HOW CAN ROBOTS HELP?
LEARNING OUTCOMES FROM A HUMAN-CENTERED ROBOTICS CURRICULA

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Using a human-centered robotics approach, an inquiry curriculum was developed for middle school students to support secondary school students in designing, building, and testing telepresence robots. Inquiry-based pedagogical strategies guided the interactions of students who were presented with the practical engineering problems of building and controlling robots meant to work in distant environments, such as controlling robots in a classroom in another part of the country. Teachers in the three classrooms adapted the human-centered robotics curriculum to meet local needs and standards. Pre-post test comparisons demonstrated that all students made significant knowledge gains, but that there was variability across the three sites. Implications for further revision are discussed.

Keywords: Robotics, Engineering design, Inquiry-based learning

PREFERRED FORMAT: on-site in Warsaw; papers available (Gomoll et al., in press, 2016, 2017)

PURPOSES AND PERSPECTIVES

To pique the interest and improve the knowledge of underrepresented middle and high school students in STEM, our project team developed a human-centered robotics (HCR) curriculum for students to design, build, and test telepresence robots for everyday use (Schaal, 2007). Human-centered robotics (HCR) involves the development of robotic technologies and applications *for everyday use*, whereas telepresence robots enable communication, operation and exploration across enormous distances, making the technology very relevant for today's world. Inquiry-based pedagogical strategies guided the interactions of students who were presented with the practical engineering problems of building and controlling robots meant to work in distant environments, such as controlling robots in a classroom in another part of the country (Hmelo-Silver et al., 2016). Learning goals centered around engineering design practices, systems thinking, and circuitry, with online learning resources available on a just in time basis. As part of a program of design-based research, we also sought to understand the local contexts as the three schools implemented the curricula in ways that met the needs of those instructional contexts.

METHODS AND DATA SOURCES

The curriculum, which asked students to design, build, and code human-centered robots, was implemented in three schools (one high and two middle schools) in spring 2016. In the high school, the HCR curriculum was implemented in an Introduction to Engineering class at a residential public high school that serves a majority of students who are under-represented in STEM careers. In Middle School A, the HCR curriculum was enacted in an elective for gifted students. In Middle School B, a rural public school, HCR was part of a STEM elective. Across school sites, we anticipated differences in learning outcomes due to varying local needs and course discipline and structure. Observations and document analysis were used to better understand the local context. See Table 1 for an overview of each school site.

Table 1: Curriculum Enactment Across School Sites

School Site	**Context**	**Curriculum Duration**	**Key Features of Curriculum Enactment**
High School	Intro to Engineering course Rural community	5 weeks	• Students in groups of 3-5 with assigned group roles each week • All robots created for same purpose, which students brainstormed together • Assigned common set of parts to be used by all groups (design a robot that students who are sick can use to

	Boarding School		attend class) but groups decided how to design and build this robot. • Prioritized programming skill development and the engineering design cycle • Communicated with Middle School B to share design ideas and process
Middle School A	Extended Learning Program (for gifted students) Urban community Traditional public school	6 weeks	• Students worked in pairs • Built robots to serve local needs (e.g. . deliver newspapers to special education classroom) • Interacted with circuitry kits for one class period • Instructor-designed additional mini challenges (e.g., drive your robot in a square) • Prioritized programming skill development
Middle School B	STEM Elective Rural community Traditional public school	5 weeks	• Students worked in groups of 4 • Groups created several design ideas for robots based in local needs; voted on one design for every group to build and adapt (a robot to help the instructor with administrative tasks during class) • Several class periods with circuitry kits • Prioritized engineering design cycle • Communicated with High School classroom to share design ideas and process

To assess what students learned, we examined learning outcomes through a pre- and post-test. These were assessed through a combination of questions: authentic scenarios related to HCR, open-ended response items related to engineering design (Resnick, 2007), systems thinking (Hmelo-Silver et al., 2015), electrical circuits, and multiple-choice items related to modeling (AAAS, 2016).

Fifty-two middle- and high-school students' pre and post-tests were scored using a detailed scoring scheme with higher scores reflecting increasingly sophisticated thinking. Two raters scored the same 15 of 52 pre and post-tests (29%) with good interrater reliability indicated by a kappa of .80.

RESULTS

The key features of the curriculum enactment are shown in the rightmost column of Table 1. There was variability in the student populations, prior achievement (e.g., heterogeneous class in Middle School B compared with gifted students in Middle School A) as well as the discplinary contexts. They implemented the unit for simular amounts of time but there were differences in terms of the activity structures that the teachers designed, the HCR goals, and what knowledge was prioritized in each site.

A comparative analysis showed significant improvements from pre- to post-tests across all three schools (Table 1). Effect sizes ranged from .74-1.26 (see Table 2), indicating moderately large to very large effects, with greater effects seen in the high school and middle school A compared with middle school B.

SIGNIFICANCE

The presentation will provide examples of specific achievements and conjecture about the elements of the curriculum that made these achievements possible and where there is room to improve in the areas of HCR, systems thinking, circuitry, and engineering design, in particular, creating learning resources that support the kinds of variability in implementation that we observed. In addition, further analysis is ongoing to help address the questions about motivation and engagement. In this presentation, we will consider how these results inform not only our own project's curriculum design for future iterations, but also inform how the assessments and curriculum can be designed to incorporate abstract and developing standards. In particular, recent revisions to state and national standards have led to increased emphasis on engineering design and computer science education, which is reflected in curriculum revision and the online resources being developed. Revision will continue the focus on how can we continue to use this kind of unit to motivate diverse students to engage with STEM learning by connecting it to their everyday lives. As part of a program of design-based research, we will consider how these results led to refinement of both our curriculum and the underlying theory that provide opportunities for diverse students to engage with ambitious learning practices and complex STEM content.

Table 2: Descriptive Statistics and Effect Sizes in Different School Contexts

	N	Pre-Test (Mean)	Pre-Test (SD)	Post-Test (Mean)	Post-Test (SD)	t	Effect Size
High School	16	43.00	16.43	61.06	14.20	5.03***	1.26
Middle School A	10	44.80	11.20	64.20	15.62	3.92**	1.24
Middle School B	26	46.27	11.28	56.92	16.69	3.79**	0.74

**: $p < .01$; ***: $p < .001$

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POTENTIAL AREAS OF COLLABORATION:

Robotics and technology contexts for STEM education; technology-support for problem-based learning

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