Identification of Strategies that Overcome Barriers to Women and Minorities in STEM

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ABSTRACT

At a time when there is concern by policy makers about the nation's STEM capacity, it is imperative not only to increase capacity, but also to address gender and racial imbalances. Leading high-tech companies require diversity to maintain globally competitive technical workforces. Research shows that workforce diversity can boost a company's bottom line by providing a creative variety of thinking styles and, thus, new business solutions. Integration of STEM education into middle and high school curricula for women and minorities poses important challenges. For example, the average female or minority teenager is exposed to less than 3 hours/week of STEM-related material in popular media as compared to over 100 hours/week of non-STEM content such as sports and entertainment. As a result, STEM issues are barely on their radar screens. The STEM research effort reported here attempts to find ways to diversify the STEM workforce through identification of pedagogical strategies for recruitment and retention of women and minorities into STEM classrooms. These strategies were identified through a comprehensive STEM immersion program involving approximately 100 middle/high school students in the Hartford area during an 18-month period. Program was funded by the University of Hartford and the National Science Foundation.

1. INTRODUCTION AND MOTIVATION

Recent research [Augustine, Clewell, Dudersdadt, Friedman] shows that global economic competitiveness requires a broad spectrum of entrepreneurial, knowledge-based industries, and a workforce skilled in the Science, Technology, Engineering, and Mathematics (STEM) disciplines that support these industries. New jobs in the economy are not going to be spawned by existing industry, but by new knowledge-intensive industries e.g. biotechnology and information technology. Whatever the path to economic health, the future will require an expanded workforce having STEM skills. Although jobs requiring STEM training are growing five times faster than other occupations, pre-college student interest in science and mathematics, essential preparation for a STEM college degree, has been eroding nationally among women and minorities. Psychologist Leonard Sax [Sax] states in his renowned book "Why Gender Matters" that gender-neutral education favors the learning style of one sex or the other, and so only drives men and women into the usual stereotyped fields. This is only too true in the STEM classroom where women and minorities are simultaneously cast into two opposing roles. On the one hand, they are active agents in the classroom because they bring to it uniquely rich perspectives and creative thinking styles, but on the other hand they are victims in the sense that they are thrust into a learning environment specifically designed for and dominated by males for the last 250 years. Today, there is a critical need for a concrete investigation of how taking gender and race into account can positively impact teaching STEM. This paper addresses this need by targeting pre-college minorities and females aged 11 to 15 drawn from a range of socio-economic backgrounds. Efforts were focused on identifying pedagogical strategies which overcome barriers in the STEM classroom. Specifically, a comprehensive STEM immersion program comprising four key components was conducted during the period from January 2010 – August 2011. Components of the program were as follows:

1) After-school classroom-based hands-on STEM workshops involving construction and test of real-life engineering subsystems in a relaxed, non-evaluative atmosphere
2) STEM summer day camp involving exposure to hands-on STEM projects 6hours/day for 5days/week for 5 weeks during the summer of 2011
3) Mentoring Program featuring opportunities to meet and speak with practicing female and minority STEM professionals, step into their shoes and experience STEM in the workplace first-hand through "shadowing"
4) Parent/guardian workshops designed to inform and empower parents in their efforts to support their children's success in STEM

2. METHODOLOGY

Identification of strategies that overcome barriers in STEM involves obtaining answers to a barrage of important questions regarding pedagogical practices and student experiences in the STEM classroom. Examples include how do boys and girls experience STEM classroom culture differently? How do minorities experience STEM classroom culture? What are the key factors driving recruitment and retention of women and minorities in STEM classrooms? How do gender and racial differences in communication styles affect the dynamics of STEM classroom learning? Does the fact that women find equal fulfillment in relationships and achievements affect learning in the STEM classroom? How does collaborative learning affect retention of women and minorities? One of the most effective ways to elicit frank responses from the population under consideration is via web-based surveys, thus a decision was made to design anonymous surveys featuring poignant, carefully worded questions to be administered on-line to students. Survey questions addressed the effect of STEM classroom practices in the following five areas

- Engagement/Interest
- Attitude/Behavior
- Content Knowledge
- Competence and Reasoning
- Career Knowledge/Acquisition

Surveys featured questions requiring *quantitative* (multiple choice selection) as well as *qualitative* (essay-type) responses and were carefully composed to include developmentally appropriate adaptations for younger students in grades 6 and 7 as well as older students in grades 8-10. Questions were optimized for gender/racial balance and to allow administration in a reasonable amount of time. Surveys were administered frequently throughout the 18-month STEM immersion program both before and after a prescribed STEM activity, thus they were sensitive to changes pre- and post- specific STEM experiences. A description of the 4 components of the STEM program now follows. Findings from surveys are presented in section 3.

