From Automation Joy to Perseverance in Engineering: How Parents Conceptualize the Impact of Robotics on their Children

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Abstract

The question guiding this research was, in what ways do parents perceive the impact of robotics in advancing their children's interest in knowledge of and learning about science and engineering. This case study draws on communities of practice and activity theory to explore the lenses through which parents conceptualize the attributes of robotics towards increasing their children's preparation and interest for engineering. The study revealed that parents perceive the acquisition of pertinent knowledge and skills as outcomes of interdisciplinary and authentic learning opportunities generated through series of goal directed activities. In addition, it was found that parents viewed beneficial characteristics of robotics across a wide range, from individual to collaborative learning; from acquisition of automation skills to immersion in multi-media projects; and from hands-on manipulation of raw materials to contentious discussions regarding optimal designs. In closing, the article situates the parents' insights within recommendations garnered from some leading reports focused on strategies and conduits for broadening participation in science and engineering.

Introduction

Several research and policy reports posit that individual opportunities and societal requirements within science, technology, engineering, and mathematics (STEM) fields are experiencing rapid growth across many global regions including the United States (e.g., Commission on Mathematics and Science Education, 2009; National Science Board, 2010; National Science Foundation, 2009).

Knowledge of STEM is not only considered to be critical for individuals entering STEM disciplines, rather for a broad range of academic and vocational pathways, including ones which until recent times have been mostly associated with humanities and liberal arts (Commission on Mathematics and Science Education, 2009; National Research Council, 2011). Therefore, it is not surprising that among the 20 fastest growing occupations projected for 2014; more than three-fourths are expected to require knowledge of STEM disciplines (Commission on Mathematics and Science Education, 2009; Lacey & Wright, 2009; President's Council of Advisors on Science and Technology, 2010).

Hill, Corbett, & St. Rose (2010) view the STEM pipeline as a universal metaphor representing the *"*path from elementary school to a STEM career*"* (p. 17)). Historically, minorities and women have demonstrated lower participation within STEM fields, particularly within physical sciences and engineering (Hill, Corbett, & St. Rose, 2010; Jacobs & Simpkins, 2005; National Science Board, 2010). Individuals who refrain from matriculating into STEM educational choices or withdraw from pursuit of degrees or careers in STEM disciplines are often referred to as "leaks in the STEM pipeline" (Jacobs & Simpkins, 2005, p. 3).

Within the above dynamics, it is important to point out that the recent decade has demonstrated some improvement. For example, since 2001, undergraduate education in the fields of science and engineering has experienced growth. However, most of the recent growth has occurred either in biological science fields or among people of Asian heritage. Simultaneously, engineering and computer sciences have not as yet attained matriculation or graduation levels previously seen during the 1980s (National Center for Educational Statistics, 2009; National Science Board, 2010).

Investigation of learning environments and associated variables, has increasingly led us to understand that in order to make meaningful and lasting impressions on youth, the learning pathways through which school age students are introduced to STEM disciplines need significant transformation (Britner & Pajares, 2006; Hill, Corbett, & St. Rose, 2010). Subsequently, more effort is required within and outside of schools to prepare and inspire youth to explore, participate, and persevere in STEM opportunities, during both, academic and occupational periods (Hill, Corbett, & St. Rose, 2010; President's Council of Advisors on Science and Technology, 2010).

In the last decade or so, robotics has been positioned as learning environment that engages K-12 students in intellectually challenging and authentic learning experiences (Bennitti, 2011; Hernando, Galan, Navarro, & Rodriguez-Losada, 2001; National Research Council, 2011; Sevo, 2009; Verner & Ahlgren, 2004).[1] The key experiences in robotics comprise design, construction, and automation of individual robot parts in order

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[1] Williams, Ma, Prejean, Lai, and Ford (2007) are likely to argue that robotics has not been irrefutably linked with positive impact on K-12 students' learning.

to achieve coordinated set of functions in the form of a single entity capable of competing under intense conditions (Benitti, 2011; Verner & Ahlgren, 2004). It is understood that participation in hands-on experiences such as those witnessed in robotics are strongly correlated with increased interest of youth in engineering and information technology (Hernando, Galán, Navarro, & Rodríguez-Losada, 2011; National Academy of Science, 2011; President's Council of Advisors on Science and Technology, 2010). The steady increase in voluntary enrollment of K-12 students in robotics clubs is viewed as a strong indicator of their positive impact (Benitti, 2011; Verner & Ahlgren, 2004).

