed post-questionnaires upon completion of the final module and within 16 weeks of starting the program.

Although quantitative survey data was the dominant basis for inference, we also collected qualitative responses from teachers and students in the post-survey and through a teacher focus group. We embedded qualitative data collection with the intent of explaining and extending upon quantitative conclusions (Plano Clark et al., 2008). Following quantitative analysis, we triangulated quantitative results with qualitative data to verify quantitative inferences and explore explanatory themes.

We assessed changes in students' declarative poultry knowledge with a series of multiple-choice quizzes taken immediately prior to and immediately following each module. panel of Poultry experts including faculty, Cooperative Extension specialists, and industry representatives contributed to content quiz development. The expert panel evaluated the face and content validity of the modules and quizzes and assisted with making necessary changes to ensure the modules and timeframe provided an appropriate context for developing poultry skills.

Instrumentation

We administered student and teacher surveys online using Qualtrics and required responses for each question before advancing (Qualtrics, Provo, UT). The student pre-questionnaire included basic demographic information. The post-questionnaire comprised items on motivation during the learning experience from Deci and Ryan's Intrinsic Motivation Inventory and open-ended questions on self-efficacy and experience with the modules (Ryan, 1982). Although the validity of the IMI was first established in laboratory settings (McAuley et al., 1989), it has since been documented as stable in classroom settings (Cortright et al., 2013; Leng et al., 2010). We selected items from interest/enjoyment, value/usefulness, and perceived choice (autonomy) subscales to construct a scale similar to the "Activity Perceptions Questionnaire" used by Deci, Eghrari, Patrick, and Leone (1994). Raw Cronbach's alphas for our sample were 0.94, 0.96, and 0.82 for the interest/enjoyment, value/usefulness, and perceived choice subscales, respectively, indicating strong internal consistency of the measure (Tavakol & Dennick, 2011). A panel of poultry industry representatives and poultry science faculty reviewed content quizzes to establish their face and content validity.

Teacher Focus Group

Within one week of the end of the program, teachers involved in the program gathered for a focus group. A trained facilitator used semi-structured prompts related to program design features to lead discussion among three teachers in attendance. Specifically, focus group prompts focused on verifying and expanding upon phenomena observed in the teacher post-questionnaire. We audio recorded focus group responses and subsequently transcribed them verbatim using an online service (Verbal Ink, Ubiqus).

Quantitative Analysis

We completed all analyses using SAS software (SAS Institute, Inc., Cary, NC). After verifying the normality of data, we computed summary statistics. Next, we completed paired t-tests to assess differences in interest and self-efficacy before and after the online learning experience. Then, we completed multivariate and univariate analysis of variance to detect fixed effects of gender, community type, high school classification, course type, and teacher. For all analyses, we declared significance at $p < 0.05$.

Qualitative Analysis

The study's qualitative phase utilized a descriptive approach involving minimal interpretation of data (Sandelowski, 2000). Two of the researchers coded qualitative responses from student and teacher post-surveys and the teacher focus group using the procedures for thematic analysis established by Braun and Clarke (2006). We achieved intercoder agreement through the collaborative coding procedure described by Richards and Hemphill (2018). In brief, we used descriptive open coding to identify themes repeated in the text. Then, we grouped selected quotes representing each theme into emergent categories that related to the study's theoretical framework. We then further refined theoretical categories based on commonalities (Auerbach & Silverstein, 2003).

Rigor and Trustworthiness

We used a number of criteria to ensure quality in our data collection and interpretation. First, we ensured credibility by utilizing well-tested research methods, gaining familiarity with participants, triangulating between qualitative and quantitative results, incorporating peer scrutiny and negative case analysis, and framing findings using prior research (Morrow, 2005). To ensure dependability, we used overlapping methods which we describe in detail in this manuscript. We addressed confirmability by describing characteristics of investigators and research methods in detail and enumerating the limitations we observed. Finally, we provided background data on student, school, and program characteristics to enhance transferability. As Shenton (2004) suggests, we leave the final decision on the transferability of various aspects of our study to readers, who have knowledge of the particular situations to which findings might be generalizable.

