2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #38089

Barriers to including engineering education into elementary classrooms (Fundamental)

Lajja Mehta, Tufts University

Lajja Mehta is a Lead User Researcher in a Financial Technology company and holds a master's degree in Human Factors from Tufts University. In her 15 years of professional career, she has dabbled in Education and Finance domains with the lens of user-centered research and design. She is passionate about learning how people interact with interfaces and making end-user experiences more intuitive and satisfying. She is particularly interested in leveraging technology for infusing STEM into early education.

Barriers to Include Engineering Education into Elementary Classrooms

Abstract

Novel Engineering (NE) is an interdisciplinary approach to teach engineering and literacy in elementary and middle schools. In order to further improve the NE program and increase its adoption, it is important to understand teachers' experiences with NE and the barriers they face in implementation of NE activities. The aims of this study were to identify the top barriers to NE implementation and uncover if any relationship exists between teachers' background and the barriers they mentioned. Data for this study were collected through one-on-one interviews and an online questionnaire conducted with 12 elementary school teachers. Risk assessment methodology was employed to assess the major barriers in the questionnaire, while a semi-structured interview was used to explore teachers' experiences in detail. Results of the quantitative and qualitative responses indicate lack of time, pressure from administration to meet standards, and access to materials as top barriers for NE implementation. This thesis analyzes the relationship between teachers' backgrounds and the top barriers, and discusses how this analysis could be used to empower teachers to efficiently infuse engineering education into their classrooms.

Introduction

Novel Engineering (NE) is an interdisciplinary approach to teaching engineering and literacy to students in elementary and middle schools. Students use classroom literature (stories, novels, and expository texts) to identify engineering problems and explore their ideas through design projects to solve these problems. This innovative approach was developed by the Center for Engineering Education and Outreach (CEEO) at Tufts University. Many teachers around the country currently practice it. The NE research team at CEEO conducts professional development (PD) workshops where elementary school teachers develop the knowledge, skills, and abilities to introduce engineering to their students. During the PD, teachers learn to integrate NE-inspired engineering design challenges into their existing reading curriculum.

In order to further improve the NE program and increase its adoption, it is crucial to receive feedback from teachers who have already tried NE in their classrooms. The aims of this research were to 1) identify and evaluate the barriers to NE implementation and 2) uncover if any relationship exists between the backgrounds of the research participants and the barriers that they experience.

Students are capable of developing engineering thinking and problem-solving skills at an early age [1]. Engineering education brings a real world perspective to kids in classrooms. It provides them an outlet to explore their ideas through hands-on activities. Especially in the twenty-first century, when our everyday lives revolve so much around engineering and technology, it is crucial to foster engineering and technology literacy from a young age. However, engineering education is still a relatively new area for many K-12 teachers and one of the major challenges in infusing engineering into classrooms is that most teachers do not have any training in engineering and design [2].

Yasar, Baker, Robinson-Kurpius, Krause, and Roberts [3] developed a survey instrument to assess K-12 teachers' perceptions of engineering and their familiarity with teaching design, engineering, and technology (DET). Their research with 98 teachers from Arizona found that teachers believed DET was important and should be part of the K-12 curriculum. However, time and administrative support were mentioned as barriers to including DET into the curriculum. Hsu, Purzer, and Cardella [4] performed similar research with 198 elementary school teachers to gather teachers' views about DET. They also found that the majority of the teachers thought DET was important, however, most of the teachers did not feel fully prepared to teach DET to their students and cited their unfamiliarity with DET education.

Project Lead The Way (PLTW) is another highly recognized engineering curriculum, which introduces engineering into middle school and high school. A study carried out with Indiana school principals identified cost of implementing PLTW as a major barrier to PLTW adoption while cost of training PLTW teachers was named as the second highest barrier [5].
Allen [6] carried out a formative study with seven elementary school teachers, of whom all but one had two-to-three years of experience working on the NE project. Lack of time to plan and

implement NE was cited as the topmost challenge for teachers. Inability to figure out books and problems, pressure from administration, difficulties in lesson planning, group dynamics among students, and safety of students while handling materials were some of the other concerns mentioned in the evaluation.

