

# Developing STEM Teachers through both Informal and Formal Learning Experiences

Donna Stokes<sup>1</sup>, Paige Evans<sup>2</sup>, and Cheryl Craig<sup>3</sup>

<sup>1</sup>*University Of Houston, Department of Physics  
dstokes@uh.edu*

<sup>2</sup>*University of Houston, Department of Mathematics and teachHOUSTON  
pkevans@central.uh.edu*

<sup>3</sup>*Texas A&M University, Department of Teaching Learning and Culture  
cherylrcraig@tamu.edu*

## ABSTRACT

This article illuminates the impact of the *teachHouston* on students' pursuing Science, Technology, Engineering, and Mathematics (STEM) teaching careers at a time when there is a considerably shortage of qualified teachers in America's urban centers. As part of a National Science Foundation Noyce Scholarship grant, both informal and formal learning opportunities were created and implemented to better prepare preservice STEM teachers and to build self-efficacy. A Noyce Internship Institute, created to prepare pre-service STEM teachers to serve as camp counselors and teaching assistants in a summer STEM camp for underserved middle school students, introduced preservice teachers to interactive training sessions that model best teaching practices. Additionally, a Physics by Inquiry course was developed and implemented by physics and *teachHouston* faculty to engage preservice high school STEM teachers in interactive, inquiry-based teaching pedagogies for physics. The course focuses on increasing the knowledge base for teaching Physics through best practices in inquiry instruction. Evaluation of the course indicates that participants had improved content knowledge and better insight of how to employ inquiry-based learning in the classroom. The informal and formal learning opportunities offered in *teachHouston*, introduced preservice teachers to professional development opportunities as well as exposed them to activities to build their science content knowledge. The outcomes of this program shows positive indication that formal and formal experiences can impact self-efficacy which may lead to increased production and retention of STEM teachers.

KEYWORDS: self-efficacy, Science, Technology, Engineering and Mathematics (STEM), professional development, inquiry-based learning/teaching, teacher education program.

## 1. INTRODUCTION

STEM education has recently been in the American spotlight because of mediocre student achievements (National Center for Education Statistics,

2009) and waning student performance in comparison to other nations (Adams, Miller, Saul & Pegg, 2013). In *A Nation at Risk*, teacher education was championed as a solution to the U.S.'s challenges to improve STEM education (Gardner, 1983). However, the model/program of teacher education was not identified. To this end, we believe knowledge of STEM teacher preparation through formal and informal experiences is necessary to develop an effective model for preservice teacher education programs.

Preparing preservice teachers for effective teaching in STEM areas has been of considerable interest for decades, and recently, interest has risen due to the global need for students trained for STEM careers. In the U.S., about 80% of jobs in the next decade will require STEM skills. The U.S. is losing jobs to the global work force because local students have been inadequately prepared for careers that require strong math and science skills. This is particularly the case in Texas where, between 2000 and 2005, the state lost more high tech jobs than any other state, and ranked 29th in the number of scientists and engineers in its workforce (The STEM Education Coalition, 2011).

Teachers are an important factor in the role of student success in STEM; therefore, incorporating key principles of research in education and learning sciences into the teacher preparation programs is paramount in transforming the nation's output of trained professionals in STEM arenas. Successful transformations of teacher education program will require that STEM teachers receive adequate training and possess a strong sense of self-efficacy, which is key to promoting student success.

The *teach*Houston/Noyce Scholarship program aims to provide formal and informal experiences through a Physics By Inquiry Course and a Noyce Internship Institute that create opportunities for students to build skills and increase self-efficacy. *teach*Houston, a STEM teacher education program which is a collaboration between and among the College of Natural Sciences and Mathematics, College of Education and local school districts, aims to combat the shortage of qualified math and science teachers. The Robert Noyce Scholarship Program, which augments *teach*Houston, specifically addresses the preparation and retention of science majors for secondary education in physics. Currently, 67% of American physics teachers in grades 8 – 12 are uncertified and unqualified (National Academy of Sciences, 2007). Many of these teachers are assigned out of field; therefore, it is critical that highly qualified teachers be prepared for STEM instruction through preservice courses. The Physics by Inquiry course was developed to teach preservice teachers physics content through an inquiry approach for knowledge and confidence building. It also exposes teachers to a teaching style that can be used in their classrooms. The course is open to *all teach*Houston students; therefore, more STEM preservice teachers will learn to teach physics content through inquiry.

