Assessing the state of Engineering Instruction in Maine's K-12 Schools

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Abstract— **In today's increasingly tech-based economy, many high-salary jobs are created in the STEM fields. These jobs often are either in or related to engineering, and thus establishing an educational engineering pipeline is critical to supply this demand. In Maine, no state-wide assessment data of engineering literacy in K-12 schools is available. Information is needed to assess if the current quantity and quality of engineering instruction at K-12 level is sufficient to generate a pathway into engineering for Maine students and support the state's economic development. The work presented here addresses this need by conducting an in-depth assessment of engineering specific instructional interventions at Maine's K-12 schools. An expert panel, comprised of a diverse group of educators and practicing engineers, support the research team in defining, examining and quantifying current Maine STEM educational efforts from an engineering perspective. Preliminary survey results show that in rural and urban cluster areas, engineering related interventions are less frequent where high indices of economically disadvantaged students are found. Additionally, preliminary data indicates that the percentage of teachers with an engineering background is less than twenty percent. Preliminary results are further presented using geographical and demographic indicators such as county and economically disadvantaged student ratio.**

Keywords—engineering instruction, teacher's educational background

I. INTRODUCTION

In 2013, there were a total of 6,600 employed engineers in Maine. This number is projected to rise to 7,300 by 2023 [1]. The projected increase suggests that by the year 2023, there will be a shortage of over 950 engineers, which the current educational system in Maine is not capable of filling. The fact that Maine is 60% below the national average in per capita graduation of engineers [1] exacerbates the situation. It is thus imperative to analyze and support the creation of a K-12 (kindergarten to 12th grade) pathway to the engineering profession to support the hi-tech economy of Maine.

Effective engineering-related instruction should increase the engineering literacy (EL) of K-12 students. Promoting EL is valuable for students interested in pursuing engineering and to avoid misconceptions of the engineering profession [2]. Increased EL is also useful for people who will interact with engineers in their daily work, or who will be impacted by the implementation of technology [3]. The assessment of engineering specific instructional interventions for teachers has been conducted previously by Kurpius-Robinson et al. [4] and Wilson [5]. Other assessment instruments have been developed [6] to study the change of attitude towards engineering when students were exposed to engineering interventions. Welty et al. [7] surveyed the engineering curricula used in the US.

The research presented here is an in-depth assessment of the state of engineering specific instructional interventions at Maine's K-12 schools. This baseline data will enable University of Maine System (UMS) researchers to:

- Develop specific programs to strengthen the engineering career pathway for Maine students,
- Inform K-12 teachers and administrators on the scope and effectiveness of current engineering instruction,
- Support the Maine Department of Education with baseline data to inform the development of standards and implementation strategies for engineering and technology education in grades K-12.

The data of this study will be analyzed according to demographic categories. According to the 2010 census of the state of Maine [8], the population of Maine was 1,328,360. Maine is divided into sixteen counties and has five main urban areas and twenty urban clusters. The largest urban area is Portland in Cumberland County. The urban clusters of Maine are mainly located in the coastal areas. The percentage of population living in urban areas, urban clusters and rural areas is 26.2%, 12.4% and 61.3% respectively.

II. METHODS

This work introduces the preliminary results of an in-depth assessment of the current quantity and quality of engineering instruction in K-12 schools in Maine. This assessment is informed by literature-based definitions and an expert panel comprised of a diverse group of educators and practicing engineers. The assessment objective is to arrive at a definition of engineering interventions that builds on the skills, behaviors, and attitudes used in a normal day of an engineer. This definition will both clarify and advance the scope of

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engineering and technology specific education in K-12 schools in Maine. The panel of experts also assisted in the formulation of questions on the main barriers to implementing engineering-related instruction.