Results

Quantitative Results

Objective 1: Compare student performance on content quizzes before and after completing each module. Average student scores on 10-point content quizzes before and after completing each module are presented in Table 5. For all modules, average scores were significantly higher in the post-test compared with the pre-test. Cohen's *d* indicated medium to large effect sizes for the increase in content knowledge following each module except Module 5 (Hill et al., 2008).

Table 5

Paired t-test comparison of mean student scores on 10-point content quizzes before and after each module. N = *169.*

Module	M-Pre	M-Post	*t*	*df*	*p*	*d*
1	4.28	6.25	10.41	168	<0.0001	0.80
2	3.02	4.95	10.03		<0.0001	0.77
3	5.92	7.27	8.16		<0.0001	0.63
4	4.58	5.69	6.53		<0.0001	0.50
5	3.89	4.94	5.85		<0.0001	0.45
6	4.66	6.41	8.65		<0.0001	0.67

Objective 2: Describe student motivation during the program in terms of perceived interest, enjoyment, relevance, and autonomy. Table 6 presents students' self-reported intrinsic motivation in the program. We assessed motivation variables using items from Deci and Ryan's Intrinsic Motivation Inventory (IMI). On the interest and enjoyment subscale—considered a direct

measure of intrinsic motivation—students exhibited low ratings and were not interested and did not enjoy the learning experience. Students experienced low-moderate autonomy during the program, as low-moderate ratings on the perceived choice scale demonstrate. Perceived choice is a contextual factor that predicts intrinsic motivation (Ryan, 1982). Students did not see the value and usefulness of the learning experience. This subscale has been used in internalization studies (e.g., Deci et al., 1994) to predict the development of intrinsic motivation towards specific tasks.

Table 6

Student Intrinsic Motivation in Program.

Subscale	n	M[1]
Interest and Enjoyment	169	2.87 ± 0.11
Value and Usefulness		2.89 ± 0.12
Choice		3.82 ± 0.11

[1]Average of Likert scale ratings from (1 – "strongly disagree" to 7 – "strongly agree") on Intrinsic Motivation Inventory (IMI) items in post-survey ± SEM.

Objective 3: Explore teacher and student perceptions of program effects on students' STEM-learning, 21st-century skills, and STEM motivation. Table 7 summarizes teacher perceptions of the effectiveness of the program. Teachers appeared to perceive the program as moderately effective as a STEM learning resource—with variation apparent in their post-survey perceptions of the program's effects on student STEM learning. The teachers agreed the program helped their students "learn STEM concepts and skills" and made their "students more aware of careers in STEM."

Table 7

Teacher perceptions of program effectiveness as an integrated STEM learning resource. N = *7.*

Item	M[1]	SD
It helped me improve my instruction of STEM concepts and skills.	4.14	1.64
It helped me support development of skills that will make my students successful in college and the workplace.	4.43	0.73
It helped my students learn STEM concepts and skills.	5.14	1.81
It made STEM learning fun for my students.	4.29	1.03
It made my students more aware of careers in STEM.	5.29	1.16

[1]Average of Likert scale ratings from (1 – "strongly disagree" to 7 – "strongly agree")

Objective 4: Explore differences in student motivation during the program among demographic groups. After verifying normality and the homogeneity of variance across groups, we analyzed data using multivariate and univariate factorial ANOVA. First, we tested a multivariate factorial model including gender, community type, year in school, course type, and teacher as predictor variables and content knowledge gains/losses in each module as dependent variables. We found a significant association between teacher and content knowledge gains/losses, $F(66, 776) = 2.07$ ($p < 0.0001$), indicating significant differences in content knowledge gains between teachers. We discovered no significant associations for other predictor variables (p > 0.05).

