Investigating Science Efficacy Before and After a Professional Development Program focused on Genetics, Muscle Biology, Microbiology, and Nutrition

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Research Type: Quantitative

Research Priority Area: Teacher Education

Investigating Science Efficacy Before and After a Professional Development Program focused on Genetics, Muscle Biology, Microbiology, and Nutrition: A Case Study

Abstract

This study investigated teachers' levels of Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE) using the Science Teaching Efficacy Beliefs Instrument (STEBI). The population included 10 teachers completing an Increasing Scientific Literacy through Inquiry-Based Professional Development in Genetics, Muscle Biology, Microbiology, and Nutrition. Assessments were made at two points. First, the participants were assessed by using a pretest followed up by a posttest 12 months later after implementing the new curriculum. The teachers experienced gains during the professional development on both their personal science teaching efficacy and their science teaching outcome expectancy. However, the mean differences were not statistically significant. Results of this study indicate that the Increasing Scientific Literacy through Inquiry-Based Professional Development may be used as a tool to increase PSTE and STOE in agricultural educators and science teachers.

Introduction/Theoretical Framework

In the 2020-2021 school year, the Nebraska student-centered assessment in the area of science indicates that only 50% of high school students meet the science expectation (Nebraska Department of Education, 2022). The lack of science proficiency is not surprising given the statistics from 2017 indicating students' proficiency gradually decreases between 5th grade, 8th grade, and 11th grade (Nebraska Department of Education, 2017). In 2017, 28% of 5th graders were below proficient, 32% of 8th graders were below proficient, and 39% of 11th graders were below proficient (Nebraska Department of Education, 2017). Proficiency scores indicate that science efficacy needs to be addressed at all grade levels, but specifically at the high school level. Based on research and theory, it is determined that outcome expectancy (OE) and science efficacy (SE) are complementary factors in determining the success of teachers in a science-based classroom. (Stripling & Roberts, 2013)

Teacher self-efficacy relates to progressive teaching behaviors and positive student outcomes. Therefore, the social cognitive theory serves as the theoretical framework for this study. The social cognitive theory identifies the capabilities of humans, and their purposeful intentions, that can and will affect their course of action (Bandura, 1977, 1997). This process is called triadic reciprocal causation and was developed by Albert Bandura (1977, 1997). Triadic reciprocal causation suggests three interrelated factors that mutually impact people: environmental, behavioral, and personal factors (Bandura, 1977, 1997). These three factors determine what a person believes about themselves and aide in their decision-making process (Bandura, 1977, 1997). Triadic reciprocal causation advocates that no one single factor determines a person's behavior, instead, it is the combination of all three factors (Bandura, 1977, 1997). When determining OE and SE, behavior could be predicted (Bandura, 1997) and efficacy beliefs help dictate motivation (Maehr & Pintrich, 1997; Pintrich & Schunk, 1996). Self-efficacy theory helps outline what motivates a person (Graham & Weiner, 1996), and so, the theory can be applied to any behavioral task and predict what will take place.

In the teacher efficacy belief literature, two dimensions of teacher self-efficacy, including Teaching Efficacy (Outcome Expectancy) and Personal Teaching Efficacy (Self- Efficacy), have been defined and utilized in subsequent studies. Several studies suggest that teacher efficacy beliefs may account for individual differences in teacher effectiveness (Armor et al., 1976; Berman & McLaughlin, 1977; Brookover et al., 1978; Brophy & Evertson, 1981). Student achievement has also been shown to be significantly related to teacher efficacy beliefs (Ashton & Webb, 1983). The measurement of Personal Teaching Efficacy has been used to predict teacher behavior with accuracy (Ashton et al., 1983).

Teachers' content knowledge affects student learning (Ballou & Podgursky, 1999; Ma, 1999; Podgursky, 2005); therefore, science teachers are expected to be highly qualified in the subject area in which they teach. Not only do teachers need to have a high level of comprehension in the content area, but they also need to display passion and enthusiasm. Additionally, standardized tests, only prove that students can memorize and focus on the content because the performance goals measured only address low levels of learning (Meece et al., 2006).