To assess these points, two surveys have been deployed to all K-12 schools in Maine: one for school principals and another for teachers involved in the teaching of engineering-related interventions. Surveys consisting of both multiple choice and open-ended questions are administered using a web-based survey tool. Principals are asked about the engineering interventions in their schools, and the challenges of implementing engineering-related interventions. Additionally, the principals are invited to refer researchers to the teachers performing engineering interventions in their schools. Teachers are asked about their educational background, the engineering interventions that they teach, and the challenges they encounter in implementing engineering interventions. Teachers are also asked to briefly describe the engineering-related instruction they employ and to rank how they address the skills, attitudes, and behaviors suggested by the advisory board.

In order to gain first-hand knowledge of specific challenges and approaches, the project team is visiting twenty-five schools that have reported implementation of engineering-related interventions via the online survey tool. The twenty-five schools were chosen to give a fair state-wide representation of the different geographical, demographic and social indicators in Maine. During the visits, the principals and teachers of these schools are interviewed, and if possible, the facilities and equipment used for engineering related interventions are inspected. The data collected will augment the prior survey-based information, and be analyzed using geographical and demographic indicators such as county, and the economic disadvantage index.

III. PRELIMINARY RESULTS

A. *Defining engineering interventions*

Twenty-five Maine educators and engineers served on an advisory board charged with defining engineering intervention and providing valuable knowledge to inform the questions used in the survey instruments. Members of the advisory board participated in two activities. During the first phase, the advisory board provided researchers with information about the engineering profession and what motivates a person to study engineering. This information, together with data from literature [8][9][10][11], helped researchers identify the most important skills, attitudes, and behaviors expected from Maine engineers. In the second phase, the advisory board helped researchers rank these skills, attitudes, and behaviors, and provided information on common and state-specific barriers to implement engineering interventions in schools.

The skills and attitudes identified in this phase were:

- Analytical and problem solving skills
- Technical skills
- Communication skills
- Personal management skills
- Teamwork skills
- Creativity
- Motivation and persistence
- Ethics and integrity
- Curiosity

B. *Surveying existing engineering interventions*

B.1. Survey 1 –school principals:

The first web-based survey was sent to 595 school principals. The current response rate for this survey is 19% (114 Schools). Principals were asked about what engineering interventions are available in their schools, their vision to expand or implementing engineering programs, how students become involved in these programs, as well as challenges related to implementing engineering-related interventions.

The preliminary responses have shown that nearly fourteen percent of the schools offering engineering interventions do so with material that they have developed or adapted locally in the school (Fig. 1). The most common program is LEGO Engineering, which has a state representative who supports and organizes local competitions for 15% of the schools surveyed. For reference, of the nine schools known to use Project Lead the Way (PLTW) [12] only two schools answered the survey.

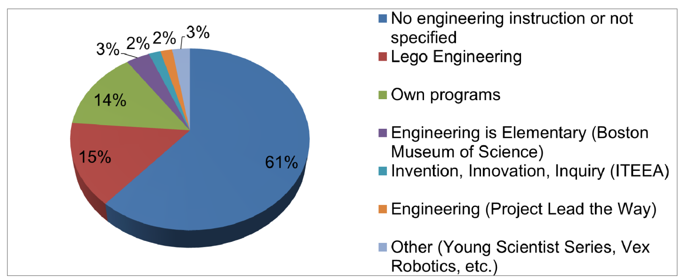

Fig. 1. Current reported engineering interventions.

The survey responses of both principals and teachers are currently being analyzed using geographical and demographic indicators such as county, and economically disadvantage index. Table 1 shows the survey results according to demographics (114 schools).

TABLE I. SURVEY RESULTS ACCORDING TO DEMOGRAPHICS

Demographic Index	**Engineering Interventions**	
	Yes	***No***
Rural Area	39 (52.7%)	35 (47.3%)
Urban Cluster	10 (66.7%)	5 (33.3%)
Urban Area	19 (76.0%)	6 (24.0%)

Preliminary survey results show that engineering related interventions are less frequent in rural and urban cluster areas, where higher indices of economically disadvantaged students are found. In addition, there is a relationship between availability of engineering interventions and the percentage of economic disadvantaged students; results indicate that engineering specific instruction is lowest in Rural and Urban Cluster areas with a higher proportion of economically disadvantaged students, while the same trend is not apparent in urban areas.