For example, at its inception 20 years ago, the For Inspiration and Recognition of Science and Technology (FIRST) organization, began with modest enrollment numbers; currently, FIRST engages approximately 100,000 students in its robotics programs specifically geared towards high school students (US FIRST, 2012).[2] Each year, robots are constructed and tested out in game-like settings. Teams including 10-30 students, design, construct, and maneuver mechanical and electrical components of robots within the complexities of pre-set rules. Customized software programs are written for each segment of the game—autonomous and remote-operated. First, electrical components are placed in specific locations on the robot, and then, the mechanical pieces are designed in tangent with them. Layers of detailed computerized instructions control a robot's capabilities and maneuvers during interactions with other robots playing on the same field. Each year, a new game design accompanied by rules aligned with the conceptual design is released by the FIRST organization. All the robotic teams registered to play and compete in local, regional and national tournaments are expected to adhere to the prescribed game and its rules. In the initial phases, although, attention to regulations is important, coming up with a solid design plan is key priority. Design plans continue undergoing modification throughout the build schedule, often extending into the competition season. Because of the emergent nature of the design, softer and less expensive materials like plywood are used to construct prototypes; as the design acquires sophistication, firmer materials, such as aluminum sheets and iron widgets are put in place.

Literature Review and Theoretical Underpinnings

Factors Influencing Readiness of Students

Successful entry and sustained participation in STEM fields, particularly physical sciences and engineering are understood to be highly correlated with academic and emotional readiness of youth to pursue opportunities in STEM fields (Ceci & Williams, 2009; Eccles, 2005; Hill, Corbett, & St. Rose, 2010; National Science Foundation, 2008; President's Council of Advisors on Science and Technology, 2010; Zeldin & Pajares, 2000). The academic preparation of school age students begins with strong foundations of coursework in science, mathematics, and scientific literacy (Commission on Mathematics and Science Education, 2009; Hill, Corbett, & St. Rose, 2010; National

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[2] The *FIRST* Tech Challenge (FTC) and the *FIRST* Robotics Competition (FRC) are two national robotics competitions operated by US *FIRST* in which teams of high school-aged youth design and build robots that compete with other teams to complete a set of prescribed tasks.
Center for Youth and Communities, Heller School for Social Policy and Management, Brandeis University (2011, p 2).

Science Foundation, 2008, 2010; President's Council of Advisors on Science and Technology, 2010). Mathematically relevant skills include formulation, conversion of numerical values, and use of quantitative evidence to justify solutions (National Mathematics Advisory Panel, 2008). In order to nurture mathematical and abstract thinking, some researchers have shed light on the importance of facilitating spatial knowledge and skills among children (e.g., Lohman, 1994; Newcombe, 2010; Wai, Lubinski, & Benbow, 2009). Likewise, skills considered necessary for success in science fields encompass abilities to apply and interpret scientific knowledge and offer scientific explanations of daily phenomena (National Academy of Sciences, 2009; National Research Council, 2011). Lesser information is available about the requisites of success in engineering and information technology; however, reformulation and reapplication of existing processes or structures are among frequently identified attributes (National Research Council, 2011; Sevo, 2009).

Communities of Practice

Communities of practice are considered fundamental units of social learning systems, where members are expected to build upon individual and collective competencies through shared experiences. In communities of practice, members are distinguished by unique set of knowledge and skills that are used towards achievement of focused goals within specific contexts, such as learning how to play chess proficiently, presenting a paper in front of academic science consortia, etc. Theories guiding social learning systems assume that knowledge acquisition and the processes of knowledge acquisition are situated within the complex functioning of self-organized groups guided by self-established goals and competencies.

As such, the social learning that takes place within communities of practice can be viewed within the intertwined domains of members' interactions, identity creation, and social and intellectual growth alongside each other (Wenger, 2000). Complex tasks create authentic contexts for learners to engage in meaningful learning opportunities (Brown & Duguid, 1996; Wenger, 1998). Within authentic contexts, learners take ownership of their contrived and structured experiences, the tools through which learning is enabled, and the artifacts through which learning is represented (Brown & Duguid, 1996; Engestrom 1999; Jonassen, Howland, Marra, & Crismond, 2008; Wenger, 1998).