2.1 After School Program

The STEM after-school program was established at three public middle/high schools in the greater Hartford area – Jumoke Honors Academy Middle School, Bloomfield High School and Simsbury High School. Bloomfield High is a multicultural suburban high school serving 700 students in grades 9 through 12 with 92% of minority students. Simsbury High School is a suburban public school serving

1500 students in grades 9 through 12 with 90% of whom are Caucasian. Jumoke Honors Academy Middle School is a tuition-free public charter school [Sharpe] that allows taxpayer dollars to empower parents and students through educational choice. Jumoke Academy serves 450 students in grades 6-8, is 98% minority and located in an urban setting. At each school, 12-15 young women in grades 9-10 were encouraged to voluntarily sign up to participate in hands-on STEM workshops one afternoon per week during the 2010/2011 academic year. Additionally, at Jumoke, young men in grades 6-8 were encouraged to sign up for an all-boys STEM after-school program conducted separately from the all-girls' program. Each weekly session lasted for two hours immediately after school. At Bloomfield High a chemistry teacher from the full-time faculty was selected to facilitate the workshops; at Jumoke, a Biology teacher on the science faculty was recruited while in Simsbury a technical education teacher on the faculty was recruited. University of Hartford students majoring in STEM disciplines were recruited to work in the classrooms as teaching assistants, not only to help with the STEM investigations but also to mentor students. At the beginning of several of the STEM workshops, guest speakers – practicing engineers and scientists – were invited to speak with the students about career experiences and pathways to STEM. Each workshop featured construction and test of state-of-the-art real-life engineering sub-systems drawn from the fields of electrical, mechanical, biomedical, civil and chemical engineering. Workshop themes included engineering materials, renewable energy, prosthetics and rehabilitation, building stability, nanotechnology and robotics. The following are examples of workshops:

• Generating Electricity From Blueberries – Intro to Nanotechnology
• Veggie Snap - Mechanical Stress and Failure using Asparagus Tips
• Solar Powered Robots
• Building the Tallest Tower - Effect of building height on stability
• Digital Data Recording
• Solar Flashlights from Soda Bottles

At each school, on a selected weekday, immediately after school ended, students gathered together in a science laboratory equipped with computers. Each 2-hour workshop comprised 5 events:
(i) serving of refreshments and informal discussion of workshop theme
(ii) presentation by professional engineer/scientist from industry or academia
(iii) student completion of web-based pre-workshop survey (typically15 - 20 questions)
(iv) hands-on STEM investigations (approx duration 75min)
(v) completion of web-based post-workshop survey (typically 8-12 questions)

During the serving of refreshments, the author introduced the day's STEM investigations, describing relevance to every day life and inviting the students to share relevant experiences. Guest speakers were introduced at this time and invited to share life/work experiences and personal STEM career pathways. This was always an exciting time for the students who were completely captivated letting loose a flood of earnest questions punctuated by "oohs!" and "aahs!". Next, web-based pre-workshop surveys created in Survey Monkey were administered anonymously. Survey questions varied widely, most were designed to elicit student responses that would identify STEM-friendly pedagogical practices hence determine best practices for teaching STEM. Some survey questions addressed STEM classroom practices and their effectiveness in student engagement; others addressed how classroom practices affected attitudes, reasoning skill development and career interest in STEM. Still more survey questions addressed individual experiences in mixed gender STEM classrooms. Once pre-workshop surveys were completed, the students moved on to the day's core activity which was to carry out the pre-selected

STEM task in small groups under the supervision of the teacher and student teaching assistants. At this time, the classroom/lab was a hub of activity; time flew by as the students excitedly planned, constructed, measured, observed and tested engineering models and sub-systems using special purpose kits (for example flexible solar panels) or everyday materials and supplies such as Lego blocks, rubber bands, asparagus tips and blueberries. During every workshop, the author was privileged to observe productive and captivating small group discussions among students as they brainstormed and developed strategies for accomplishing STEM tasks in a 75-90 minute time window. The STEM workshop was concluded with closing comments by the author followed by student completion of the post-workshop survey.