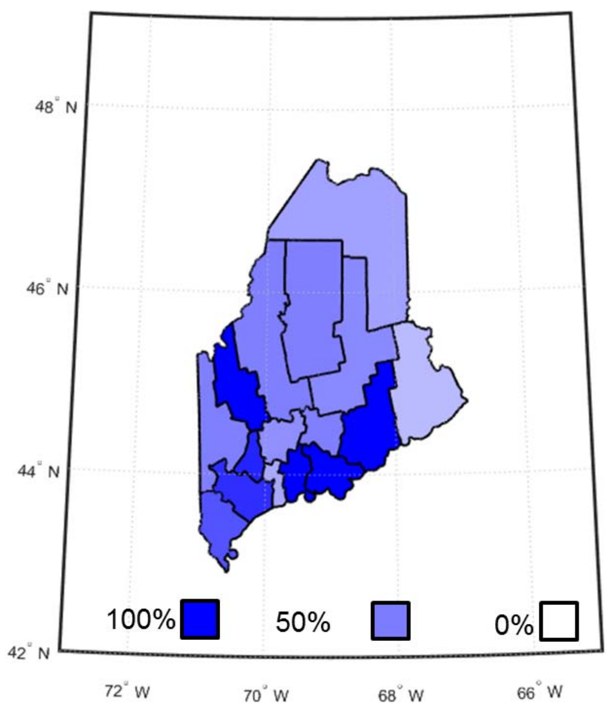

Fig. 2. Percentage of affirmative answers to the question "do you have an engineering intervention in your school?" with respect to county (principals' response).

Furthermore, the availability of engineering related instruction is highest in the most populated areas in the state. Fig.2 shows the percentage of schools with engineering related instructions by county. It is evident that schools in the southern and some coastal counties have a higher percentage of engineering-related instructions. For example, schools in the more highly populated and affluent Cumberland County and York County that have responded to the survey have an 81.8% and 67% rate of engineering instruction, respectively. In the coastal counties of Hancock and Lincoln, all the schools that have responded to the survey have engineering interventions (Lincoln County only has nineteen public schools). The percentage decreases in the more economically disadvantaged and less populated northern counties like Washington County and Aroostook counties, with 27.3% and 37.5% of schools with engineering-related instruction. Currently in five counties, less than four schools per county have responded to the survey. Schools in these counties will be approached to increase their participation.

Principals that answered yes to the question of whether they have engineering related instruction in their school were asked if they thought that there was a need to increase/expand this type of instruction. The results of this question show that 81% of the principals think that there is a need to expand engineering related instruction. In addition, the principals of the schools that do not currently offer engineering related instruction reported a perceived need to offer this type of instruction: 79% of the surveyed schools that do not offer engineering related instruction responded that they would want to incorporate this type of instruction.

School principals were asked to identify the main barriers to advancing engineering related instruction. Preliminary results are presented in Fig. 3. Principals have identified the four main barriers as financial resources, training, physical resources, and time. In contrast, student motivation, student knowledge, and parent support are not perceived as main barriers for implementing engineering related instruction. The link to financial resources once again is apparent in the geographic distribution over the more affluent and less affluent counties.

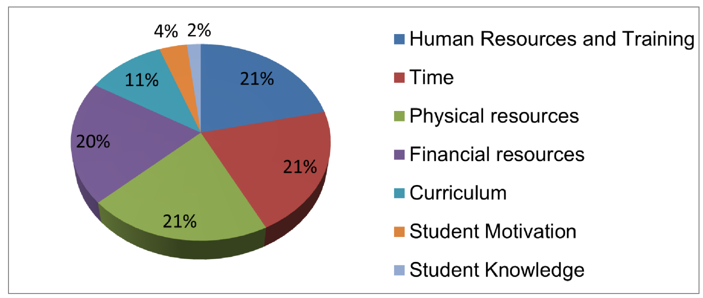

Fig. 3. Major challenges to implementing engineering-related instruction at your school (principals' response).