Next, we conducted a series of three factorial ANOVAs, using each Intrinsic Motivation Inventory subscale as a dependent variable and testing the predictor variables outlined above (Table 8). Partial eta squared (η_p^2) effect size is reported for each test (Richardson, 2011). The teacher significantly predicted both student value/usefulness ratings and student ratings of perceived choice, indicating that differing teachers explained a significant proportion of the variance in student ratings in both scales. For all Intrinsic Motivation Inventory (IMI) subscales, η_p^2 of teacher approached or exceeded Cohen's criteria for moderate effect size (Cohen, 1988). For the 12 teachers, least squares means (LSM ± SEM) of student ratings of program value/usefulness ranged from 1.82 ± 0.52 to 4.75 ± 0.68, and of perceived choice from 2.75 ± 0.47 to 5.48 ± 0.62. We discovered no significant effects on interest/enjoyment, value/usefulness, or choice ratings for other independent variables (p > 0.05). We did not test interaction effects because sample size and statistical power were insufficient to detect differences (Heo & Leon, 2009).

Table 8

*Univariate results for gender, community type, year in school, course type, and teacher effects on student Intrinsic Motivation Inventory (IMI) subscale ratings (*n = *169).*

Independent Variable	*Dependent Variable*	*df*	*MS*	*F*	*p*	η_p^2
Gender	Interest/Enjoyment	2	1.00	0.59	0.55	0.0080
	Value/Usefulness		0.78	0.43	0.66	0.0059
	Choice		1.38	0.92	0.40	0.0124
Community Type (Rural vs. Urban)	Interest/Enjoyment	1	1.07	0.63	0.43	0.0043
	Value/Usefulness		2.91	1.62	0.21	0.0109
	Choice		2.69	1.80	0.18	0.0121
Year in School	Interest/Enjoyment	3	1.73	1.03	0.38	0.0206
	Value/Usefulness		0.97	0.54	0.66	0.0109
	Choice		3.42	2.29	0.08	0.0446
Course Type (Biology vs. Ag)	Interest/Enjoyment	1	1.69	1.01	0.32	0.0068
	Value/Usefulness		0.46	0.26	0.61	0.0017
	Choice		0.34	0.22	0.63	0.0015
Teacher	Interest/Enjoyment	11	2.90	1.72	0.073	0.1143
	Value/Usefulness		3.97	2.21	0.017	0.1419
	Choice		3.76	2.52	0.006	0.1584

Qualitative Results

Selected quotes from program participants represent each theme that emerged in qualitative analysis. Unless indicated with the word "TEACHER," statements are from student participants.

Theme 1: Interest in poultry determines science learning motivation during program. In many cases, participants commented that the program helped them better understand both STEM and agriculture as disciplines. In general, students reported experiencing more motivation towards science after the integrated learning experience helped them connect learning with realistic problems. The following student statements support this idea:

- "They made me want to learn science more in school."
- "It helped me understand the process of ag and how the body works for chickens. This has helped me with understanding more of the science terms and functions of the body."
- "I have become more energized and motivated to learn in my science class."
- "It has made me be able to comprehend more material I learn in class."
- "I now know the different fields of science and am now more convinced that I want to major in science."

Although students reacted positively to the learning experience as a whole, several students commented that they would have preferred learning science independent of the poultry science context. For example:

- "…we are only learning about chickens compared to general sciences where I would feel like I absorbed a lot more useful information."
- "I don't really think that learning about chickens is teaching me very much useful science knowledge."

Teacher focus group participants and survey respondents indicated that more in-depth STEM content would have made the program a better use of class time. Although the program aligned with selected high school course standards, teachers mentioned a need for more STEM integrated within the subject.

Theme 2: Program expands views of scope and applications of STEM.

- "It shows the things I learn in school can be applied to different industries."
- "The poultry modules affect how well I learn science in school because it shows me many different fields of science."
- "It has helped me understand the process of ag and how the body works for chickens. This has helped me with understanding more of the science terms and functions of the body."
- "The poultry modules helps [sic] students connect science they learn in school with a real life example of how it is used."
- "The poultry modules helped me learn that there is more to biology than most know."

Theme 3: Students had mixed perceived relevance of STEM-Poultry integration. The program's integration of STEM and poultry science content received contrasting reviews from both students and teachers. While some students and teachers commented that the integration made content more interesting and enjoyable, some students mentioned that poultry science was not relevant to their lives.