Three characteristics distinguish a community of practice from a group of people working together. First, members intentionally make personal contributions and also hold each other accountable towards achievement of joint enterprise (Wenger, 1998, 2000). It is important to mention that all members are not expected to demonstrate comparable levels of proficiency, rather, almost always members tend to demonstrate wide ranging knowledge and experience—from novice to proficient—all, contributing to shared enterprise at individual level of expertise (Engeström, 2007, 2008; Greeno, 2006; Wenger, 2000). Second, the members build upon individual competencies through regular interactions that are driven by clearly established norms. By participating in a community of practice, individuals acknowledge the importance of shared conventions and mutual beliefs towards achieving collective goals of members (Greeno, 2006, Wenger, 1998). According to Wenger (2000), a key requisite within a community of practice, is for individuals to "be able to engage with the community and be trusted as a partner in these interactions" (p. 229). Third, members of a community of practice use shared resources, such as tools, vocabulary pertinent to group activity(s), problem solving methods, modes of information exchange that enable the execution of a joint enterprise. As such, the community itself can be viewed as the curriculum and learning as the outcome of activities among participant members (Wenger, 1998).

Activity Theory

Activity theory is associated with the idea of conducting a specific action on a designated object (Engeström, 1987, 1999; Kaptelinin & Nardi, 2006). Some early references to activity theory can be found within Vygotsky's (1978) work; he viewed learning as mediated process, wherein people carry out actions on an object in order to achieve a desired outcome. Following a small break, researchers like Engeström (1987) and Leont'ev (1978) escalated the concept of activity theory from individual to group achievements.

In most frequently cited model, the basic components of activity theory include: subject, object, tool, outcome, community, and rules (Engeström, 1987, 1999). The subject is the individual who conducts an action or series of actions (activity) on an object in order to achieve a specific goal (outcome). The tool is seen as a mediating entity that allows the subject to conduct some action (activity) on the object. Although, the outcome is portrayed as the desired end state; it is important to note that the activity theory recognizes that outcomes are not fully predictable because activities are likely to experience disruptions and pitfalls (Engeström, 1987). Community and rules are recent additions to Engeström's (1999) positioning of activity theory, whereby the community is defined as the group of people who are motivated to act upon the same object under parameters of commonly accepted guidelines (Engeström, 2007). While the subject-object axis continues to operate as the fulcrum of activity theory, more recently, Taylor (2009) has proposed that activity theory should include communication and discourse because they bear strong influence in determining how subjects' negotiate object-tool relationships in order to generate outcomes.

Now, it may be helpful to provide an example that illustrates the between and among the various components. A simple representation of the different elements of activity theory can be understood within a teacher (subject) crafting a lesson plan (object) to teach a fifth grade science lesson (outcome) using a software program (tool). In order to accomplish the activity the teacher builds upon the ideas shared by colleagues (community) under a collective agreement regarding what and how to develop the curricula (rules).

Research Method

This study took place as an adjunct of a broader investigation regarding the involvement of parents in their children's educational progress within STEM fields. This narrow investigation specifically focused on robotics as a learning environment, and the perceptions of parents about the ensuing impact of their children's participation in robotics. Although the role of parents in children's education has been extensively qualified in extant literature, the specifics of how parents perceive the impact of different kinds of learning environments on their children's persistence in the STEM pipeline remains relatively unexplored. Using a case study analysis, this research draws upon understandings emerging from the fields of communities of practice and activity theory to investigate and describe the different ways within which parents conceptualize the impact of robotics on their children. The primary question guiding this study was: in what ways do parents perceive the impact of robotics in advancing their children's interest in acquisition of knowledge and learning about STEM disciplines. A sub-question was: how do parents conceptualize the variables associated with children's learning within the context of constructing a robot?