2.2 STEM Summer Program

A five-week STEM summer day camp – STEM UP! - was conducted at the University of Hartford during the months of June and July 2011. Programs like these seldom turn out as planned. Planning and recruitment for STEM UP! commenced in Jan 2011 targeting students in grades 6-10 within a 25-mile radius of the University. The response was overwhelming – a total of 150 applications were received for 24 places, consequently only 1 in 6 students was offered a place. Program was designed for students to experience 5-weeks of STEM-immersion featuring exciting and relevant projects in science, engineering and architecture. There were weekly field trips to STEM-related industries and institutions including the CT Science Center, Hanger Prosthetics and Othopedics and a nearby 4H farm in Bloomfield. Program featured knowledgeable speakers drawn from practicing STEM professionals at nearby engineering giants such as Pratt & Whitney, Hamilton Sunstrand and medical institutions such as Hartford Hospital. Since program was generously funded by National Science Foundation, it was offered at essentially zero cost to the student (small registration fee of $25 charged to cover administrative expenses). Each week of STEM UP had a different theme reinforced by a field trip at the end of the week (see table 1).

Table 1 STEM UP Summer Program Schedule

	STEM UP!	SUMMER	PROGRAM
WEEK	**DATES**	**THEME**	**FIELD TRIP**
1	JUN 20-24	ROBOTICS	CT SCIENCE CENTER
2	JUN 27 - JUL 1	ARCHITECTURE	4H FARM CONSTRUCTION SITE
3	JUL 5 - 8	AUDIO TECHNOLOGY	LAKE COMPOUNCE
4	JUL 11-15	BIOMEDICAL EXPL	HANGER PROSTHETICS
5	JUL 18 - 22	COOL CHEMISTRY	PARENT WKSHP CLOSING EVENT

Week 1 focused on Robotics taught by the author. Robots (LEGO NXT Mindstorms) were constructed and programmed to perform a wide variety of tasks which included MARS Exploration, Mexican Wave and Sumo Wrestling. The first week was concluded with a field trip to the new Science Center. Week 2 theme was Architecture taught by a teacher from a local high school. Students built and tested bridges for strength and visited an actual construction site – a housing development in Cheshire, CT. The theme for week 3 was Audio Engineering taught by a University of Hartford professor who showed students how to use modern audio equipment to creatively mix and modify sounds. Week 4 was themed Biomedical Explorations and taught by a local middle school biology instructor. She challenged each student to construct an artificial arm and compete in an arm-breaking contest. The week concluded with an eye-opening visit to Hanger Orthotics and Prosthetics Inc. the national leader in orthotics and prosthetics manufacture located in Newington CT. The final week – Week 5 was themed Chemistry of Cool Materials featuring stimulating chemistry activities with everyday materials. The week ended with a parent workshop and closing event described in section 2.4. During the summer program, anonymous web-based pre- and post-workshop surveys were administered to students at the beginning and end of each camp day. Additionally, STEM professionals were invited into the classrooms to speak to the students on average 3 times/week. Many brought with them artifacts of their trade, including aircraft engine parts, stethoscopes, tuning forks and microphones.

Art in STEM – Hip Hop Dance/STEP

Each summer camp day started off with 30min of physical activity in the form of a hip-hop dance and step show. A professional hip-hop dance instructor was hired to teach hip-hop dance to the students using STEM-related lyrics composed by students (see examples below).

"S! T! E! M!
STEM is cool! Robotics! Computers!
What do you Need?
We can do it with speed
A smart phone, a laptop
We can do it with STEM!"

This was a very effective way to integrate artistic creativity into STEM, in addition to the physical exercise benefits. Students helped to choreograph the dance and staged a performance for parents and University community at the end of the summer program.

2.3 Mentoring

Mentors were drawn from the pool of after-school and summer program speakers. Most were female and/or minority individuals who worked within a 20-mile radius of the university. They included medical doctors, mechanical and electrical engineers, chemists and professors in the STEM fields. They made arrangements for students to visit their places of work in order to experience STEM in the workplace firsthand. For example one family practice physician had students visit his office to "shadow" him for an afternoon. The mentoring program is hugely popular and on-going, facilitated by parents who are responsible for transporting the student to the mentor.