The Noyce Internship program is a six-week paid summer internship that includes: a two week Noyce Internship Institute prior to the camp and four weeks as counselors/teaching assistants in STEM summer camps. The Noyce Internship Institute offers interactive professional development sessions addressing emergent needs of secondary STEM teachers and hands-on experience with developing/implementing innovative lessons for STEM camps.

This study investigated whether a relationship existed between formal and informal experiences of the scholarship program and self-efficacy/confidence in preservice teacher's ability to be successful in their job. In particular, it aimed to determine if there was a significant difference in confidence in professional preparedness among those engaged in the formal/informal experiences of the *teach*Houston/Noyce Scholarship program through the Physics by Inquiry course and the Noyce Internship Institute.

## 2. THEORETICAL FRAMEWORK

It is critical that teacher education programs provide ongoing informal and formal experiences that create opportunities for preservice teachers to build teaching and professional skills which can increase self-efficacy (Tuchman & Isaacs, 2011). A strong sense of self efficacy is important for teachers to influence students' academic performance in STEM where teacher -efficacy has been correlated to student achievement outcomes (Moore & Esselman, 1992; Ross, 1992; Muijs & Reynolds, 2002) as well as to student self-efficacy (Anderson, Green & Loewen, 1988). Bandura identified four sources which can be used to determine levels of self-efficacy: mastery experience, vicarious experience, social persuasion and emotional/physiological states (Bandura, 1997). Exposure to multiple forms of formal/informal teaching experiences related to these sources may help preservice teachers become more confident and competent as they embark in their future roles as teachers.

Mastery experiences gained through formal activities of the Physics by Inquiry course were used to determine self-efficacy. Research has shown that teaching methods (Bandura, 1997) as well as mastery of the content can improve teacher confidence in the classroom. Inquiry teaching, which traces its roots in constructivist learning theories (Piaget, Dewey, 1997; Freire, 1984; Vygotsky, 1962), develops higher-order thinking skills and is a teaching method which strongly correlates with how well students learn physics (Fencl & Scheel, 2005; McDermott 1993, 2007). Most pre- and in-service teachers have not been exposed to learning/teaching science through inquiry; therefore, it is difficult for them to conduct their classrooms using this type of instruction. Teacher

preparation through the inquiry course coupled with activities offered in the Noyce Internship Institute, creates opportunities to improve teacher self-efficacy (National Science Education Standards, 1996).

Modern professional development research/theories reject the ineffective workshop model and encourages professional development based on opportunities that promote pedagogical skill development geared toward a specific content which has a strong effect on practice as well as address how teachers learn (Blank, de las Alas, & Smith, 2007; Wenglinsky, 2000; Snow-Renner & Lauer, 2005). The Noyce Internship Institute provides content specific interactive professional development sessions which cover topics including: Working with Middle School Students; Professionalism; What is Facilitation; Classroom Management; Technology; and Growth and Fixed Mindset. For example, extensive work has been done on the importance of teacher self-efficacy in classroom management, student engagement, and student success (Bandura, 1993; O'Neill, 2011; Khan, 2013). O'Neill developed a metric, Classroom Management Self-Efficacy (CMSE), to separate this vital component of self-efficacy from other forms of self-efficacy. It has been suggested that self-efficacy be improved in pre-service teachers by increasing the direct instruction of classroom management strategies in teacher preparation. Tuchman and Isaacs (2011) found that classroom management may be improved by formal teacher preparation at the university level, i.e., through teacher education program activities.

Another source used to determine self-efficacy is vicarious experiences, like the informal experiences gained through discussions in the Physics By Inquiry and STEM camp interactions, i.e., interactions of preservice teachers with master teachers, who guide them through curriculum development, and campers, may motivate and strengthen self-efficacy early in their career.