Student:

- "They helped me learn better and also helped me understand science better."
- "It made the topics easier to understand and enjoy a little more."
- "They allow students to get engaged and have fun with learning and it helped with better understanding the information."
- "I want to learn about science but not in poultry."

- "They did not affect my school learning because they are so far removed from anything else I am currently doing in my high school classes. On top of that, the topic is just not very interesting so I was not motivated to put a high amount of effort into it."
- "The modules are not useful to anyone unless they were already interested in poultry."

Theme 4: Students shared the program promoted critical thinking, self-regulated learning skills. Students mentioned developing reading, critical thinking, and study skills as a result of program participation. Several student statements alluded to developments in the holistic, systems thinking characteristic of reflective problem-solving (Reynolds, 2011). In addition, students spoke of developing self-regulated learning skills related to studying, reading, and writing (Zimmerman, 1996). Teachers confirmed that the program's incorporation of collaborative learning was successful, and cited STEM problem-solving as the source of critical-thinking skills.
Student:

- "It helped me not rely on the teacher."
- "[My confidence] has improved because I know how to look for important details."
- "It helped me expand my mind in science classes."
- "They make me a better reader."
- "It helps me learn how to study."
- "It takes it step by step and reflection questions help too. So in science classes I take it step by step and also reflect to see if I understand."
- "It affected how well I learn science in school by teaching me how to pay attention for a long period of time."
- "It affects the perspective of things I see."

Teacher:

- "All of the sudden, it was 'wait a minute, we've got to think a little bit more.'"
- "It offered the small group side of it – gave them the opportunity to talk to each other."
- "I think it definitely helped them with their critical thinking, especially some of the math problems."
- "…offered the small group side of it – gave them the opportunity to talk to each other."

Theme 5: Students felt more self-confident during program. For students, skill and knowledge acquisition was accompanied by increased self-efficacy. Importantly, students often mentioned confidence gains in a growth-oriented manner—referencing expending effort towards the modules as contributing to positive beliefs in their ability (Hochanadel & Finamore, 2015).
Student:

- "I wasn't really confident about the things I learnt [sic] before now, but the completion of the modules has given me more confidence in myself."
- "My confidence has increased because I know so much more."
- "It has made me more interested and confident in myself in learning agricultural science."
- "It has made me more confident because I can learn more if I try harder."
- "[The program] made me want to learn science more in school."

In contrast, teachers expressed some uncertainty related to their ability to facilitate program use in the classroom. "There was much more content in the [program] than what I normally teach," one teacher said. The majority of teachers had little to no expertise in or experience with poultry science. Another teacher commented: "I learned a lot during it, too. There were things that I normally don't teach about because I didn't know them."

Limitations

Several important factors limited our study. First, our study was limited by the short, semester-long timeframe of program implementation and data collection. We collected qualitative data at a single time point following the program and did not assess motivational variables during the program. Although we observed moderate to large effect sizes with regard to certain program effects, students took the pre-test and post-test immediate before and after completing each module, and the pre- and post-tests on motivation before and after the program. We were unable to follow-up with students longitudinally to determine the stability of program effects over time. Second, we assessed a small, convenience sample. We observed multiple schools, but we selected a sample of students in schools within a limited geographical region. Third, our study was limited by experimental design. Our single-group study design prevented causal inference from quantitative data (Cronbach, 1975). Content quizzes were also subject to certain testing effects such as habituation. However, the proximity of the experience relative to testing and participants' blindness to correct responses enhanced the internal validity of content quiz results. Finally, we assessed a novel program designed to create new forms of expertise. Although our program capitulated in a case study (Module 7) designed to test students' integrative STEM knowledge, we focused quantitative program assessment on declarative knowledge and motivational variables, which may not have captured the integrative learning taking place in the program. Integrative STEM skills are not straightforward to measure with traditional assessments, and few validated tools currently exist (Chamrat et al., 2019). As such, we relied on open-ended qualitative data to understand these effects on students.

