2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #38432

Board 148: A Qualitative Study of Factors Influencing K-12 Students' Interest in STEM Career (Fundamentals)

Tristan Robert Straight, Wartburg College
Jennah Meyer, Wartburg College
Dr. Ibukun Samuel Osunbunmi, Utah State University - Engineering Education

Ibukun Samuel Osunbunmi is an Assistant Research Professor, and Assessment and Instructional Specialist at Pennsylvania State University. He holds a Ph.D. degree in Engineering Education from Utah State University. Also, he has BSc and MSc degrees in mechanical engineering. His research interests include student engagement, design thinking, learning environment, evidence-based pedagogy, e-learning, broadening participation in STEM education, sustainable energy, and material characterization. This work was conducted while he was a postdoctoral research associate in the Department of Engineering Education at Utah State University, Logan, USA.

Bolaji Ruth Bamidele, Utah State University
Murad Musa Mahmoud, Wartburg College

Murad is an Assistant Professor at the Engineering Science Department at Wartburg College. He has a Ph.D. in Engineering Education from Utah State University. Research interests include recruitment into STEM, diversity in STEM as well pedagogy and instruc

Prof. Kurt Henry Becker, Utah State University - Engineering Education

Kurt Becker is a Professor in the Department of Engineering Education at Utah State University. His research includes engineering design thinking, systems engineering, engineering education professional development, technical training, and adult learning cognition. He is currently working on a USAID funded project in Egypt, "Center of Excellence in Water", and Department of Education funded GEARUP projects in the area of STEM education related to engineering education. He has extensive international experience working on technical training and engineering projects funded by the Asian Development Bank, World Bank, and U.S. Agency for International Development (USAID). Countries where he has worked include Armenia, Bangladesh, Bulgaria, China, Egypt, Indonesia, Macedonia, Poland, Romania, and Thailand. In addition, he has taught undergraduate and graduate courses in engineering education for the department.

Dr. Jonathan D. Phillips, Utah State University

Qualitative Study of Factors Influencing K-12 Students' Interest in STEM Careers (Fundamental)

INTRODUCTION

Background

For the U.S. to remain globally competitive, maintain its world power, and sustain its robust economy, there is a need for K-12 schools to prepare students to continue their post-secondary education and persist until completion [1]. Bybee warned that the STEM workforce would continue to decline unless a more deliberate effort is invested in recruiting and retaining STEM majors in our higher institutions [2]. A declining workforce may adversely affect global productivity [2]. Therefore, there is a need to broaden the participation of K-12 in STEM fields in college. One of the ways this can be achieved is to investigate what factors influence K-12 interest in STEM careers. Moreover, knowing what factors influence their interest provides foundational knowledge of how those factors can be managed to improve K-12 interest in pursuing STEM careers in the future.

Evidence shows that students' interest in STEM courses can be improved by teaching non-traditional applied STEM courses in schools rather than a more traditional curriculum [3]. Implementing such courses helps provide a strong background in STEM for K-12 students, which further prepares them for the STEM workforce in the future [4]. However, it is worthy of note that students' attitudes play a more significant role than instructional and non-instructional interventions in influencing students' motivation to pursue STEM fields [5]. Other studies have found that students are motivated to pursue STEM careers through parents' and teachers' continuous and consistent support [6]. Reider, Knestis, and Malyn-Smith [7] commented that when schools provide K-12 students with the opportunity to explore STEM content and develop an interest in STEM, their desire to pursue STEM discipline in their later life is positively influenced. However, studies have suggested that professional development techniques used in many school districts may fail to fully equip instructors to teach STEM courses effectively [7]. When teachers are not well equipped with state-of-the-art pedagogy and assessment skills in facilitating learning experiences in the STEM classroom, students' interest in the STEM field may be negatively affected [8].

One of the nation's ongoing efforts in broadening K-12 participation in STEM is the Gaining Early Awareness and Readiness for Undergraduate (GEAR UP) STAR program with the primary purpose of broadening K-12 participation in STEM. Over the past five years, the GEAR UP program at Mountain West University organized experiential, hands-on learning for K-12 students during summer camps. The camp's primary purpose is to increase K-12 students' interest in pursuing STEM careers in the future. This study was carried out during one of those camps. The study aims to explore what factors affect K-12 students' interest during the GEARUP camp.