Research Context

This research study took place in a purposefully selected group of parents (n=39). Their children are members of a robotics group: Access to Scientists and Engineers (ASE),[3] an active member of the FIRST organization. ASE is located on the outskirts of a medium sized city in the northeastern corridor of the United States. Since 1999, each year, professionals voluntarily mentor 35-40 youth to learn fundamentals of robotics and participate in friendly interactions and competitions with other teams. The study was conducted over a period of 18 months starting from September 2010 and culminating in March 2012. A key reason for selecting ASE group was grounded in their high percentages of matriculation into STEM degrees at two and four year post-secondary institutions. In contrast to national trends which indicate that each year less than 15% of high school graduates matriculate into post-secondary STEM degrees, data obtained from the ASE governing board reveals that the general trajectories of ASE participants demonstrate significantly higher percentages (National Center for Educational Statistics, 2009). For instance, in 2011, graduates of the ASE program matriculated into STEM or STEM related degrees at two or four year post-secondary institutions at more than three times the national average. The number of students matriculating into engineering degrees was four times the national average.

Research Sample

Study participants demonstrated a wide range across educational, economic, and occupational attributes; among the 39 parent participants, 23 demonstrated middle class characteristics, i.e., some level of post-secondary education among one or both parents, and familial access to basic lifestyle affordances (Gilbert, 1998). Sixteen parents belonged to low income or working class groups (Gilbert, 1998). Diversity was also seen across racial/ethnic backgrounds—the research sample included students whose families are African American, Asian, Caucasian, Hispanic, Middle Eastern, and Mixed Race. Also included were four single parents with sole or shared custody of their children; one grand-parent serving as the primary caregiver; two step-parents; two recent immigrants, one with limited proficiency in English; and two parents of children with learning disabilities. Their children attend a mix of public (n = 22) private (n = 9), and home school (n=1); out of these, seven students attend single gender schools (n = 2 boys; 5 girls).

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[3] A pseudonym

Data Collection and Analysis

The study included multiple sources of data in order to strengthen the construct validity of the findings (Maxwell, 2005; Stake, 2003). The findings of this study were based on the results of surveys, interviews, and focus group discussions conducted among parents (n = 39; 18 fathers, 21 mothers) whose children were members of the ASE program during the years of 2009-2011. In some cases, more than one adult family member was included per child. Although the data was collected from participants representing mixed-class, mixed-race, and mixed-gender, the same survey and interview protocols were used to ensure a consistent sampling.

The parent surveys included a combination of multiple choice and short-answer questions and sought general demographic information pertaining to participants. In particular, prompts were attentive to participants' perceptions about the importance of STEM fields in general; importance of engineering within children's educational choices; the range of resources and learning opportunities perceived to be useful by parents within the realm of their children's progress in engineering. Within the results of the parent interviews, specific areas of benefits associated with children's participation in the ASE program were focused on, e.g., automation principles, computer programming, design procedures, construction of robot. Finally, the focus group discussions were facilitated among four to five parents at a time, with the explicit goal of further probing their discernments regarding the impact of the ASE program on their children's learning trajectories.

Data analysis overlapped with some phases of the data collection, and took place from February 2011 through March 2012. The data analysis was guided by Maxwell's (2005) postulation regarding validity of qualitative research by deliberately paying attention to the nuanced details about people's actions and interactions. Understandings from three bodies of extant literature—students' readiness for exploring and entering STEM fields, communities of practice, and activity theory—were collectively used to generate codes and themes to sort and categorize data. Emerging themes within surveys, interviews and focus groups were tagged and categorized using software tools; though, at several junctures, the researcher manually revisited the tags and codes. Recursive analysis of data proved to be helpful in checking for corroborative themes and capturing noteworthy conclusions of the study (Lincoln & Guba, 2000).

Limitations

In spite of thoughtful design and implementation, the study has limitations. First, the study focused on a selective group of parents and their adolescent children affiliated to a well-established robotics club with a successful track record.[4] Therefore, the students are likely to have prior interest in pursuing science and engineering. Second, ASE program is located within 50 miles of well-established biomedical and industrial research organizations; it is likely that parents may have acquired knowledge about the importance of STEM fields and variables particularly associated with success in STEM fields. Third, the study was able to record students' success into STEM disciplines only until matriculation into post-secondary degrees. However, transition periods between

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[4] Defined by longevity of the program and low attrition levels among mentors and participants

secondary and post-secondary education is of significant value to researchers because large numbers of students are unable to complete STEM degrees even after matriculation.

