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# 4-H Engineering Design Challenge Program: Engaging Youth in STEM Learning

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# 4-H Engineering Design Challenge Program: Engaging Youth in STEM Learning

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**Abstract**. The University of Minnesota 4-H Engineering Design Challenge program is an experiential learning opportunity in which youth work with adult volunteers to create Rube Goldberg influenced machines to address real-world issues. The program components are designed to help youth develop STEM work skills using an Engineering Design Process, increase interest in STEM content knowledge, and explore STEM career interests/aspirations. Evaluation indicates a majority of participants learn the engineering design process, principles of mechanical engineering, teamwork, public speaking, and problem solving. Programmatic outcomes and supports provide for the successful replication, adaptation, and implementation in both formal and non-formal learning environments.

## INTRODUCTION

The University of Minnesota 4-H Engineering Design Challenge (EDC) program engages youth in problem solving as they design and create a Rube Goldberg-influenced machine. Youth practice an engineering design process, increase interest in STEM content knowledge, explore STEM career interests/aspirations, and develop STEM work skills.

Research suggests that nonformal/out-of-school educational settings, such as 4-H, are important to address science, technology, engineering, and math (STEM) learning needs (Bell et al., 2009; Krishnamurthi et al., 2014; Meyer et al., 2010; Smith et al., 2004). Extension, including 4-H, plays a vital role in educational reform that excites and trains a diverse, next-generation STEM literate workforce (Meyer et al., 2014; Heck et al., 2012; Kraft, 1999). Educators have mobilized at the national and state level to meet the call to increase youth interest and achievement in STEM fields. Minnesota 4-H decided to prioritize engineering design, creating a new program that aligns with the Next Generation Science Standards (Minnesota Standards: Science K–12, 2009; National Research Council, 2013).

## PROGRAM DESCRIPTION

The EDC program is an intensive learning experience of limited duration (two to six months). Youth in grades three through twelve work in teams of three to ten to design and create a multi-step machine. EDC machines use a series of chain-reaction steps that culminate in accomplishing a two-step task connected to solving a real-world issue. The program continues to evolve since its beginning in 2014; see Table 1 for examples of recent challenges.

The program offers a Level 1 and Level 2 option for teams. In Level 1, teams create machines using mechanical engineering. In Level 2, machines must include four types of engineering including mechanical, chemical, electrical, and fluid power. All teams use simple machines, including inclined planes, levers, wedges, wheels and axles, pulleys, and screws to create their machines.

In the EDC program, youth use an engineering design process model as a step-by-step approach to learning (Figure 1). This is a decision-making process, typically iterative, in which the basic science, math, and engineering concepts are applied to develop optimal solutions to meet a determined objective (Mangold & Robinson, 2013). The engineering design process incorporates a design cycle process model as outlined in the Next Generation Science Standards.

**Table 1.** Minnesota 4-H Engineering Design Challenge Tasks

| Challenge Year | Task |
|---|---|
| 2020 | Land a spacecraft on Mars and collect a sample off the surface. |
| 2019 | Remove pollution from water and place in an appropriate container. |
| 2018 | Plant a seed and water it. |

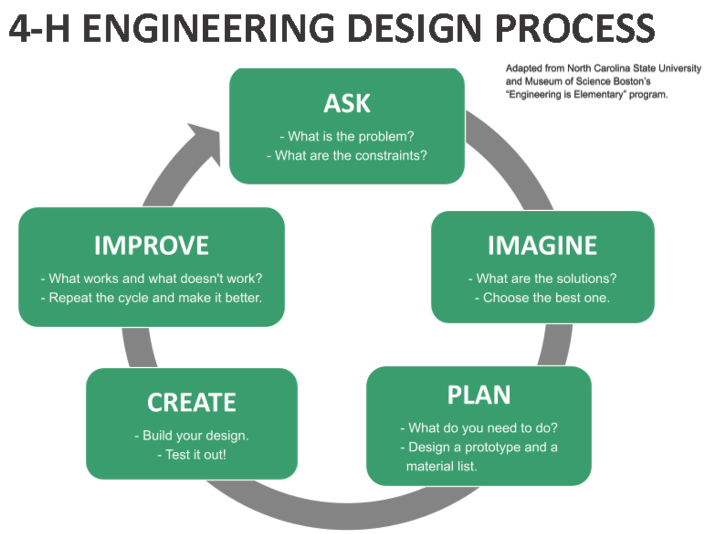


**Figure 1.** Engineering design process model. Adapted from North Carolina State University and Museum of Science Boston's "Engineering is Elementary" program.