GEARUP Program Description

During the summer of 2022, high school students and teachers attended a two-day GEAR UP camp at Mountain West University. The camp was set up to prepare K-12 students for a STEM career and serve as an intervention program to improve K-12 students' interest in pursuing a STEM discipline. The Summer 2022 camp was a project-based experiential rocket-building camp. Project-based learning is becoming an accepted learning strategy in engineering education [9]. During the camp, students were introduced to the principles of rocket propulsion and stability and the mathematics and physics behind the design and assembly of rockets. In addition, the camp provided practical experience in testing these principles applied in assembling and testing water-propelled and solid-fuel rockets.

The basic principle of rocket design learned during the camp was applied in building water-propelled rockets. The primary lesson learned from the water-propelled rocket was the optimum ratio of air and fuel (water as fuel) for an optimal rocket flight. Also, by experimenting with fins, nose cones, and ballast, the participant learned stability and aerodynamics. The lesson learned doing the design, assembling, and launching of the water-propelled rocket was applied to the second phase of the rocket project. The project's second phase was to design, build and launch a chemically powered (solid fuel) rocket. Each participant assembled their chemically powered rockets under the supervision of a tutor, engineering student mentors, and expert professors in the field. The participants had access to Estes "Designer's Special" flying model rocket parts kits. These kits include cardboard body tubes, plastic nose cones, parachutes, engine mounts, and balsa wood sheets for cutting fins. Students could customize the length of the body tube, design their shape and size of fins, and determine the best location for the engine mount. Colored duct tape was used for decorating and personalizing each rocket. Each rocket had to pass a safety test, in which the rocket was attached to the end of a 2-meter string and twirled above the head to verify the correct relationship between the center of gravity and the center of pressure. Modeling clay was provided as ballast for rockets that needed more weight in the nose.

Each rocket designed, assembled, and safety tested was eligible for launching in an open field. The performance criteria for evaluating each propelled rocket were the height the rocket reached in space and the proximity of the rocket's landing spot to a set target. Altitude finders and trigonometry were used to measure rocket height. The camp was a collaborative and independent learning experience for all high school students.

The role of the university professors in the camp was two-fold. First, the professors recruited and trained the engineering student mentors. The mentors had two preparation days during which they learned rocket theory and gained experience building and testing water and solid-fuel rockets. The mentors' primary role was instructing the participants and assistants during rocket construction. The faculty members supported the mentors and gave the participants feedback during the camp's design, build, and launch portions.

METHODS

The explorative qualitative research design was the method that guided the study [10], [11]. The research question, data collection, and data analysis are discussed below.

Research Question

The research question that guided this qualitative study is as follows.

RQ 1: What factors influence K-12 students' interest in STEM careers?

Data Collection

Six participants who attended the GEARUP STARS camp were interviewed at the end of the camp. The students were high school students in the mountain west city in the United States. Five to fifty participants have been suggested as enough samples for qualitative research [12], [13]. In addition, the authors recruited 6 participants in a qualitative study in the past [11]–[14]. Small sampling for qualitative research helps to explore in-depth the lived experience of the participants[11], [15], [16].

At the end of the engineering camp, the students were interviewed and asked questions. The questions were semi-structured, open-ended questions. They were carefully worded to explore the factors influencing K-12 students' interest in STEM. The interview questions were pilot-tested, feedback was received, and the researcher kept a journal while pilot-testing the question [17]. Sample questions include "*How have STEM-related courses at school influenced your interest in STEM careers*," and "*How have your parents or other family members influenced your interest in STEM careers?*"

Data Analysis

The qualitative data were analyzed using the MAXQDA 2022 software. The interviews were recorded and transcribed. The transcribed data were checked for accuracy, formatted, and organized. The data were explored, memos were jotted, and a codebook was developed during the data exploration phase [12]. The researchers' positionality was that of an insider since they worked together with the participants in exploring and making meaning of the lived experiences of the participants [18]. To ensure the trustworthiness of the data analysis, two independent coders coded and analyzed the data. After each cycle of coding, the coders met and discussed their codes. As a result, interrater reliability of over 80% for both coding processes was achieved. Thematic analysis was the qualitative analytical method utilized in the data analysis. Sixteen subthemes emerged, which were re-categorized into four main themes [19].

Results

Four major themes emerged from the thematic analysis of the data. They are *motivation, social influence/relationships, experiential learning, and engineering camps*. The findings from the coding are summarized in Table 1. Figure 2 shows the graphical representation of Table 1. A discussion of those findings follows.