Findings

Data analysis revealed four primary categories of impact through which parents identify the benefits of their children's participation in robotics. In the following sections, each of these themes is discussed in detail.

1: Parents' Perceptions Regarding Advancement of Problem Solving Skills

Parents' narratives reveal that opportunities for problem solving within the paradigm of robotics are omnipresent. In spite of the differences in parents' descriptions of problem solving, e.g., "cooking new ideas," "determining the tear on the aluminum sheets after 50 runs'" and "finding ways to balance weight without dropping height," the importance of new or adapted ideas to solve problems emerged as a central theme. These parents indicated that children found the aspect of delving into design based construction not only stimulating but also powerful means of learning new concepts and modifying or clarifying previously learned ideas. For example, one father revealed that his daughter was fascinated by the construction activities taking place because they allowed iterative experimentation and revision of the numerical variables until she and her team members were able to balance the weight and height of the robot so that it was able to stand without support:

> My daughter is often so excited when she gets back from a whole day at the robotics lab. Like, yesterday, she tells me, "The [prototype] was too top heavy; maybe a subpart in the [prototype] was weak. We tried to fix that all afternoon." She liked that she and the other kids are allowed to tinker with the weight and height of different pieces to figuring it out.

2: Parents' Perceptions Regarding Iterative Processes and Authentic Contexts

Earlier in the article it was stated that activity theory involves the interactions of subjects with objects and tools within iterative engagements (Engestrom 1999; Jonassen, Howland, Marra, & Crismond, 2008).

Close to three-fourths parents noted that their children enjoyed being guided through a rotation of many experiences: electrical and mechanical activities, website construction, robot repair etc. One parent summarized his understanding of the underlying experiences:

> Before building begins on any [component], the team must first decide each [component's] function – how it will be used, how it will interact with other parts of the robot, what action it's supposed to complete. Once functions are assigned to individual parts of the robot, students get to brainstorm multiple designs. Then they start making plans for the [prototype].

The mother of a male eleventh grader was gratified to see that encompassing activities had moved away from being individual to collective responsibility, and from isolated ideas to interconnected ideas. To affirm her perspective, she recalled:

> I saw one time, one student designed the sensor, and [initially], other students were quite accepting. Then one student said, “I don’t think this is going to work because there is not enough tension in the coil for it bounce back rapidly enough before the robot has to make a backwards movement.” And then two kids started drawing a model on a large sheet of paper and hung it on the wall.
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> Then the mentor said something like, “we may not know if any design is going to work or not, till we test them out.” And one more kid pulled out a whiteboard and said, “let’s us all sketch here to see what the different designs will look like.” And then, then they were comparing the differences in the [sketches] to [determine] which design made most sense to test out. Before actually building anything.

Parents see their children engaging in complex problems accompanied by several conditions that necessitate series of interactions and negotiations with peers. A mother, whose son has ADHD[5], summed up the cumulative value of the shared and yet intense experiences in the iterative process from design phase to actual construction of the robot:

> I imagine stuff like this must be going on all the time. This [aspect] of asking each other for more information but not agreeing to all ideas that are tossed around…this working with several boys and girls who are also looking for ways to build a solid robot. But I find them also pulling others’ ideas apart in order to get a good structure in place…I guess all this is needed for building a [functioning] robot.

3: Parents’ Perceptions Regarding Increased Capabilities in Technology

Technological experiences provide another layer of outcomes through which parents expressed their positive perceptions regarding robotics. Two broad categories of technology experiences were resonant within the parents’ accounts: software programming and website construction. Parents argued that design and construction of a well-designed robot provide a “real need” for students to write codes and test them out in an environment that is naturally amenable to multiple attempts. For example one father reported: “by learning to write codes for automation and manipulate the different physical components of the robot, my son and his friends are able to explain the content of images, to construct images or develop learning materials for others to follow.” In turn, parents claimed that these activities were helpful to their children in understanding mathematical and mechanical concepts underlying the digital representations.