Similar findings were uncovered in a survey of 70 elementary and middle school teachers done by Coppola, S.M., Madariaga, L. and Schnedeker, M. [7]. They found that lack of time, access to materials and resources, and unfamiliarity with the content were major barriers that prevent integrating engineering into the classroom.

Research Methodology

A list of potential barriers for NE implementation were hypothesized based on past conversations with teachers and findings from similar studies:

- Lack of time for lesson planning
- Lack of time to include NE
- Difficulty in NE lesson planning
- Inability to figure out books and problems
- Materials and expense
- Difficulty in evaluating NE projects
- Lack of freedom to plan curriculum or class schedule
- Pressure from school administration to meet standards
- Lack of support from school administration
- Lack of support from NE team at Tufts

This study employed a mixed methods approach, combining quantitative and qualitative research methods.

1. Questionnaire Framework

A questionnaire was designed using Qualtrics software to gather quantifiable responses about the

10 identified factors from 12 elementary school teachers. Instead of asking teachers to simply rank these factors, a risk assessment methodology was utilized to explore each of the factors in detail and understand their specific impact on teachers.

Risk assessment is a common practice in areas like aerospace, healthcare, and environmental science to analyze possible risks or hazards to humans or the environment. The risk assessment methodology determines implications of a potential failure of a machine or a project by addressing two-dimensions: probability (chances of potential failure) and impact (severity of the worst case scenario). Risk score is calculated by multiplying the probability value with the impact value.

Risk assessment methodology was adapted for the educational context for this study. Failure for this study was defined as not implementing NE, which would ultimately mean students not being able to learn hands-on engineering integrated with reading and writing. Terms Chances of Failure (CoF) and Impact of Failure (IoF) were used to measure the probability and impact of potential failure. Additionally, since the goal was to recognize which factors out of the 10 acted as barriers for NE, the term Barrier Index (BI) was used to signify multiplication result from CoF and IoF values.

First section of the questionnaire included questions around the 10 factors to gauge CoF based on the situations and perceptions of teachers. For each of the 10 factors, a corresponding question was included in the second section to assess IoF. Questions in each of the two sections include Likert scale type response levels. Response levels were coded to numerical numbers 1 - 5, with 1 indicating lowest CoF or IoF and 5 indicating highest CoF or IoF. The questionnaire contained a total of 20 closed questions (two for each of the 10 factors, one in each section). It also included six open-ended questions to seek further explanation from teachers about very high or low ratings of some of the factors. Table 1 and 2 illustrate a sample question and associated response levels in CoF and IoF sections respectively.

Table 1: Sample question in the CoF section

What amount of pressure do you feel from school administration in terms of meeting standards?		
Response levels	**Chances of Failure (CoF)**	**CoF rating**
None	None	1
Very little pressure	Low	2
Some pressure	Medium	3
A lot of pressure	High	4
A great deal of pressure	Very high	5

Table 2: Sample question in the IoF section

How does pressure from school administration to meet standards affect your ability to successfully implement Novel Engineering in your classroom?		
Response levels	**Impact of Failure (IoF)**	**IoF rating**
Does not affect at all	None	1
Affects slightly, but, still manageable	Low	2
Affects moderately, chances of successful implementation are less	Medium	3
Affects a lot, chances of successful implementation are minimal	High	4

Makes it impossible to implement	Very high	5

Multiplication of CoF and IoF ratings produce BI values for each of the 10 factors. The value of BI would range from 1 - 25. Higher BIs indicate top barriers for NE implementation.

2. Interview Framework

Semi-structured style interviews were carried out with 12 teachers to allow rich discussions about their NE experiences and uncover NE barriers that were not covered in the questionnaire. In order to avoid response bias, the interview was carried out first, followed by the questionnaire so that the participant was not exposed to the factors already identified as potential barriers. Questions for the semi-structured style interview were designed to understand teachers' experiences with hands-on activities, process of planning NE, how NE looked in their classrooms, major challenges they faced when planning and implementing NE, strategies they employed to overcome the challenges they had, suggestions they had for other teachers, and whether or not they saw value in NE approach.