Theme 1: Motivation

The most frequently re-occurring theme that influenced students' interest in STEM careers was intrinsic and extrinsic Motivation in STEM-related activities. One subtheme under that main theme was self-satisfaction. Most of the participants interviewed commented that they enjoy STEM-related activities and therefore are interested in STEM. For example, participant 1 said, "*Building the rockets was fun. We put a pen on the top for the water rocket to make it more aerodynamic."*

Another subtheme under motivation for the STEM field was good career prospects. Participant 4 commented, "*STEM is a good career option. I feel like more people should be looking to STEM as a career option because it will always be needed. It's a solid career option. Exploring the experiences of high school showed that those who have predetermined to take on STEM careers in the future do well in their STEM courses*. Participant 2 noted, "*I can do well on those courses. I got a five on my BC calculus test. And I just finished AP physics…. All those courses are relevant to aerospace, which I want to do."*

Also, participants with a positive attitude towards a STEM-related activity seem interested in the field.

"I'll just take, like, a whole day and just, like, dedicate myself to learning about, like, that subject. I did that a few times in a computer programming class I took. It was, like, I'd go home, spend the rest of the night, build something just for fun, not actually turning it in but just seeing what I can do with it." (Participant 1)

Furthermore, K-12 students are motivated for STEM when they have a positive, challenging class experience that motivates them to learn. For example, participant 6 commented, "*AP chemistry challenged me for the first time and gave me a close experience to the college. It helped me learn and face challenges.*"

In addition to this, academic performance was a subtheme that emerged. Those students who have good academic performance in STEM-related courses in high school are motivated to take up STEM careers in the future. For example, participant 3 commented, "*I've noticed I'm good at math, I'm good at science, I'm good at making things, and half the time, I'm creative. I'm not too bad at being smart. So those are kind of all the qualifications of an engineer*."

However, those struggling with STEM courses are contemplating whether they want to pursue a STEM career. Participant 5 said, "I want to go into the STEM field, but *what if none of the STEM courses, like, what if none of the categories fit me? What do I do?"*

Theme 2: Social Influence/Relationship

The second theme was relationships or social influence. The social influence affecting K-12 students in STEM are peers, teachers, accomplished scientists and engineers, parents, and extended family. One good example of how parents influence K-12 students' interests is encapsulated in Participant 4. *"So, my dad is a mechanical engineer. So that's what he does. And I've always just been interested in what he has done with his work."*

The interest of students in STEM has not only been influenced by parents but also by extended family.

"My grandpa is, like, a huge--he was an electrical engineer most of his life, but he just retired. But, it's just, like, cool seeing how he'd go home and build a robot for fun, just like, from scratch. And so it's just, like, cool seeing that he's done that and now knowing I can do that if I give myself time. Like, just fun to see how everything works, you know." (Participant 1)

The role of instructors in influencing students' STEM interests must be emphasized in the semi-structured interview. For example, participant 4 noted, "*I've had several excellent STEM teachers that teach math and science in high school, and those teachers have made me think about going into a STEM career."*

Almost all the participants commented on how peers have influenced their interest in STEM courses and discipline. Similar interest in STEM courses is also a factor K-12 students consider in choosing their friends. Participant 1 commented, "*I guess, yeah, my friends have always just been super supportive of, like, I don't know. We're all, like, in, like, STEM classes together." One other subtheme in this category was*."

Participant 4 also said, *"My friend group, they're all interested in going to STEM, and that's helpful because they're very supportive. We all support each other because we want to go into similar careers. I have several friends who want to go into engineering. And it just that it's good to have like-minded people around you."*

One final subtheme in this category is accomplished scientists and engineers. Most of the participants interviewed have been influenced to go into STEM discipline directly or indirectly because of the accomplishment of distinguished experts in the field of STEM. Others have studied experts in STEM careers and are patterning their learning after them. One good example of this is a marked response by Participant 4 during the interview.

"I know that he [Thomas Edison] invented the lightbulb, and I know it took him a long time. And he got close to giving up, but eventually, he found the right filament to use. So, it shows perseverance is key. So, if everything is failing, you must keep going, and eventually, you'll find something that works."

Theme 3: Experiential Learning

Reoccurring subthemes in this category include problem-solving, assembling engineering parts, and design process. Participants were motivated by seeing the result of the rocket they assembled during the camp. Participant 1 commented, "*The process of building and assembling the rocket is the coolest thing…. Seeing the result--knowing that I built the entire thing myself, was satisfying*."