The second most commonly technology experience identified by parents pertained to the design and construction of the team website. In addition to constructing a robot, sub-groups of ASE students take charge of updating the team’s website; this includes creation of several elements, e.g., team members’ profiles, animated manuals in response to each year’s game design, safety procedures, simulation(s) of the game design and possible scenarios. The website becomes the tool through which team members display all artifacts associated with the evolution of each game’s custom designed robot, and communicate with members of other teams. Every 2-3 years, ASE mentors encourage students to take down the entire website and construct it from beginning.

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[5] Attention Deficit Hyperactivity Disorder is associated with difficulty in sustained concentration. According to the Center for Disease Control and Prevention, 9.5 percent of boys and 5.9 percent of girls are diagnosed with ADHD.

Sometimes, students utilize previously displayed text and graphic components within reformatted arrangements.

One parent stated, “when my kid has to create an electronic manual on how to design a [sensor] for the new game, it is definitely more inspiring then when he is randomly assigned any topic in tech class. It is not inspiring to a 17 year old to work on a random topic picked out of an old fishbowl.” He sought his wife’s opinion for additional comments, “do you remember what else Jason enjoyed at ASE?” In response, she called out from the kitchen, “the website. Do you remember how much he liked making the website? He and his friends made that whole system of how many different ways the game could be played. All this makes him want to go to engineering.”

During the focus group discussions, 14 more parents concurred with the above and pointed that in contrast “to simply viewing a simulation on a computer screen,” ASE students learn how to program an automation sequence and create ‘how-to’ manuals for sharing with other teams. The opportunity to “do things” was found to be of more value to the parents whose children find classrooms sedentary by nature.

4: Parents’ Perceptions Regarding Cognitive-Emotional Impact

Finally, the above three areas are underscored by these parents’ views in terms of emotional satisfaction and motivation gained as a result of participation in robotics. For the most parts, this attribute stood out overwhelmingly. While some parents were not able to locate indications of problem solving or shared and collaborative learning, they commented on how routinely labor intensive activities provided their children with an invigorating learning environment. Further, the gradual increases in confidence to accomplish complex tasks enable their children to overcome learning challenges that may have seemed inimical during earlier attempt(s). Ultimately, this cultivates readiness for the rigor associated with pursuing engineering and other challenging majors as viable post-secondary options. For example, one father reported his son’s takeaways about activities involved in robotics:

> All this…getting the robot together in one piece, it is hard work…I like it so much because I can always get help for the difficult stuff. I am guessing going to engineering school will be like this, I will need to ask for help for doing [complex] stuff. Engineering will need me to work hard too.

Secondly, according to many parents, iterative and authentic learning within physical sciences lacks in schools. In one parent’s words: “either my daughter submits a perfect lab report in physics or not such a good one. There is only one shot at doing it right.” In contrast, another parent opined, “at ASE, other kids and mentors keep pointing out [aspects] that need improvement…until my son gets it to a level of being [thorough]. According to my son, that is the most exciting part of being in the ASE program, he can keep doing same [tasks] again and again till he gets it right. Just like an engineer. There is no full stop.” Yet another parent identified an attribute that was meaningful for her child: the lack of competition to participate in exciting learning opportunities:

> At [my son’s] school the way Science Olympiad works is that all the kids in the class have to compete to participate, then the top 15 kids are chosen for the training. Well he did not make it…he was 17 or 18 in the [rankings]. Maybe 19 kids, but that’s it. Now he was left out…I said let him just come to the training class…just so he can learn, he doesn’t have to compete, just be part of it. The teacher said no

> because she wanted to concentrate on kids who had a chance of winning…so he, he got left out. Here, at [ASE], he is getting all this exposure to technology, to learning about sensors, to cutting devices and tools…and all this hard, difficult stuff that is fun to learn…well…all this needs to happen at school too.

Discussion

The earlier sections of this article also referred to recent research and legislative works focused on broadening STEM participation among youth in the United States. In spite of a few differences, several comparable tenets consistently emerge across them.

Recommendations of Leading STEM Reports

To begin, the President’s Council of Advisors on Science and Technology (2010) posits that “STEM education is most successful when students develop personal connections with the ideas and excitement of STEM fields” (ix). The report recommends that providing youth with engaging activities that spark their curiosity should be a key underlying objective of STEM curricula. The encompassing activities should advance learning strategies and incorporate including hands-on materials and assessments capable of transforming the quality of STEM education for students. This is likely to empower students from different strengths and perspectives, working in shared spaces and increasing scientific, technological, and mathematical knowledge and skills.