Conclusions

Student ratings of program enjoyment and motivation were ambiguous. Moderate ratings on the perceived choice subscales of the intrinsic motivation inventory showed that the program provided students some of the necessary conditions to experience intrinsic motivation with program activities (Ryan, 1982). Lower ratings for the interest/enjoyment and value/usefulness IMI subscales, however, do not offer strong evidence that STEM motivation in the program might continue to develop through internalization processes. Deci and colleagues (1994) suggested that people are unlikely to internalize regulation (i.e., become intrinsically motivated) for activities or domains they do not consider valuable or useful to their lives. Internalization processes are necessary to dissociate motivation from external contingencies, allowing motivation to continue after rewards or consequences are removed (Deci et al., 1991). Based on our IMI results, it appears our instructional design effectively supported situational intrinsic motivation in the program's STEM learning activities. Evidence suggests that repeated or prolonged situational experiences of situational interest may contribute to the formation of longer-term interest and motivation (Hidi & Renninger, 2006). However, long-term interest maintenance requires an internalized value component—a condition that our program did not appear to produce (Linnenbrink-Garcia et al., 2010).

Preliminary studies have shown varying motivational effects of integrated STEM programs. Although many studies have associated integrated STEM experiences with positive effects on interest and motivation (e.g. High, Thomas, & Redmond., 2010; Monterastelli et al., 2011), Burghardt, Hecht, Russo, Lauckhardt, and Hacker (2010) documented decreased perceived relevance of mathematics in high school students after a STEM infusion curriculum. However, research connecting perceived relevance and interest to specific features of STEM program design is limited (NRC, 2014). In our study, student statements indicated that that program features, which enhanced their STEM motivation, did so by increasing their self-efficacy or broadening their views of the scope and applications of science. However, many students mentioned that the context did not make the usefulness of STEM more apparent. Best practices for communicating value to students or selecting culturally relevant contexts for STEM instruction are important topics for future research. Much more work needs to be done before intentionally designed programs can be implemented to effectively increase STEM career interest and persistence.

Qualitative data offered further evidence that the program students learned knowledge and understanding of STEM topics. Although we did not quantitatively measure developments in career readiness skills, students shared based on qualitative data that the program contributed to the development of skills such as critical thinking, self-regulated learning, problem-solving, and collaboration. Participants mentioned that our integrated STEM-learning program broadened students' understanding of both STEM and agricultural disciplines and the applicability of knowledge in each domain to careers and continued study. Although empirical work assessing soft skill development in integrated programs is limited, integrated approaches theoretically have great potential for supporting 21st-century skill development (Stohlmann et al., 2012). Morrison (2006) showed enhanced problem-solving and logical thinking with integrated STEM education. Our program's application of problem-based learning may also have contributed to 21st-century skill development (Qian & Clark, 2016).

Teacher, classroom, and school characteristics influenced students' overall experience with our program, as multivariate and univariate analyses of variance on motivation and declarative knowledge variables indicate. Importantly, teacher was the only significant predictor of program effects, though we tested course type (agriculture vs biology) and student variables such as gender, school year, and community (rural vs. urban). This finding has several implications for future efforts to promote STEM-Ag integration in high schools. First, it appears that STEM-Ag programs similar to ours can be effective across a diverse range of students of varying ages, genders, from various communities, and in various types of courses. However, the effectiveness of integrated STEM-Ag appears to depend greatly on teacher and school characteristics. As a consequence, selecting, training, and supporting teachers may be critical areas to consider in planning effective program implementation.

In our study, the qualitative data collected from teachers after the program provided preliminary insight into teacher-based effects. In our focus group and teacher survey, several teachers mentioned feeling uncomfortable with the program content. To our knowledge, our program is the first to contextualize integrated STEM instruction within poultry science. As a result, teachers had no experience with the program itself or similar experiences. More generally, our teacher participants had little experience with poultry science, poultry science teaching, and online learning. As a consequence, the implementation of our program was likely affected by teachers' low knowledge and low self-efficacy towards program content and teaching methods. Diefes-Dux (2015) demonstrated that teachers' conceptualization and classroom interpretation of integrated STEM instruction affected the learning experience they provided. According to Nadelson and colleagues (2012), teachers with more content knowledge and pedagogical content knowledge enhance the benefits of integrated STEM instruction for students.