### 3. METHODOLOGY.

#### 3.1. Participants

Participants for this study were students enrolled in the *teach*Houston who were/were not participants of the Noyce Scholarship Program. This included students enrolled in the Physics By Inquiry course and interns from the Noyce Internship Institute. The sample for this study was  $n = 121$  which was comprised of majors/minors of the following disciplines: physics biology/biochemistry, chemistry and Math. The sample consisted of 65 females and 56 males.

#### 3.2. Measures

Recognition of informal learning activities by the learner and validation of how they impact their outcomes is of great importance for achieving success. For

example, the TRAILER (Tagging, Recognition, Acknowledgment of Informal Learning Experiences) project (Garcia-Penalvo, 2013) is based on analyzing reports by learners of informal learning experiences, tagging these experiences and relating them to particular competencies. For this work, qualitative analysis of Teacher Interest and Pre and post Inquiry-Based Instruction Surveys, were used to ascertain the effects of formal/informal experiences on preservice teacher self-efficacy. The Teacher Interest survey utilized was adapted from the Teachers' Sense of Efficacy Scale created by Tschannen-Moran and Woolfolk Hoy (2001). The Inquiry-Based Instruction Survey was adapted from Marshall and Petrosino (2010). These surveys, comprised of Likert scale questions, gave insight into the effect of the Physics By Inquiry course and Noyce Internship Institute on their success and self-efficacy/confidence as a teacher. Dependent variable of informal teaching experiences were self-reported where respondents were able to indicate multiple types of informal teaching experiences for analysis. Qualitative interviews were also conducted to determine the nature by which the formal/informal experiences impacted their self-efficacy.

#### 4. RESULTS.

Pre- and post-survey responses were analyzed to determine identifiers which could be directly connected to remarks about content knowledge and their comfort level with utilizing the inquiry style teaching method in their classroom. Pre Inquiry-Based Instruction Survey data showed that 77% of the students were familiar with inquiry teaching/learning before enrolling in the course. Respondents recognized that inquiry teaching would entail active participation; however, they were not clearly aware of how/what was required in inquiry based instruction in a classroom. For example, when asked 'What do you consider to be the key elements of inquiry-based instruction? In other words, how would you recognize inquiry-based teaching in a secondary science classroom?' one student, we will refer to as Respondent A, responded:

"I believe it is based more on independent research than on detailed instruction in the classroom."

Remarks of this type were labelled as markers indicating low self-efficacy related to inquiry teaching activities. Post-surveys indicated that, after completion of the Physics By Inquiry course, 100% said they would implement inquiry in their classrooms based on their experience which strengthened their content knowledge and confidence in using inquiry teaching style, hence,

indicating improved self-efficacy. When asked the same question on the post survey, Respondent A commented:

“Students are allowed to make discoveries, inferences, and hypotheses on their own. Instead of formulas and algorithms being given to them and just being told to “believe it”, they get to actually see and figure them out for themselves.”

An additional comment which indicated improved self-efficacy related to inquiry teaching activities included:

“I’m really excited to adapt the methods I learn in this class and apply them in my future biology class. I think it is incredibly effective and enjoyable when the student gets to explore and I’m looking forward to better understanding this method of teaching.”

Teacher Interest Survey data was used to determine how professional development in conjunction with camp experiences, effected teacher self-efficacy. Multiple types of formal/informal teaching experiences were reported by the participants. Examples of informal experiences included: discussions with Master teachers and interaction with campers. Qualitative data, based on comments from the survey, demonstrated improved confidence in the participant’s ability as a teacher. For example, comments included:

“The camp increased my confidence about becoming a teacher. I see myself helping students and enhance their learning abilities through the use of technology”

“Participation in a camp prepared me for the difficulty a teacher can experience in managing student/child behavior.”

Based on the survey results, participants were selected for qualitative interviews which were transcribed to determine common themes related to program participation and increased self-efficacy. Sample quotes from these interview are used as indicators for self-efficacy. A math major observed:

“Receiving the Noyce Scholarship has really opened new doors for me in regards to my teaching career. I am now pursuing a minor in Physics, and I am planning on receiving a teaching certification for both mathematics and physics, which I feel will provide me with an opportunity to become a more well-rounded teacher in the future.”