B.2. Survey 2 – K-12 engineering teachers:

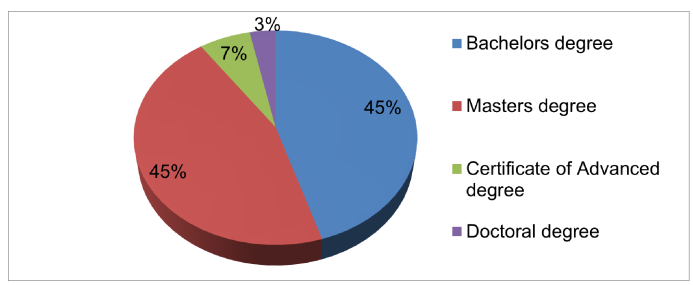

Fig. 4. Reported highest degree completed by teachers involved in engineering interventions.

The second web-based survey has been sent to eighty teachers that were identified by their principals as being involved in engineering-related interventions. Thirty-four teachers have participated in the study so far. The teachers were first asked about their background. Fig. 4 shows the preliminary results of the highest degree attained by the surveyed teachers. These initial results indicate that more than half of the teachers possess a postgraduate degree. Most teachers surveyed have a bachelor's degree in education and less than twenty percent have a bachelor's degree in engineering. Most of the surveyed teachers who possess a master's degree majored in education, while around twelve percent possesses a master's degree in engineering.

Teachers were asked about the engineering related instruction they used, including whether this instruction was a stand-alone module or course, an embeded part of a module or course, or an after school program. 55% of the engineering instructions were reportedly embeded in a module or course, and 40% were stand-alone module. The remaining 5% of the responses to this question were "after shool program. All of the engineering related instruction had hands-on components.

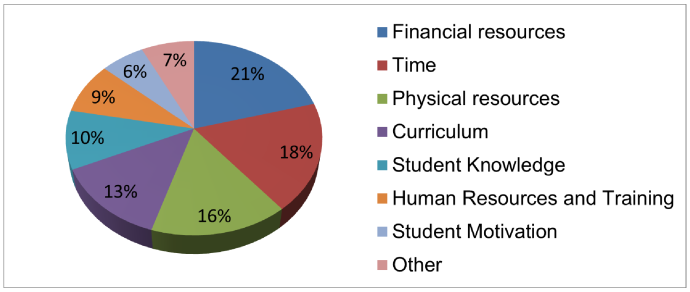

Fig. 5. Reported major challenges to implementing engineering-related instruction at your school (Teachers' response).

Teachers were also asked what they thought the main barriers to advancing engineering related instruction were. Preliminary results, presented in Fig. 5, show that the four main barriers are financial resources, time, physical resources, and curriculum. The main difference between teacher and principal answers is that teachers ranked lower the barrier of human resources or training. Also, teachers rate significantly higher student motivation and student knowledge on this question.

Additionally, teachers were asked if they think there is room to expand engineering interventions in their schools. 92% of teachers answering responded affirmatively to this question. This result is in congruence with the responses given by school principals.

It is apparent from both the teacher and principal responses that in addition to lacking financial resources, additional training is needed to provide appropriate engineering education. This offers opportunities for higher education institutions and the Department of Education to support this development in the schools. In addition, comments suggest that it is important to consider the specific needs of engineering instruction in computational resource allocation, as, for example some tablet operating systems do not allow the use of engineering specific software or hardware interfaces.

IV. Conclusions

This research project is providing insight into what is being done in Maine K-12 schools regarding engineering-related instruction. The project goal is to build the foundation for the development of an efficient engineering pathway for Maine students. Preliminary survey results show that the most common engineering-related instruction is LEGO Robotics. This result is partly due to the presence of an organization in the state which provides local support and organization of local competitions for K-12 students. Survey results indicate that the majority of engineering related instruction is embedded in a course or module.

Preliminary results also show that engineering-related instruction is less frequent where high indices of economically disadvantaged students are found, in rural and urban cluster areas. The results also show that engineering related instruction is most common in Cumberland and York counties, which have the largest urban population in Maine. The information gathered at the local visits suggests that schools located in rural areas depend on grants to support engineering instructional programs.