Teams of youth document and communicate their learning to others in a public conference judging setting in their county or during an annual state showcase event. At the state event, youth present their machines to other teams, participate in STEM learning sessions, tour a university campus, hear from engineering faculty, and learn about career opportunities from STEM professionals. In addition, teams recognize peers for special awards honoring creativity, problem solving, and teamwork.

## PROGRAM SUPPORTS

The program recruits adult volunteers from local communities to serve as team coaches. Coaches guide teams as they apply an engineering design process to create their machine, helping youth learn content and develop teamwork and problem-solving skills. They support teams as they share their knowledge and showcase their machines.

To support coaches, Minnesota 4-H provides a volunteer role description and online resources, which include a clear program description, machine building specifications, and curriculum. We conduct personal phone calls during the program cycle to offer feedback, provide guidance and answer questions.

We developed an EDC curriculum to facilitate a learning process that incorporates the practices of science and engineering. Coaches used the curriculum to engage youth in engineering content (types of energy, energy transfer, simple machines). Learning activities allowed youth to identify engineering problems, provide solutions backed by evidence, and engage in oral presentations and machine exhibitions. For Level 2 teams, we developed a guidebook to help teams apply four types of engineering to their machines.

## PROGRAMMATIC OUTCOMES

We used a variety of methods to evaluate program design and outcomes. Initial program design improvements were completed based on evaluations from volunteer coaches and judges at the state showcase. Results showed youth learned STEM work skills including teamwork, problem solving, public speaking and critical thinking. Moreover, youth learned STEM content, including the engineering design process, simple machines, and energy transfer. Over half of the youth participants indicated they would like to study or pursue a career in engineering as a result of the EDC. For purposes of this article, we reference the 2019 evaluation results, which parallel prior years of evaluation data (Figures 2, 3, 4 and 5).