Data Collection

A total of 21 teachers were contacted by email with the help of the NE research team at Tufts CEEO, out of which 12 responded with their interest to participate in the study. All 12 respondents were elementary teachers and had implemented NE at least once. Of the 12 teachers, 10 were based in Massachusetts, while the other 2 teachers were teaching in California. 11 out of the 12 teachers were female and 1 was male.

The NE research team at Tufts CEEO facilitates periodic Professional Development (PD) workshops for teachers. Formal PD workshops are either one full day or spread across ranges of three-to-five days. During the interview, data was gathered on whether the participants had received formal PD training or not. Half of the participants had received formal PD.

The goal of the study was clearly mentioned to the teachers and teachers were specifically asked to provide honest responses. Interviews with six teachers were carried out in-person at their schools and the other six teachers were interviewed on the phone. All 12 teachers were provided a hyperlink of the questionnaire at the end of the interview. In order to avoid response bias, teachers were asked to work on the questionnaire in the absence of the researcher.

Data Analysis and Findings

Participants' responses to questionnaire questions about 10 factors were analyzed to highlight factors that received high ratings from maximum participants. A cutoff rating value for each section was decided in order to group the responses into high and low rating categories. Participant responses to Chances of Failure (CoF) and Impact of Failure (IoF) sections of the questionnaire were gathered and Barrier Index (BI) was calculated by multiplying CoF and IoF for each of the 10 factors. Based on the responses, rating value 7 was used as a cutoff to identify top barriers. To identify the top barriers, frequencies of rating value greater than 7 were calculated for each factor. Table 3 depicts all 10 factors and highlights corresponding frequencies based on the BI values. Mean and standard deviation incorporated all values of BI (1 - 25) for each particular factor.

Table 3: Findings from the BI section (n=12)

Factors	**Frequency (Rating > 7)**	**Mean**	**Std. Dev.**
Pressure to meet standards	5	7.08	4.66
Lack of time to include NE	4	6.58	4.14
Inability to figure out books and problems	4	6.58	6.69
Lack of freedom in choosing a curriculum	4	6.33	4.40
Difficulty in NE lesson planning	4	6.08	2.75
Lack of support from school	4	4.92	2.97
Materials and expense	3	6.75	5.58

Lack of time for lesson planning	3	6.50	4.17
Lack of support from NE team	3	6.33	6.04
Difficulty in evaluating NE projects	3	5.42	2.47

Audio recordings of the interview responses from 12 participants were transcribed and analyzed. Background information of the participants were then extracted and organized according to common themes. Various challenges mentioned by the participants during the interview were grouped and frequencies were counted. Table 4 presents NE barriers revealed by participants during the interview and corresponding frequencies. Lack of time and access to materials were mentioned the most during the interview.

Table 4: Barriers shared by participants during the interview

Common themes	**Challenges shared by participants**	**Frequency**
Lack of time	Time to do NE in classroom	5
	Time to come up with ideas and plan it out	1
Access to materials	Gathering materials	3
	Being limited by recycled materials, want to expand and use engineering materials	2
Lack of knowledge	Not knowing which direction to follow, what lessons to cover, which books to choose from engineering perspective	3
	Not having knowledge to be able to find age appropriate resources	2
Doing it well	Gearing the kids in right direction without giving out too much info	2
	Getting the kids of different reading levels to read the same level book	1

	Making sure kids are working together and creating one thing instead of 3-4 little things	1
Classroom space	Storing the projects	2
	Storing materials	1
Difficult group dynamics	Special-Ed and English language learners	1
	Student personalities	1
Less opportunities for kids at school	Lack of writing support	1
	Lack of open ended project opportunities	1
Fantasy based solutions		1
Lack of support from NE team		1

Discussions

1. Top Barriers

Lack of time to include NE, pressure from school administration to meet standards, and access to materials clearly stood out as the top barriers for NE implementation. Pressure to meet standards was rated as a top barrier in the questionnaire, with the highest BI value from maximum number of participants. However, none of the participants cited this factor during the interview.