2.4 Parent Workshop

Parents play an important part in motivating students to select STEM careers. By informing parents about steps toward STEM career readiness, they can better steer students toward activities and opportunities that make them stronger candidates for success in the chosen STEM field. The fourth component of the STEM immersion program was the parent/guardian workshop designed to inform and empower parents in their efforts to support their children's success in STEM. At the end of the summer program, parents and students were invited to attend a workshop on STEM. This two-hour event was combined with the closing ceremony conducted on the last day of the summer program. Speakers included STEM mentors who gave practical advice to families on how to carve out a successful STEM career beginning with activities in middle and high school. They addressed a broad range of issues including STEM efficacy and gender/racial bias in STEM fields.

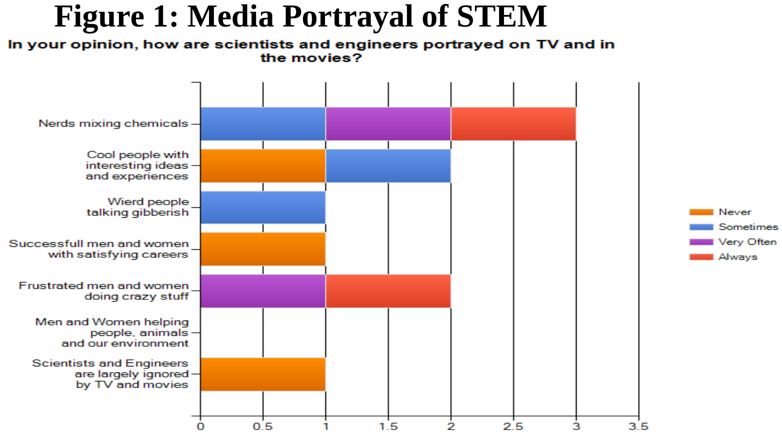
3. RESULTS AND CONCLUSIONS

A set of pedagogical insights and strategies that overcome many of the barriers to women and minorities in STEM have been uncovered. Analysis of over 6000 survey responses from 100 women and minorities during the 20-month period from January 2010 to August 2011 indicate that some very specific pedagogical practices tend to positively impact young females and minorities in the STEM classroom. Selected survey responses from the four-part STEM immersion program are presented in figures 1and 2 and in the appendix. The three most critical pedagogical practices identified thus far in order of importance are:

(i) *Peer Instruction* – the presence of enthusiastic female and/or minority college level STEM majors in the STEM classroom working side by side with the teacher as teaching assistants had a major impact on over 80% of the student participants. These teaching assistants were viewed by students as “contemporaries” rather than formal instructors; they bridged the “academic and social” gap between the students and the teacher and were an incredible source of motivation in the STEM classroom. Students very quickly bonded with the TAs and were comfortable admitting ignorance or asking “stupid” questions.

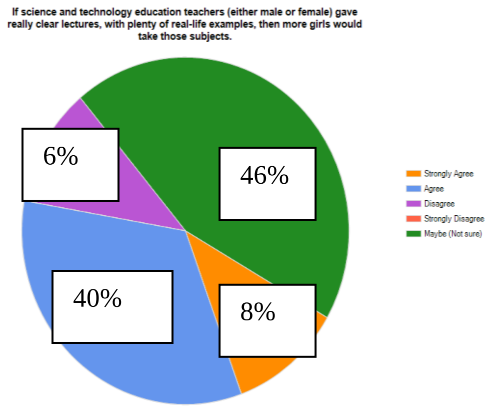
(ii) *Inclusive & Reassuring Illustrations* – the majority of students felt more comfortable and more self-confident when the teacher made explicit verbal, written or graphical reference to “normal looking” successful individuals in STEM particularly those who looked like the students – i.e. female and/or minority. Without a doubt, the fact that STEM practitioners invited as speakers into the classroom were confident well-dressed female/minority 24-35 year-olds who were clearly enjoying their professional careers, helped to reassure the students that STEM careers were desirable (figure 1). In fact, in response to a specific survey question about the image of STEM, 95% of girls surveyed indicated that seeing “normal” persons in STEM “with great hair and nice clothes” was reassuring.