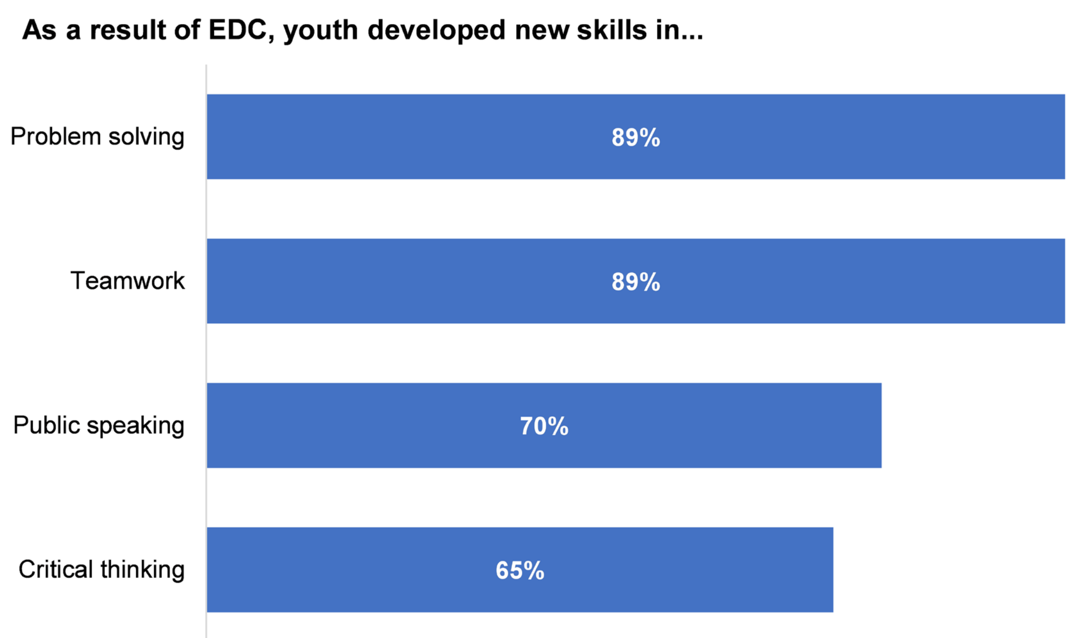


**Figure 2.** Coaches' perceptions of youth learning STEM work skills (N = 37).

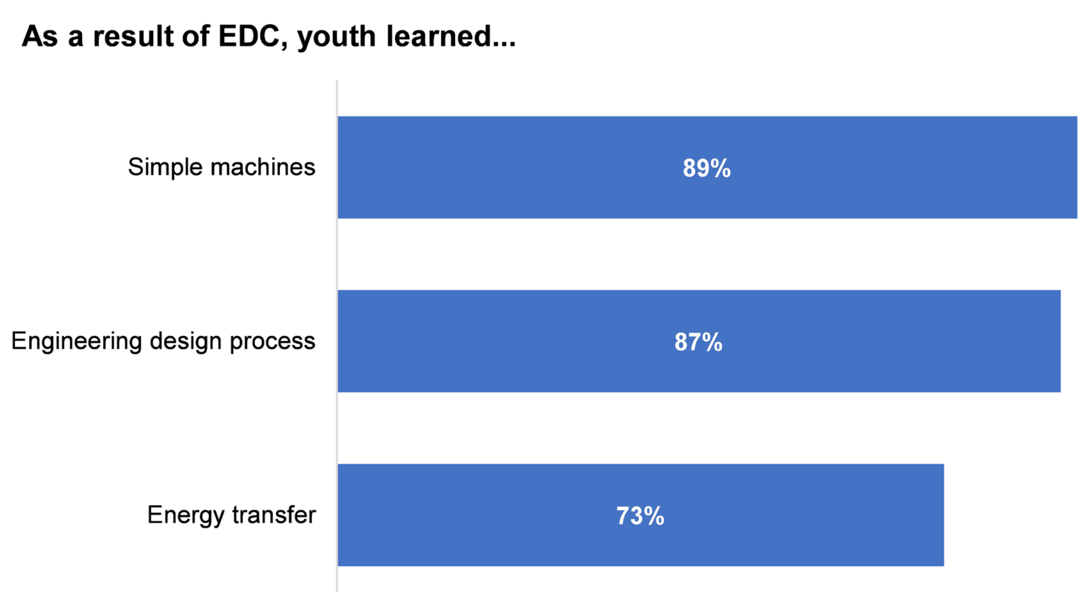


**Figure 3.** Coaches' perceptions of youth learning of STEM content (N = 37).

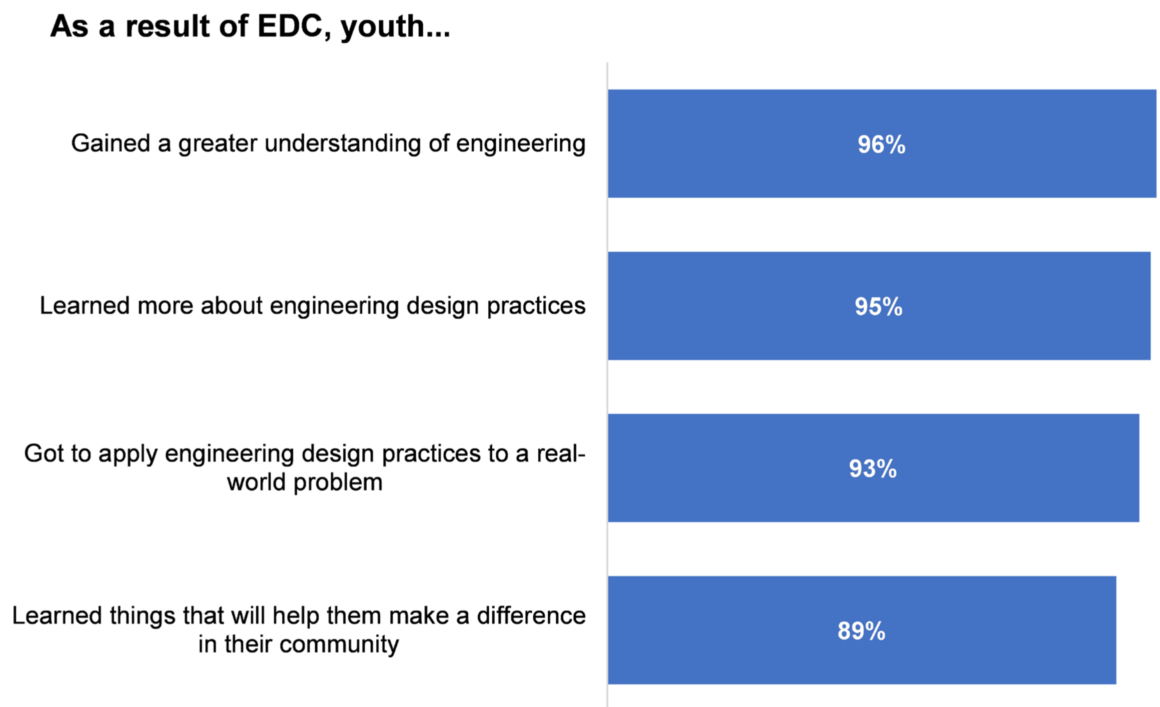


**Figure 4.** Youth participants' reported learning (N = 92).

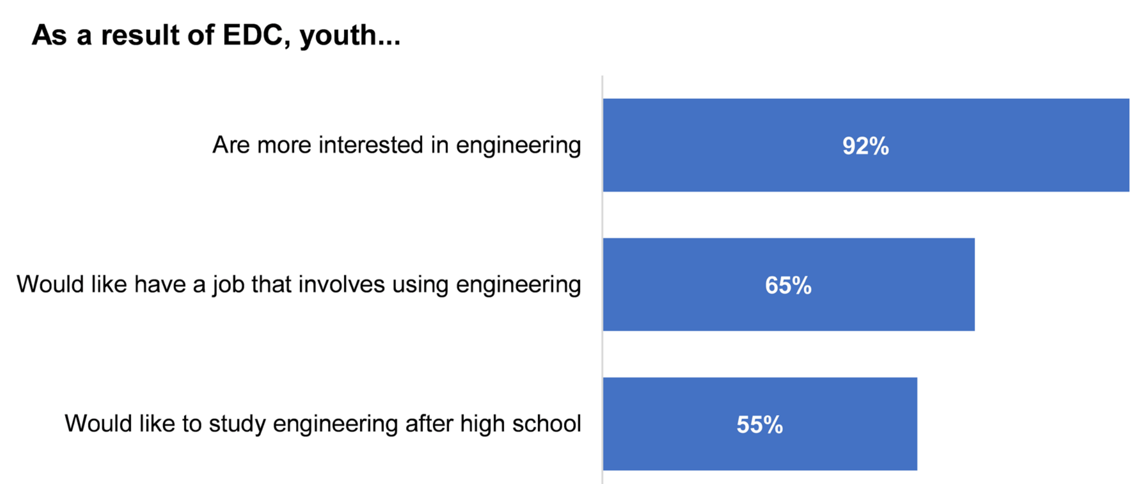


**Figure 5.** Youth participants' interest in engineering (N = 92).

## CONCLUSION

The University of Minnesota 4-H EDC program is a highly engaging, experiential learning opportunity for youth to develop STEM work skills as they use an engineering design process to address an issue in a team environment, work directly with adult volunteers, showcase their learning, and connect to STEM careers. Programmatic outcomes and supports provide for the successful replication, adaptation and implementation of the EDC program in both formal and non-formal learning environments.

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