Teacher self-efficacy has also been connected to beginner agriculture teachers' pledge to the teaching career (Knobloch & Whittington, 2003). Teaching efficacy is a more specific type of self-efficacy (Stripling & Roberts, 2013; Stripling et al., 2008), and is a teacher's belief in their competence to facilitate the learning environment and produce desired learning results (Guskey & Passaro, 1994; Soodak & Podell, 1996). Beginning teachers who are more efficacious tend to have a greater obligation to teaching than those who are not as efficacious and consequently are more motivated to remain in the teaching profession (Whittington et al., 2003). In fact, beginner teachers could have an exaggerated sense of self-efficacy because of their student teaching experience (Knobloch, 2006).

This professional development program utilized inquiry-based learning as the main instructional approach. There have been numerous studies that show inquiry-based learning is an effective method for teaching science (Keys & Bryan, 2001). Inquiry-based learning requires students to manage their own learning and their success will be based on their engagement in the lesson through active listening and problem solving. Inquiry-based learning opportunities provide the foundation for students to make observations, pose questions, compare evidence, predict outcomes, and communicate research results (National Research Council, 2000).

Purpose/Objectives

The purpose of this study was to determine the teachers' level of science efficacy in the agricultural education and science classrooms and compare the results as the teachers progressed through the yearlong professional development. The modified science teaching efficacy scale (based on Enochs & Riggs, 1990) consists of both personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE).

Objectives include:

1. Investigate secondary life science teachers' personal science teaching efficacy (PSTE) within the sciences before and after the Increasing Scientific Literacy through Inquiry-Based Professional Development in Genetics, Muscle Biology, Microbiology, and Nutrition.

2. Investigate secondary life science teachers' science teaching outcome expectancy (STOE) before and after the Increasing Scientific Literacy through

Inquiry-Based Professional Development in Genetics, Muscle Biology, Microbiology, and Nutrition.

Two null hypotheses were used to guide this inquiry:

H01: There is no significant difference in the personal science teaching efficacy (PSTE) of life science teachers before and after the Increasing Scientific Literacy through Inquiry-Based Professional Development in Genetics, Muscle Biology, Microbiology, and Nutrition treatment.

H02: There is no significant difference in the science teaching outcome expectancy (STOE) of life science teachers before and after the Increasing Scientific Literacy through Inquiry-Based Professional Development in Genetics, Muscle Biology, Microbiology, and Nutrition treatment.

Methods/Procedures

Professional Development

This professional development (PD) program provided an opportunity for high school agricultural education teachers and science teachers to participate in a 12-month long PD. Applicants were encouraged to join the program with both a science and agriculture teacher from their school. The purpose of this was to bridge the gap between agriculture and science disciplines. After applications were submitted, there were not enough paring entries from all the same schools, so science and agriculture teachers were coupled from different schools (N = 10). For this study, the participants will be referred to as life science teachers. Applicants were recruited in the Spring of 2017. The project was divided into three phases.

Phase I

The PD program began in summer 2017 with a one-day workshop that took place at three different locations throughout Nebraska. The workshop introduced information centered around how students learn, more specifically, experiential learning, short-term and long-term memory, Bloom's taxonomy, and learning styles. From there, the inquiry-based learning teaching method was introduced. All learning activities that were developed and used in this PD incorporated inquiry-based learning and allowed teachers to experience learning activities as students.

Basic scientific disciplines including biology, chemistry, and mathematics are interrelated in the growth and development of living beings. For this reason, scientific units of study that focused on the Scientific Principles of Food Animal Systems were developed. The following units were included:

1) Genetics
2) Growth & Development / Chemistry of Muscle Biology
3) Microbiology of Food Safety
4) Physiology and Chemistry of Nutrition

Each unit provided basic content knowledge, hands-on inquiry-based learning activities, and student reflection instruments. Content knowledge included educational videos and

PowerPoint slides that could be used to introduce high school students to the topic and provided the scientific basis of the topic and related activities. Instructional materials also included a listing of necessary supplies and equipment, ordering information, and easy-to-follow instructions. For those secondary life science educators that participated in the PD, selected supplies that would not normally be present in a typical high school science laboratory were provided to facilitate the small-group student learning activities.

Finally, through inquiry-based learning, it is imperative that high school students be asked to reflect upon what they've just learned; to evaluate the results and to project how those results might relate to new situations or scenarios (Kolb, 1984). To facilitate this final component of inquiry-based learning, instruments were developed to encourage high school students to reflect upon what they just learned and how that new knowledge may be applied to different situations in the future. Scientific principles related to genetics, muscle biology, microbiology, and nutrition were used to demonstrate a hands-on, inquiry-based learning pedagogy.