Figure 1: Media Portrayal of STEM



(iii) *Application-Oriented Teaching* – 87% of survey responses strongly indicated that teaching **content and practice** that strongly emphasized broader impacts of STEM activities on society were very important; classrooms in which the teacher made a concerted effort to forge clear and consistent linkages between STEM and everyday issues presented fewer barriers to girls and minorities than those in which this did not take place (figure 2). A case in point was the study of genetics and its impact on inherited diseases like sickle cell anemia which is prevalent in minority populations. Multiple visits by the executive director of the state non-profit organization Citizens for Quality Sickle Cell Care to the classroom inspired the students – many of whom had a case of sickle cell anemia in the family - to research careers in areas of medicine such as hematology.

Figure 2 Future Career – Desirable Attributes



Although these three insights were the most important of several derived from analysis of survey data and detailed observation of STEM classroom activities, additional valuable insights came from discussion with science teachers and teaching assistants all of whom were also required to periodically complete on-line surveys. Additional selected survey results are presented in the appendix.

4. FUTURE WORK

What are the next steps? Strategies identified as being STEM-friendly for these populations can be used to transform teaching in STEM classrooms. At the current time, the STEM peer instruction strategy is undergoing planning for implementation on a pilot basis in classrooms in a local middle school. The framework for this already exists on the University of Hartford through a nationally acclaimed program Educational Main Street (EMS) launched 22 years ago. The EMS program provides trained tutors drawn from University student population to tutor children individually and in small groups during the school day and after school. Originally in 1990, there were only three schools in the design, but by the year 2000, the number of schools increased to five and later eleven partners.

5. ACKNOWLEDGEMENTS

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APPENDIX: ADDITIONAL SURVEY RESULTS