Also, the problem-solving experience that the hands-on learning provided the students with critical thinking avenues for a better design. In the words of Participant 3, "*With the bottle rocket, I was able to do the fins on ours, and I was able to get them, like, almost the same. So, I think we could perfect the cone if we had more time. But, it is cool to see how high our rocket went*."

It is interesting to know that the creative experience that comes with the whole design process fascinated the interest of the research participants in STEM. In Participant 4 words:

"So we built two different types of rockets. And I think one of my favorite parts about these kits is, like, they have so many materials in them, and it's not just, like, you build one type of rocket. You can go creative with it. And it's been enjoyable to ask, "Okay, how do I want to build my rocket? What do I want my rocket to do?" And it's been a nice experience to sit down and think about what I want to do."

Our study revealed that contrary to the hands-on learning experience that students have during camps, one of the challenges that high school students face with STEM courses is when they are theoretically constructed with little or no hands-on learning incorporated into the course instruction. Participant 5 commented, "*STEM courses aren't hands-on, so. ……Like, I have a hard time learning things when that's not hands-on*".

Theme 4: Engineering Camps

The final theme that emerged from this study is camps. Three subthemes under this theme include learning environment, active learning, and camp duration. The camp happening in a college environment gave a campus touch to the students. Participant 2 said, "*Attending this camp gave me a college campus feel. I don't even know if I want to go there, but it's nice to experience college a little*".

In addition to this, sleeping over in the college environment during the camp provided ample opportunity and time for the research participant to ruminate about lessons learned and where to improve the next day. Participant 4 noted,

"I like this 2-day camp as I can sleep on it. As I was going to bed, I couldn't sleep on time as I was thinking about all the things I would do tomorrow, all the cool ideas. Because we started designing our rockets yesterday, I couldn't just go to bed thinking, "Okay, what do I want to change so I can finish it tomorrow?" So, how--you just--it feels less rushed, too, that I'm not rushing to do anything, but I have the time to do it."

More importantly, structuring the classroom learning environment to facilitate active learning provided a rich experience for the participants, which influenced their interest in STEM. Participants were excited about the blending of structured and ill-structured nature of the classroom they experienced, which got them to be actively involved in learning. Participant 4 noted the mixed feeling she had before the camp. However, her experience in the camp turned out to be an exciting one. She noted,

"One of the things I always worried about coming here is everything would just be, like, super laid out. Like, if you do this and do this, and like, step by step. So, it's boring because you don't get to be creative. Because that's the whole idea with engineering, is to be creative…… However, one of my favorite things about this camp is how they structured it. We—like, first learn fundamental principles, then we get to apply those fundamental principles, be creative and develop new ideas. And I think that's really what made this camp fun."

CONCLUSION

This study shows that motivation is the most recurring theme influencing students' interest in STEM careers. This finding aligns with the study by Matthew Linger, which found that students' attitude is the most influential motivational factor influencing interest in STEM careers [5]. Also, the outcome of this study indicates that project-based experiential learning positively influences high-school student interest in STEM. Studies have shown that STEM project-based learning benefits and bridges the achievement gap of low-achieving high school students, who are usually predisposed to losing interest in STEM. The author recommends that STEM-based design and assembling activities and competitions should be encouraged in high school. Also, teachers in high schools are encouraged to increase the use of project-based learning and problem-based learning in STEM classrooms [20].

Furthermore, this research showed that it is typical for students to be influenced by their relationships to pursue a STEM career. This finding corroborates the result of the study done by Jungert and colleagues [6]. Since parents play a pivotal role in influencing their children to take on STEM careers, raising STEM awareness among parents is encouraged [21]. In addition, outreaches and programs involving high school students, their families, friends, and community members in a fun STEM activity should be encouraged. Such events provide a positive relationship bonding environment and a place where high school students can make new STEM-like-minded friends.

Other implications of this research to practice include workshops on evidence-based pedagogical training that should be conducted for K-12 tutors by administrators. Role-model playing, project-based learning, peer learning, real-life problem-solving, individualized learning, and ill-structured learning experience are recommended to be implemented in the classroom. School districts should announce and encourage students and tutors to participate in engineering camps.