The Committee on Highly Successful Schools or Programs for K-12 STEM Education (National Research Council, 2011) argues that successful entry and retention in STEM-related majors and careers require students to apply and use STEM knowledge in settings that move beyond tests, such as solving problems and working collaboratively. While participation in formal STEM education opportunities are useful, internship and research experiences created through out- of-school clubs or programs provide stimulating contexts for harnessing students’ interest in STEM fields.

The report, “Fostering Learning in a Networked World” compiled by the National Science Foundation Task Force on Cyberlearning (2008), espouses the facilitation of 21st century knowledge and skills among students through intertwined understanding of technology and science. The report strongly recommends for the deliberate placement and utilization of technology-based instructional tools within learning activities. Finally, the Commission on Mathematics and Science Education (2009) proposes that students benefit more from well-crafted learning experiences that are not dependent on rote memorization of content.

The Parents’ Perceptions Vis-à-Vis Recommendations of Leading STEM Reports

In the context of above understandings, based upon how parents conceptualize the impact of learning environments comprising meaningful attributes that promote learning and excitement about learning this study provides some meaningful takeaways. The above themes highlight the parents’ views regarding ongoing formative valuations provided by children’s peers and mentors, as more meaningful and transformative rather than grades and evaluations based on stand-alone and isolated assignments. These parents’ narratives speak to their children’s increased motivation powered by negotiation of complex mathematical variables; these are attributes that are considered critical for success in engineering.

It was seen that parents find significance knowing that their children are continually supported through collaborations with mentors and peers; frequently, they are able to secure feedback on their developing work before it reaches a stage of finality or irreversible stage. Parents view the added element of quick turnaround feedback as encouraging, formative, and leading towards meaningful revisions. One mother identified the added value of projects and tasks that "don't expire because suddenly the class shifts from one topic to another." In the parents' views, such attributes motivate their children "to learn difficult things."

The parents find that their children's learning is further enhanced by growing knowledge about the robot's functioning—in terms of what is working and what needs to be revised in order to make it work. Ultimately, this leads to longer lasting retention of mathematical and mechanical content knowledge because of being constantly drawn upon during phases of problem solving and design planning. For example, parents found that working with software and mechanical sensors allowed their children to see the connections between conceptual ideas in mathematics and physics with engineering applications. In turn, the application of acquired knowledge and skills made the design process transparent and the learning more personally relevant. A critical tenet that emerges across the parents' attributions speaks to their appreciation for children's learning by trial and error as well as the freedom to celebrate failure in order to achieve progressive levels of mastery of science and engineering relevant concepts.

Conclusion

The perceptions of parents regarding the beneficial aspects of their children's participation in robotics can be better appreciated also because of close alignment with the recommendations of several reports and studies focused on STEM education and its pressing dynamics, especially within physical sciences and engineering. In summary (also see Figure 1), parents in this study identify the useful aspects and worth of robotics for their children in terms of: 1) preparation and inspiration for the academic rigor associated with engineering; 2) authentic contexts where learning takes place in iterative cycles characterized by presence of transparent, collaborative, and forward leading assessments; and 3) enhanced and long term retention of mathematical and mechanical concepts through hands-on immersion in technology and teamwork.

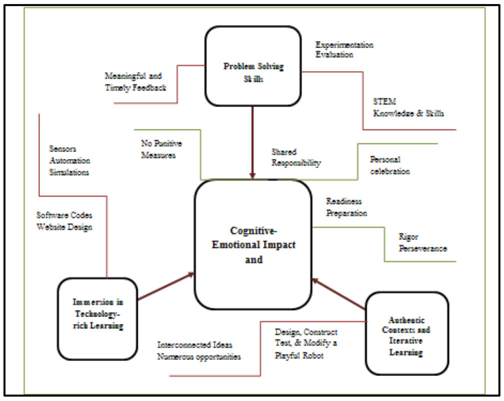

Figure 1: Parents' Understanding Regarding their Children's Participation in Robotics

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