Additionally, the information obtained in the surveys, indicate that the percentage of teachers with an engineering background is less than twenty percent. Principals also pinpoint the human resource and training area to be one of the dominant barriers to implementing engineering instruction. This information suggests that there is a need to support teachers to improve and increase local efforts to implement engineering-related instructions.

Survey results indicate that there is support among both principals and teachers to increase or implement engineering-related instructions. However, according to the results of the survey, financial resources, physical resources and time are the main barriers to implementing this type of instruction. Future visits to schools will help researchers gain more insight into these barriers, so that successful programs can be designed to provide an engineering career pathway for Maine students.

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References

[1] Humphrey, Dana. 2016. "Role of Engineering in Maine's Economy" Presentation at 12th Maine Society of Professional Engineers Educational Symposium. February 26, 2016, University of Maine, Orono. Presented by Dean of Engineering, Dana Humphrey, Ph.D., P.E.

[2] Jordan M. E., & Snyder, J. (2013) "Middle school students' conceptions of engineering",; 2013 IEEE Frontiers in Education Conference (FIE), Oklahoma City, OK, 2013, pp. 1945-1950.doi: 10.1109/FIE.2013.6685174

[3] Krupczak, J., Mina, M., & Young, J. E. (2012). Minors as a Means of Developing Technological and Engineering Literacy for Non-Engineers. 2012 ASEE Annual Conference & Exposition. San Antonio, Texas: American Society for Engineering Education. Obtenido de https://peer.asee.org/21696

[4] Kurpius-Robinson, S., & Baker, D., & Krause, S., & Roberts, C. (2006, June), A Valid And Reliable Survey Instrument For Measuring K 12 Teachers' Perceptions And Needs On Design, Engineering, And Technology Paper presented at 2006 Annual Conference & Exposition, Chicago, Illinois. https://peer.asee.org/651 *(references)*

[5] Wilson, S. M. (2016). Measuring the Quantity and Quality of the K-12 STEM Teacher Pipeline (SRI Education White Paper). Menlo Park, CA: SRI International.

[6] Robinson, M., & Kenny, B. (April de 2003). Engineering Literacy in High School Students. Bulletin of Science, Technology & Society, 23(2), 95 - 101. doi:10.1177/0270467603251300

[7] Welty, K., & Katehi, L., & Pearson, G., & Feder, M. (2008, June), Analysis Of K 12 Engineering Education Curricula In The United States—A Preliminary Report Paper presented at 2008 Annual Conference & Exposition, Pittsburgh, Pennsylvania. https://peer.asee.org/3547

[8] U.S. Census Bureau, (2012) 2010 Census of Population and Housing, , Population and Housing Unit Counts, CPH-2-2-21, Maine, U.S> Government Printing Office, Wahington D.C. Retreived 2/24,/2017 https://www2.census.gov/library/publications/cen2010/cph-2-21.pdf

[9] National Academy of Engineering and National Research Council. (2009). Engineering in K-12 Education: Understanding the Status and Improving the Prospects. Washington, DC: The National Academies Press. doi:https://doi.org/10.17226/12635.

[10] Essential Career Skills for Engineers, (1995) Shabab Saeed and Keith Johnson, Engineering and Management Press, Norcross, GA:

[11] Martin, R., Maytham, B., Case, J., & Fraser, D., (2005) "Engineering graduates' perceptions of how well they were prepared for work in industry", European Journal of Engineering Education, 30(2), pp 167-180, doi: 10.1080/03043790500087571

[12] Chenicheri Sid, N., Arun, P., & Patricie, M., (2009) "Re-engineering graduate skills - a case study", ,European Journal of Engineering Education, 34(2), pp. 131—139,doi: 10.1080 /03043790902829281

[13] Project Lead the Way - Find a PLTW School Near You, Retreived 2/24,/2017 https://www.pltw.org/experience-pltw/school-locator?search_school=&state=ME&lat=&long=

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