Table 1: Summary of the themes and sub-themes, as well as the frequency of each

Theme/sub-them	**Motivation**	**Social Influence**	**Experiential Learning**	**Camps**
Sub-Theme 1/Count	Attitude/9	Extended Family/5	Problem Solving/11	Active Learning/5
Sub-Theme 2/Count	Academic Performance/4	Friends/Peers/12	Design Process/7	Learning Environment/7
Sub-Theme 3/Count	Self-satisfaction or Enjoyment/16	Parents/12	Assembly/ Building/16	Camp Duration/5
Sub-Theme 4/Count	Class Experience/16	Accomplished Experts/5	X	X
Sub-Theme 5/Count	Future Career/16	Teachers/9	X	X

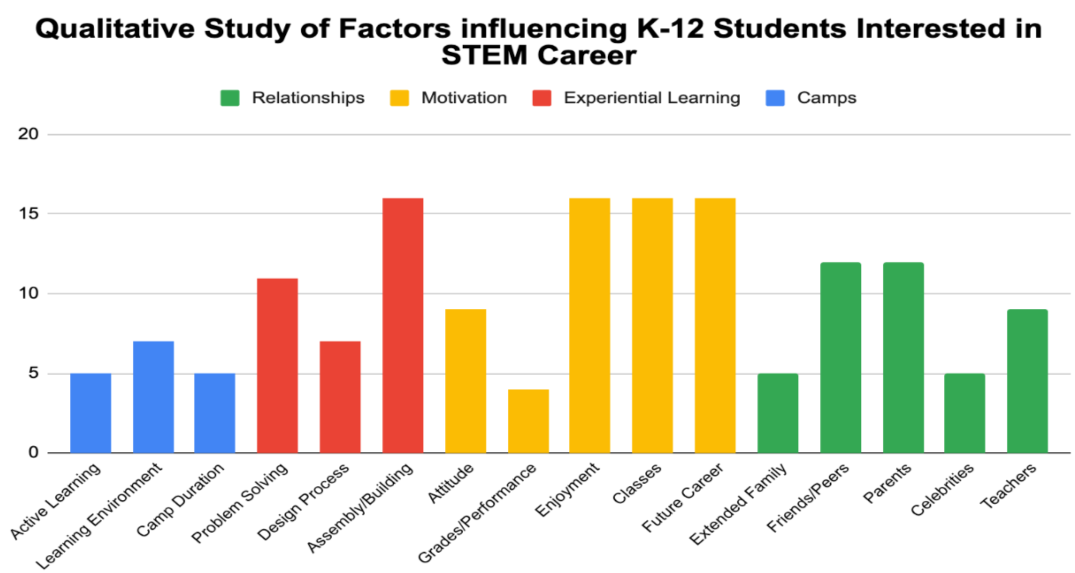

Figure 1: Summary of the frequency of each sub-theme

REFERENCES

[1] E. Seymour, “Tracking the processes of change in US undergraduate education in science, mathematics, engineering, and technology,” *Science Education*, vol. 86, no. 1, pp. 79–105, 2002, doi: 10.1002/sce.1044.

[2] R. W. Bybee, *The Case for STEM Education: Challenges and Opportunities*. NSTA Press, 2013.

[3] M. A. Gottfried, “The Influence of Applied STEM Coursetaking on Advanced Mathematics and Science Coursetaking,” *The Journal of Educational Research*, vol. 108, no. 5, pp. 382–399, Sep. 2015, doi: 10.1080/00220671.2014.899959.

[4] E. Glennie, M. Mason, B. Dalton, and J. Edmunds, “Preparing students for STEM college and careers: The influence of redesigned high schools in North Carolina,” *The High School Journal*, vol. 102, no. 3, pp. 228–257, 2019.

[5] M. Linger, “Plumbing the STEM Pipeline: Exploring Areas of Influence for Promoting STEM Education,” Ed.D., Hofstra University, United States -- New York, 2016. Accessed: Feb. 13, 2023. [Online]. Available: https://www.proquest.com/docview/1821362161/abstract/6D3942D119AA4036PQ/1

[6] T. Jungert, S. Levine, and R. Koestner, “Examining how parent and teacher enthusiasm influences motivation and achievement in STEM,” *The Journal of Educational Research*, vol. 113, no. 4, pp. 275–282, Jun. 2020, doi: 10.1080/00220671.2020.1806015.

[7] D. Reider, K. Knestis, and J. Malyn-Smith, “Workforce Education Models for K-12 STEM Education Programs: Reflections on, and Implications for, the NSF ITEST Program,” *J Sci Educ Technol*, vol. 25, no. 6, pp. 847–858, Dec. 2016, doi: 10.1007/s10956-016-9632-6.