Lack of time to include NE was the most cited issue during the interview and a second highest barrier in the questionnaire results. After lack of time, access to materials was cited as the second biggest barrier during the interview.

The factors lack of knowledge, inability to figure out books and problems, and difficulty in NE lesson planning were described as major concerns after the top three barriers. From the interview responses, it is apparent that figuring out books and problems is just one aspect of knowledge when it comes to integrating NE into curriculum. Being knowledgeable about which direction to follow, what lessons to cover, and finding age appropriate materials were some of the other problems identified by teachers.

2. Effects of PD

In order to determine whether there might be any relationship between participants' background information and various factors identified as barriers, the Pearson correlation analysis was conducted.

Results of the Pearson correlation analysis demonstrated several significant relationships between whether or not participants had received PD and their responses to various other factors in the questionnaire. Not having received formal PD significantly correlated with finding NE lesson planning difficult ($R = 0.845$, $p = 0.001$). In other words, participants who did not receive formal PD gave high ratings to the factor "difficulty in NE lesson planning".
Professional development is a crucial way to impart content knowledge to teachers and improve their classroom teaching practices [8]. Professional development for Novel Engineering is no exception. Bell, Wilson, Higgins and McCoach [9] measured the effects of professional development on teacher knowledge and found a significant increase in Mathematical Knowledge in Teaching (MKT) for participants who attended the high-quality professional development program, Developing Mathematical Ideas (DMI). Various other earlier researches have also registered positive influence of PD. Correlation analysis results of this study reinforces these findings.

Out of the six participants who received formal PD, none found NE lesson planning difficult. Lack of content knowledge or lack of engineering perspective was cited as the reason behind finding the NE lesson planning difficult by most teachers. It is likely that attending the PD workshops would help teachers in gaining the knowledge they lack, learning the techniques of NE lesson planning, and ultimately reduce the impact of one of the major barriers to NE.

Findings from correlation analysis indicated significant positive influence of formal PD on teachers' NE experiences. Comments from most teachers reinforce this analysis. One of the participants who received formal PD and have been implementing NE since about five years, explained her process of implementation:

I usually try to find the book that I've heard other teachers have done it. I read through the book and kinda think about the parts where I can stop the kids, talk about different problems that arise and have them have opportunity to start thinking about solving the problem. I usually know overall goals… both the literacy goals and reading goals but also the goals for the engineering and the teamwork.

On the other hand, NE experience of another participant who had no formal PD training and less experience in engineering education, was quite different:

It was too free form… Without any sort of plan, it was messy at times and I felt like we did an okay job, but if there had been sort of an outline, just a trajectory of like the kinds of topics which could be covered, it would have been easier to see where it was going… It was so disconnected from rest of the curriculum and rest of the school.

3. Value of NE and Teachers' Suggestions

During the interview, participants were questioned about whether or not they valued NE and whether the NE activities were worth the time and resources required to implement. All participants clearly mentioned that they did value NE, the NE activities they carried out were completely worth the time and efforts, and their students loved it. On further probing about why they saw value in the NE approach, most participants mentioned that NE integrated literacy and engineering very well. They stated that NE increased the validity of the book for the students and students were thinking about the story in ways they wouldn't normally think of it. Some participants also described how NE helped students think critically and provide them with a real world perspective.

Participants provided suggestions to make the NE activities more successful for teachers brand new to NE. Most participants recommended doing smaller introductory hands-on activities during the beginning of the year before incorporating a larger, more complex NE activity. Teaching teamwork early on, letting go of control, and providing English language support to students who need it were some of the other ideas coined by participants.