Phase II

The program continued throughout the 2017-2018 academic year. Conference calls through Zoom, a video conferencing platform, took place in August and December of 2017, and April of 2018. The calls were used to discuss how life science teachers were implementing the prescribed learning activities that focused on genetics, muscle biology, microbiology, and nutrition.

Phase III

Life science teachers were placed in small teams and asked to develop additional inquiry-based learning activities that were presented during the final PD session in June of 2018. Each team was assigned a specific unit (genetics, muscle biology, microbiology, or nutrition) to focus their efforts. The overall purpose of this activity was to help life science teachers learn how to develop their own inquiry-based learning activities and share their activities with a broader audience.

Data Collection

Quantitative methods were used to determine the change in teachers' science teaching efficacy by using a modified science teaching efficacy scale (based on Enochs & Riggs, 1990). The instrument used for data collection was created by Enochs and Riggs (1990) to measure the self-efficacy of science teachers, called the Science Teaching Efficacy Belief Instrument (STEBI). Additionally, the data collected for this study was part of a larger data set.

The STEBI consisted of 23 questions scaled from 1 (strongly disagree) to 5 (strongly agree). Terminology was adjusted by researchers to accommodate for high school teachers instead of preservice elementary science teachers. Example questions from Enochs and Riggs (1990) include "I will continually find better ways to teach science," "The inadequacy of a student's science background can be overcome by good teaching," "The low science achievement of some students cannot generally be blamed on their teachers," and "When a low achieving child progresses in science, it is usually due to extra attention given by the teacher."

The STEBI (Enochs & Riggs, 1990) is comprised of two scales that measure the constructs personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE). All items use a 5-point rating scale (1 = strongly disagree to 5 = strongly agree). The following item was modified from Enochs and Riggs (1990) by removing the word elementary: "I understand science concepts well enough to be effective in teaching elementary science."

Additionally, Enochs & Riggs (1990) stated reliability analysis produced Cronbach's alpha coefficients of .90 for PSTE and .76 for STOE. Post-hoc reliabilities for PSTE and STOE were .799 and .732, respectively. These measures of internal-consistency are acceptable given the nature of the constructs and present reliabilities on comparable measures (Ary et al., 2014).

Data Analysis

Data were analyzed using IBM SPSS version 20. Descriptive statistics (i.e., frequencies, percentages, and means) were used to describe the science teaching efficacy data. Additionally, based on Haynes and Stripling (2014) and Dossett et al. (2019), low, moderate, and high self-efficacy was defined as 1.00 to 2.33, 2.34 to 3.67, and 3.68 to 5, respectively. Data was summarized using descriptive statistics (i.e., frequencies, percentages, and means). Paired samples t-tests were utilized to determine if a significant difference existed in science teaching efficacy and outcome expectancy (OE).

The STEBI contains 23 items in the survey and 13 are designed to address science teachers' level of belief that they can teach science (Personal Science Teaching Efficacy or PSTE) and 10 assess the respondents' belief that their teaching will have a positive effect on the students they are teaching (Science Teaching Outcome Expectancy or STOE). Paired t-tests were run on the pre and post survey scores for the PD. The PSTE and STOE section, scores were analyzed separately. Therefore, all analyses of group mean differences were done as two tailed tests.

Results/Findings

The first and second objectives were to investigate the level of PSTE/STOE of the professional development participants before and after the PD. During the first phase of the study teachers reported before the PD, they had a mean personal science teaching efficacy (PSTE) score of 3.83 (SD = .27) and an outcome expectancy (OE) of 3.35 (SD = 0.48). The second phase conducted after the 12-month PD teachers reported an increase in both areas with a mean PSTE of 3.95 (SD = 0.33) and an OE of 3.47 (SD = 0.47).

Means and analysis results for the surveys are presented in Table 1 and Table 2. Analysis of surveys from the PD indicated no significant pre/post shifts on PSTE or STOE scores, however there were small actual mean differences.