[8] K. Perez, “Influence of Subject Taught (STEM), Title I, and Grade Level of Instruction for Components in an Effective Professional Development Design,” Ph.D., Florida Atlantic University, United States -- Florida, 2018. Accessed: Feb. 13, 2023. [Online]. Available: https://www.proquest.com/docview/2054017323/abstract/C884E71767B040E9PQ/1

[9] I. Osunbunmi and N. Fang, “Work in Progress: An Early Look Into the Systematic Review of Project-Based Learning in Engineering Education,” in *2022 ASEE Annual Conference & Exposition*, 2022.

[10] L. Given, *The SAGE Encyclopedia of Qualitative Research Methods*. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc., 2008. doi: 10.4135/9781412963909.

[11] A. Minichiello, S. Marx, L. McNeill, and C. Hailey, “Exploring student study behaviours in engineering: how undergraduates prepared textbook problems for online submission,” *European Journal of Engineering Education*, vol. 44, no. 1–2, pp. 253–270, Mar. 2019, doi: 10.1080/03043797.2018.1474342.

[12] J. W. Creswell and V. L. P. Clark, *Designing and Conducting Mixed Methods Research*. SAGE Publications, 2018.

[13] S. L. Dworkin, “Sample Size Policy for Qualitative Studies Using In-Depth Interviews,” *Arch Sex Behav*, vol. 41, no. 6, pp. 1319–1320, Dec. 2012, doi:10.1007/s10508-012-00166.

[14] I. Osunbunmi, “A Mixed-Methods Study of College Experiences and Learning and Study Strategies of High-Achieving Engineering Students,” *All Graduate Theses and Dissertations*, Dec. 2022, [Online]. Available: https://digitalcommons.usu.edu/etd/8690

[15] J. W. Creswell and J. D. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed. Los Angeles: SAGE Publications, Inc., 2018.

[16] C. Glesne, *Becoming Qualitative Researchers: An Introduction, 5th Edition*. Pearson, 2016.
[17] R. J. Chenail, “Interviewing the Investigator: Strategies for Addressing Instrumentation and Researcher Bias Concerns in Qualitative Research,” p. 8, 2011.
[18] J. W. Creswell, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. SAGE Publications, 2012.
[19] J. Saldaña, *The Coding Manual for Qualitative Researchers:*, Fourth. Los Angeles: SAGE Publications Ltd, 2021.
[20] S. Han, R. Capraro, and M. Capraro, “How Science, Technology, Engineering, and Mathematics (stem) Project-Based Learning (pbl) Affects High, Middle, and Low Achievers Differently: The Impact of Student Factors on Achievement,” *International Journal of Science & Mathematics Education*, vol. 13, no. 5, pp. 1089–1113, Oct. 2015, doi: 10.1007/s10763-014-9526-0.
[21] S. Watson, O. M. Williams-Duncan, and M. L. Peters, “School administrators’ awareness of parental STEM knowledge, strategies to promote STEM knowledge, and student STEM preparation,” *Research in Science & Technological Education*, vol. 40, no. 1, pp. 1–20, Jan. 2022, doi: 10.1080/02635143.2020.1774747.

APPENDIX

Interview Protocol for the Study.

1. How would you describe your experience with the GEAR UP Engineering Summer Camp so far?
   a. What did you enjoy the most about the camp?
   b. What did you dislike about the camp?
2. How does your experience in the previous five days of summer camps compare with your experience at these two days of GEAR UP summer camp?
   a. Which of the camps do you prefer and why?
   b. Do you prefer several different activities in a 5-day camp to a single activity in a two-day camp?
3. Why did you decide to come to this camp?
4. Describe your interest in STEM (Science, Technology, Engineering, and Mathematics) fields?
5. How has participating in GEAR UP summer camp influenced your interest in STEM?
   a. Can you give examples of how some GEAR UP activities have influenced your interest in STEM?
6. How has your experience with STEM-related courses at school influenced your interest in STEM careers?
   a. Can you describe your perceptions of your abilities in STEM-related subjects?
   b. How do you consider the relevance of STEM courses to your future career?
7. What other factors influenced your interest in a STEM career?
   a. Do your parents/family/relatives influence your interest? Explain How?
   b. Do your peers/friends have any influence on your interest? Explain How?
   c. Any role model influencing your interest? Explain How?
8. Do you have any other questions or anything else you want to share with me?