Figure A-1: Distraction – Mixed Gender STEM

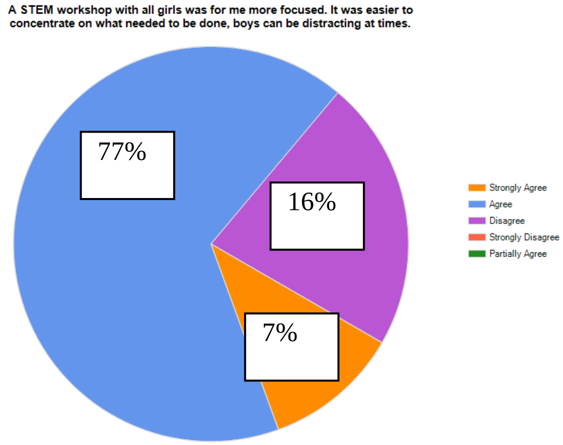


Figure A-2: Natural Ability v Hard Work

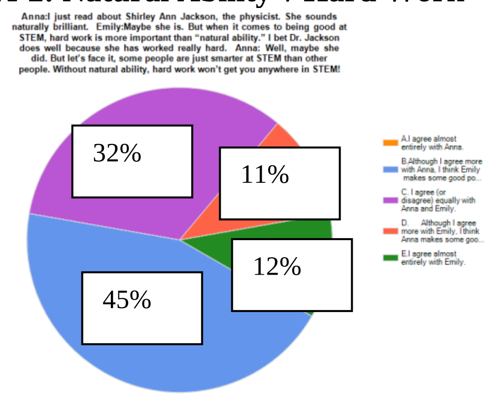


Figure A-3:Gender composition of STEM classroom

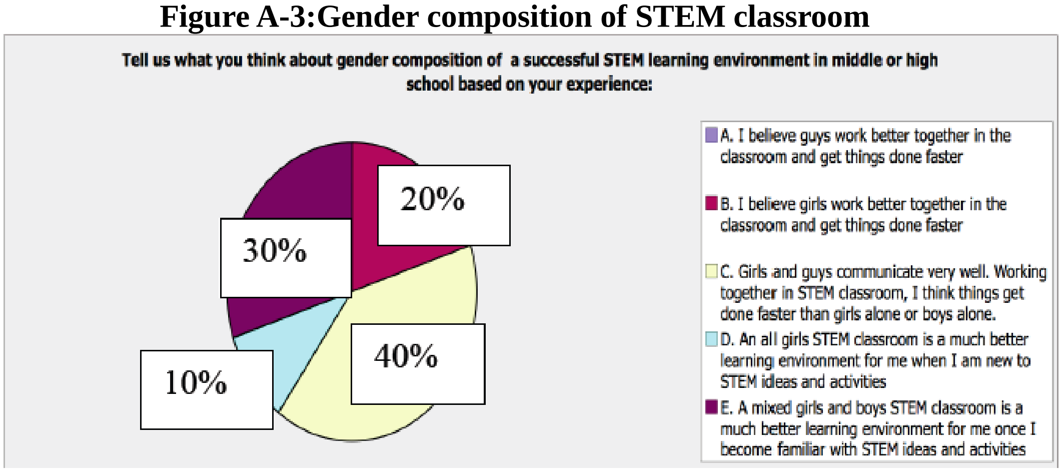


Figure A-4: Who is In Charge?

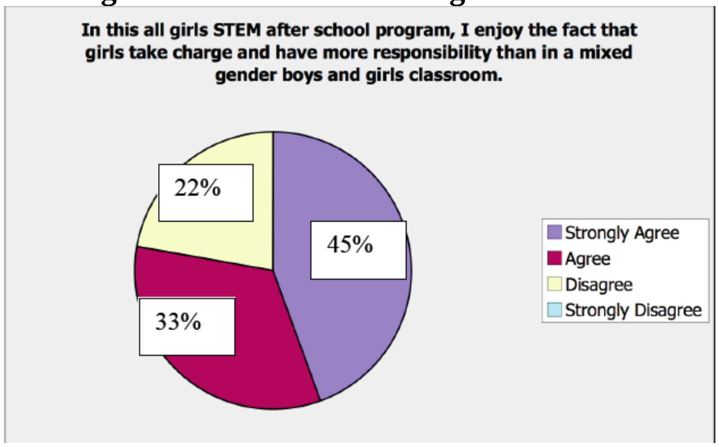


Figure A-5: Why are you here?

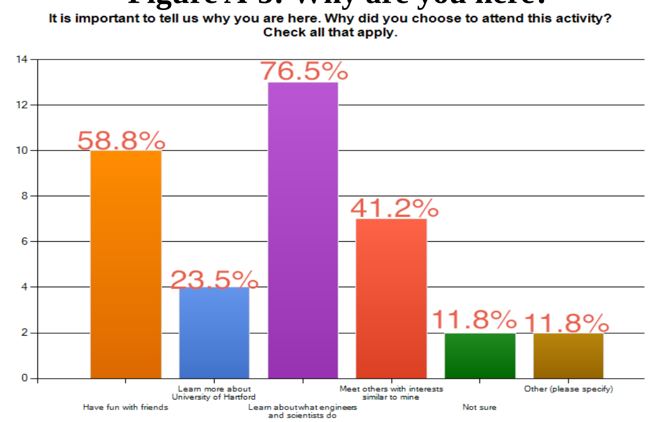
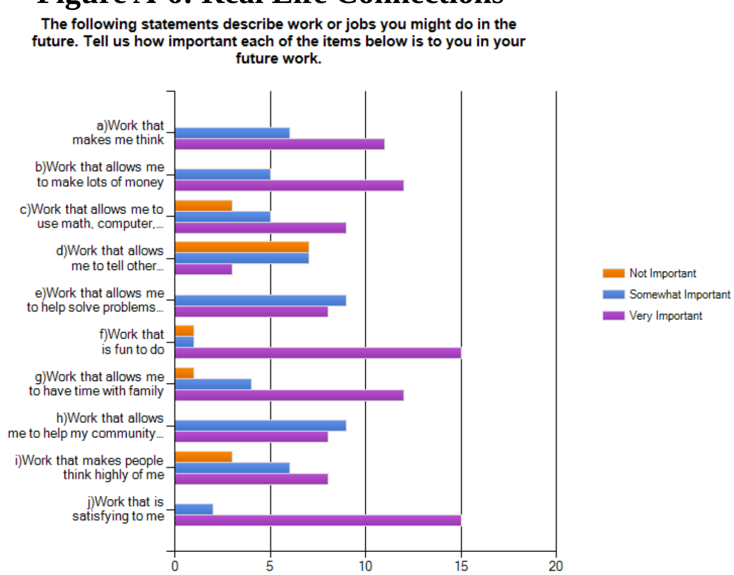


Figure A-6: Real Life Connections



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