Table 1

Personal Science Teaching Efficacy Scores

			Low		*Moderate*		*High*	
	M	*SD*	*f*	*%*	*f*	*%*	*f*	*%*
Pretest	3.83	0.27	0	0.0	3	30.0	7	70.0

			Low		*Moderate*		*High*	
	M	*SD*	*f*	*%*	*f*	*%*	*f*	*%*
Posttest	3.95	0.48	0	0.0	1	10.0	9	90.0

Note. 1.00 to 2.33 = *low efficacy*, 2.34 to 3.67 = *moderate efficacy*, 3.68 to 5 = *high efficacy*.

Table 2

Science Teaching Outcome Expectancy Scores

			Low		*Moderate*		*High*	
	M	*SD*	*f*	*%*	*f*	*%*	*f*	*%*
Pretest	3.35	0.48	0	0.0	6	60.0	4	40.0
Posttest	3.48	0.47	0	0.0	6	60.0	4	40.0

Note. 1.00 to 2.33 = *low efficacy*, 2.34 to 3.67 = *moderate efficacy*, 3.68 to 5 = *high efficacy*.

The mean differences between the pre and post teaching efficacy scores for PSTE and STOE are in Table 3. Analysis revealed a .11-point increase in PSTE, a .13-point increase in the STOE. However, the mean differences were not statistically significant. Thus, the null hypotheses were not rejected.

Table 3

Summary of Paired Samples t tests

	Mean difference	*SD*	*SE*	*t*	*p*
PSTE posttest – pretest	.11	.20	.06	1.79	.11
STOE posttest – pretest	.13	.51	.16	.79	.45

Conclusions/Recommendations/Implications

The purpose of administering the modified STEBI (based on Enochs & Riggs, 1990) was to investigate teachers' level of science efficacy in the agricultural education and science classrooms and compare the results as the teachers progressed through the professional development. Personal science teaching efficacy (PSTE) slightly increased from pre and posttest and science teacher outcome expectancy (STOE) also changed during the PD.

Analysis revealed a .11-point increase in PSTE, and a .13-point increase in STOE. However, the mean differences were not statistically significant. Thus, the null hypotheses were not rejected. Results of this study indicate that the Increasing Scientific Literacy through Inquiry-Based Professional Development program may be used as a tool to increase PSTE and STOE in life science teachers. Professional development opportunities focused on teaching science through inquiry-based learning could be a way to increase science efficacy (SE) and outcome expectancy (OE) over time. If professional development workshops could continually increase SE and OE, the SE and OE could be used to help determine teacher success in a science-based classroom, thus aligning with Stripling and Roberts' (2013) assertion that OE and SE can be used to determine teacher success. Teacher educators should purposefully design teacher professional development programs to allow teachers to practice their science teaching skills, thus providing an opportunity for the teacher to increase their SE and OE. To align with Kolb (1984), the professional development should be designed to have purposeful reflection activities that allows the teachers to critically examine their ability and confidence when teaching science concepts.

We found life science teachers in this study to be moderately efficacious in their ability to teach science concepts before and after the conclusion of the PD. However, 20% of the life science teachers in this study moved from moderate to high efficacy with PSTE. According to Bandura (1997), self-efficacy influences behavior. Thus, theoretically, being highly efficacious in PSTE should positively impact the teaching of contextualized science in school-based agricultural education and science programs; on the other hand, being moderately efficacious may negatively impact the teaching of contextualized science. Additionally, educating life science teachers in technical science content aligns with Ballou and Podgursky, 1999, Ma, 1999, and Podgursky, 2005 assertion that teachers content knowledge impacts student learning. Therefore, we recommend the continuation of professional development programming that aims to increase technical content knowledge. Providing in-depth technical content knowledge should allow the teachers to increase their confidence because they will have a better understanding of the technical content and will feel more comfortable teaching the technical content in the classroom. It is important to note that the small sample size limits the generalizability of the findings.

Future research should be conducted to determine why approximately an equal number of teachers are moderately or highly efficacious in PSTE and determine if moderate self-efficacy negatively impacts the teaching of contextualized science. In regard to science teaching outcome expectancy, a majority of the life science teachers were moderately efficacious in STOE. Theoretically, being moderately efficacious in STOE may negatively impact the teaching of contextualized science. The said research will also aid the planning of professional development for agricultural education and science teachers and can be used to guide experiences offered in agricultural and science teacher education programs.

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