Conclusion

The goal of the research was to unearth barriers to NE implementation. In order to ascertain an accurate picture of teachers' experiences with NE, findings from both quantitative and qualitative methods from 12 elementary school teachers were integrated and analyzed. Risk assessment framework of the questionnaire provided a two-dimensional approach to identify top barriers from the list of 10 potential factors. On the other hand, the open-ended interview offered deeper insights into experiences of elementary school teachers with NE. Top barriers identified from both questionnaire and interview responses were found to be aligned with each other.

Lack of time to include NE, pressure from school administration to meet standards, and access to materials were identified as top barriers for NE. These findings suggest that in order to increase the adoption of NE and make its implementation successful, it is imperative to focus our attention to the concerns of time and materials, and devise ways to better manage these barriers.

41 out of the 50 U.S. states include engineering components into elementary education standards and particularly, Massachusetts has strong explicit engineering standards [10]. Therefore, pressure to meet standards was unexpected as one of the top barriers for NE.

Formal PD was found to have significant positive influence on teachers' NE experiences. Teachers who do not receive formal PD are more likely to find the NE lesson planning difficult and to seek outside support.

Despite various challenges identified by the elementary school teachers, all of them strongly acknowledged the value NE brings into classrooms and their intent to include NE in the future.

Teachers suggested doing smaller activities in the beginning of the year to familiarize students with hands-on activities and teamwork.

In conclusion, information obtained from this research can help professional developers in devising workshops, lesson plans, and other resources to properly equip teachers in order to help them overcome NE implementation barriers. Findings from this study can also help policymakers and stakeholders in creating a thriving environment for STEM education for teachers to successfully integrate engineering into classrooms.

Bibliography

[1] C. M. Cunningham, "Engineering is elementary," *The Bridge*, vol. 30, no. 3, pp. 11–17, 2009.

[2] Ş. Purzer, T. J. Moore, D. Baker, and L. Berland, "Supporting the implementation of NGSS through research: Engineering," *NARST*, Jun. 20, 2014. https://narst.org/ngsspapers/Engineering_June2014.pdf.

[3] Ş. Yaşar, D. Baker, S. Robinson-Kurpius, S. Krause, and C. Roberts, "Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology," *J. Eng. Educ.*, vol. 95, no. 3, pp. 205–216, Jul. 2006, doi: 10.1002/j.2168-9830.2006.tb00893.x.

[4] M.-C. Hsu, S. Purzer, and M. E. Cardella, "Elementary teachers' views about teaching design, engineering, and technology," *J. Pre-Coll. Eng. Educ. Res. J-PEER*, vol. 1, no. 2, p. 5, 2011.

[5] C. J. Shields, "Barriers to the implementation of Project Lead the Way as perceived by Indiana High School principals," *J. Ind. Teach. Educ.*, vol. 44, no. 3, 2007, [Online]. Available: https://scholar.lib.vt.edu/ejournals/JITE/v44n3/shields.html

[6] S. Allen, "Formative evaluation report on Tufts University's Integrating Engineering and Literacy Project," unpublished raw data, 2012.

[7] S. M. Coppola, L. Madariaga, and M. Schnedeker, “Assessing teachers’ experiences with STEM and perceived barriers to teaching engineering,” in *American Society for Engineering Education Annual Conference & Exposition*, Seattle, WA, 2015.

[8] T. R. Guskey, “Professional development and teacher change,” *Teach. Teach.*, vol. 8, no. 3, pp. 381–391, 2002, doi: 10.1080/135406002100000512.

[9] C. A. Bell, S. M. Wilson, T. Higgins, and D. B. McCoach, “Measuring the effect of professional development on teacher knowledge: The case of developing mathematical ideas,” *J. Res. Math. Educ.*, vol. 41, no. 5, pp. 479–512, 2010.

[10] R. L. Carr, L. D. Bennett, and J. Strobel, “Engineering in the K-12 STEM standards of the 50 US States: An analysis of presence and extent,” *J. Eng. Educ.*, vol. 101, no. 3, pp. 539–564, 2012.