Discussion and Recommendations

#1. Providing Advance Teacher Training Opportunities Can Assist Integrated STEM-Ag Implementation by Boosting Teachers' Confidence with Both Content and Teaching Methods

Historically, teachers' preparedness for STEM instruction has been a topic of contention. Many teachers lack authentic experience in STEM and consequently feel underprepared to teach (Nadelson et al., 2012). Successful integrated STEM instruction, according to Pang and Good (2000), depends largely on teachers' proficiency with subject matter. The inquiry-based approaches commonly used in integrated STEM instruction may present further difficulty for teachers. Constructivist pedagogies such as inquiry-based learning require a great deal more involvement and knowledge from teachers (Ejiwale, 2013). When implemented alongside novel integrated STEM methodologies, teachers may be overwhelmed by the requirements to successfully enact inquiry-based learning in the classroom (Nadelson et al., 2012).

Accordingly, Ejiwale (2013) suggests that successful integrated STEM implementation begin with robust teacher preparation. Teachers gain proficiency and self-efficacy as they become experienced with content and methods (Robinson & Edwards, 2012). In our study, we provided teachers a facilitator's guide, but did not offer in-person training for using the program. Although previews of module content were made available to teachers several months before the start of the semester, teachers did not have access to the final version of the program until implementing it in their classes. Providing teachers in our program more advance preparation for the program may have facilitated more effective classroom implementation and promoted teacher efficacy.

#2. Multi-School Integrated STEM-Ag Initiatives Can Achieve More Consistent, Durable Outcomes by Establishing Support Networks Among Teachers

In our program, we provided no structured opportunities for dialogue between teachers until after the program's conclusion. According to Stohlmann and colleagues (2012), teachers need not only proper preparation but also support throughout integrated STEM teaching programs. In their study, teachers held regular discussions to share ideas about teaching the lessons, which they reported helped them feel much more comfortable teaching. Future programs providing teachers more opportunities for collaboration may improve the program experience for both students and teachers.

#3. Supporting Successful Implementation of Hands-On Components May Be Critical to Engaging Students in Online-Based Integrated STEM-Ag Programs

Our program was online-based and suggested prompts for short 5-10-minute discussions following completion of the online activities. In their comments, both teachers and students expressed a desire for more discussion prompts and hands-on activities within programming. There is evidence that providing students more opportunities to discuss content, contemporary issues, and career possibilities can help teachers communicate the relevance of integrated STEM activities (Woolnough, 1994). High school students have developing conceptions of the types of expertise needed in the workplace, and discussion-based activities can often uncover their underlying assumptions and improve learning (Laughlin, et al., 2007). Activities with hands-on components have also been shown to improve students' attitudes towards STEM fields (Fouts & Myers, 1992). Evidence suggests that hands-on approaches may aid comprehension by offsetting the additional cognitive load incurred in the complex, multidisciplinary problem-solving that characterizes integrated STEM learning (Kontra, et al., 2015). Future integrated STEM programs may consider supporting teachers in implementing hands-on activities in the classroom by providing lesson plans and materials and following-up to ensure successful implementation (Stohlmann et al., 2012).

Summary

Integrated STEM-agriculture programs similar to our poultry science-based online learning program have potential to be effective and motivating STEM learning resources. However, more research is needed to understand how best to prepare teachers to assume the expanded role involved in integrated STEM instruction and support them throughout the process. Understanding teacher-related factors may be particularly important for programs that are online, multi-school, and those involving unfamiliar subjects. Further work is also needed to understand how to select and personalize agricultural contexts to communicate the relevance of integrated STEM content to students. Future studies considering both students' and teachers' experiences with integrated STEM learning programs can advance efforts to improve STEM learning and literacy outcomes in K-12 education to meet workforce development needs.

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