A Biology/Biochemistry major noted:

“I am very grateful to have received the Noyce Scholarship and have access to all of the wonderful professional development opportunities that came along with being a Noyce scholar ...”

Pre- and post-surveys and interviews indicated that through formal and informal experiences, Noyce scholars and interns, felt they were better prepared to teach and motivate their students. Providing content specific courses and professional development was associated with improved self-efficacy; thereby, teacher education programs should consider including these types of experiences for producing STEM educators.

#### 5. IMPLICATIONS/DISCUSSION.

Many studies have establishing guides for recognizing, validating and evaluating informal learning experiences and their influence on the outcomes of the learner and the system, i.e., educational program (Halliday-Wynes, 2009; Garcia-Peñalvo, 2013). This study was designed to elucidate how informal/formal learning experiences in teacher preparation programs help to build not only pedagogical skill, but also teacher self-efficacy in the areas of instructional strategies, student engagement and classroom management. This analysis required real-world field experience, like those of the Noyce program, where pre-service teachers applied theory and pedagogy through their personal lens.

This study informs university teacher preparation programs about the need to include informal/formal teaching experiences. In particular, content-specific courses utilizing alternative teaching technique such as inquiry which has been shown to improve learning gains in STEM subjects, are important for building self-efficacy/confidence in content knowledge. These courses also offer content specific training for those not majoring in that field, thereby increasing the number of teachers trained to teach specific subject areas.

#### 6. CONCLUSIONS

Overall, the study revealed that formal and informal teaching experiences related to improved self-efficacy in the areas of content knowledge and professional development. Preservice teachers appear to be more apt to utilizing inquiry- based instruction in their classrooms if they have a personal STEM experience learning in this manner. A professional development component further assists prospective teachers with the classroom implementation of inquiry-based instruction.

Through the *teach*Houston/Noyce Scholarship Program, eighteen Noyce Scholars have graduated; ten graduates are certified to teach physics (prior to

this program, the university had not graduated any students certified to teach physics in over a decade); There are currently fourteen continuing scholars. Forty-eight interns have served as camp counselors and all but four of the interns remain enrolled. The retention rate of scholars and interns is 95%. The “Physics by Inquiry” course has enrolled 95 students in five semesters with enrollment continuing to increase. Incorporation of this course led to 12 students pursuing the Science Composite Certificate; and strengthened the physics content knowledge for students not majoring/minoring in physics. Due to the course’s success, a similar course was created for preservice middle school teachers and a Biology/Biochemistry By Inquiry course has been developed. This program’s outcomes demonstrate that formal/informal experiences can impact self-efficacy which may lead to increased production and retention of urban STEM teachers.

#### ACKNOWLEDGEMENTS

This work is supported by the National Science Foundation Grant DUE-1240083 and 1557309.

#### REFERENCES

- ADAMS A.E., MILLER, B.G., SAUL, M. & PEGG, J. (2013). Organization for Economic: Electronic Journal of Science Education [ejse.southwestern.edu](http://ejse.southwestern.edu) Co-operation and Development.
- ANDERSON, R. GREEN, M. & LOEWEN, P. (1988). Relationships among teachers' and students' thinking skills, sense of efficacy, and student achievement. *Alberta Journal of Educational Research*, 34(2), 148-165.
- BANDURA, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist*, 28(2), 117-148.
- BANDURA, A. (1997). *Self-efficacy: the exercise of control*. New York: W. H. Freeman and Company.
- BLANK, R.K., DE LAS ALAS, N. & SMITH C. (2007); Analysis of the quality of professional development programs for mathematics and science teachers: Findings from a cross-state study. Retrieved from Council of Chief State School Officers website:  
<http://www.ccsso.org/content/pdfs/year%2020new%20final%20NSF%20Impde%20Fall%2006%20%20Report%20-032307.pdf>.

- DEWEY, J. (1997). *How we think*. Mineola, New York: Dover Publications.
- FENCL, H., & SCHEEL, K.R. (2005). Engaging students: an Examination of the effects of teaching strategies on self-efficacy and course climate in a non-majors physics course, *Journal of College Science Teaching*, 35(1), 20-25.
- FREIRE, P. (1984). *Pedagogy of the oppressed*. New York: Continuum Publishing Company.
- GARCIA-PENALVO, F.J., ET AL., (2013). TRAILER Project (Tagging, Recognition, Acknowledgment of Informal Learning Experiences). A Methodology to Make Learners' Informal Learning Activities Visible to the Institutions. *Journal of Universal Computer Science*, 19(11), 1661-1683.
- GARCIA-PENALVO, F.J., ET AL., (2013). A Tool to Aid Institutions Recognize Their Employees Competences Acquired by Informal Learning. In *Scaling up Learning for Sustained Impact. 8th European Conference on Technology Enhanced Learning*, 552-555.
- GARDNER, D. (1983). *A Nation at risk*. Washington, DC: National Commission on Excellence on in Education, U.S. Department of Education.
- HALLIDAY-WYNES, S., BEDDIE, F. (2009). *Informal learning: At a glance*. National Centre for Vocational Education Research, Adelaide.
- KHAN, M. (2013). Academic Self-Efficacy, Coping, and Academic Performance in College. *International Journal of Undergraduate Research and Creative Activities*, 5(4), 1-11.
- MARSHALL, J.A., PETROSINO, A.J. & MARTIN, H.T. (2010). Pre-service teachers' conceptions and enactments of project based instruction. *Journal of Science Education and Technology*, 19(4), 370-386.
- MCDERMOTT, L. (1993). Guest comment: How we teach and how students learn—A mismatch? *American Journal of Physics*. 61, 295-298.
- MCDERMOTT, L. (2007). Preparing K-12 teachers in physics: Insights from history, experience, and research. *American Journal of Physics*, 74, 758-762.

- MOORE, W.P., & ESSELMAN, M.E. (1992). Teacher efficacy, empowerment, and a focused instructional climate: Does student achievement benefit? *Paper presented at the annual conference of the American Educational Research Association, San Francisco, CA.*
- MUIJS, D., & REYNOLDS, D. (2002). Teachers' beliefs and behaviors: What really matters? *Journal of Classroom Interaction, 37*(2), 3–15.
- NATIONAL ACADEMY OF SCIENCES (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*, Washington DC.
- CHEN, X. & WEKO, T. (2009). U.S. Department of Education, NATIONAL CENTER FOR EDUCATION STATISTICS, *Stats in Brief: Students Who Study Science, Technology, Engineering, and Mathematics (STEM) in Postsecondary Education (NCES 2009-161).*
- NATIONAL RESEARCH COUNCIL (1996). *National Science Education Standards*. Washington, DC: National Academies Press.
- O'NEILL, S. & STEPHENSON, J. (2011). The measurement of classroom management self-efficacy: a review of measurement instrument development and influences. *Educational Psychology: An International Journal of Experimental Educational Psychology, 31*(3), 261-299.
- PIAGET, J. (1970). *Piaget's theory*. In P.H. Mussen (Ed.), *Carmichael's manual of child psychology*. New York: Wiley.
- ROSS, J.A. (1992). Teacher efficacy and the effects of coaching on student achievement. *Canadian Journal of Education, 17*(1), 51–65.
- THE STEM EDUCATION COALITION (2011). *Texas' K–12 STEM Education Report Card, The Academy of Medicine, Engineering and Science of Texas*. Retrieved from [http://www.tamest.org/assets/docs/edu\\_summary\\_report.pdf](http://www.tamest.org/assets/docs/edu_summary_report.pdf).
- TSCHANNEN-MORAN, M., WOOLFOLK HOY, A., & HOY, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research, 68*, 202-248.
- TUCHMAN, E., & ISAACS, J. (2011). The influence of formal and informal

formative pre-service experiences on teacher self-efficacy, *Educational Psychology: An International Journal of Experimental Educational Psychology*, 31 (4), 413-433.

WENGLINSKY, H. (2000). How teaching matters: Bringing the classroom back into discussions of teacher quality. Princeton, NY. ETS Policy Information Center Report. [https://www.ets.org/research/policy\\_research\\_reports/publications/report/2000/idxn](https://www.ets.org/research/policy_research_reports/publications/report/2000/idxn).