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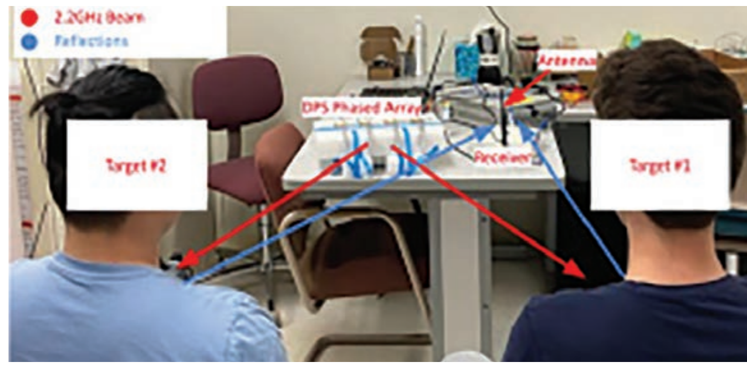

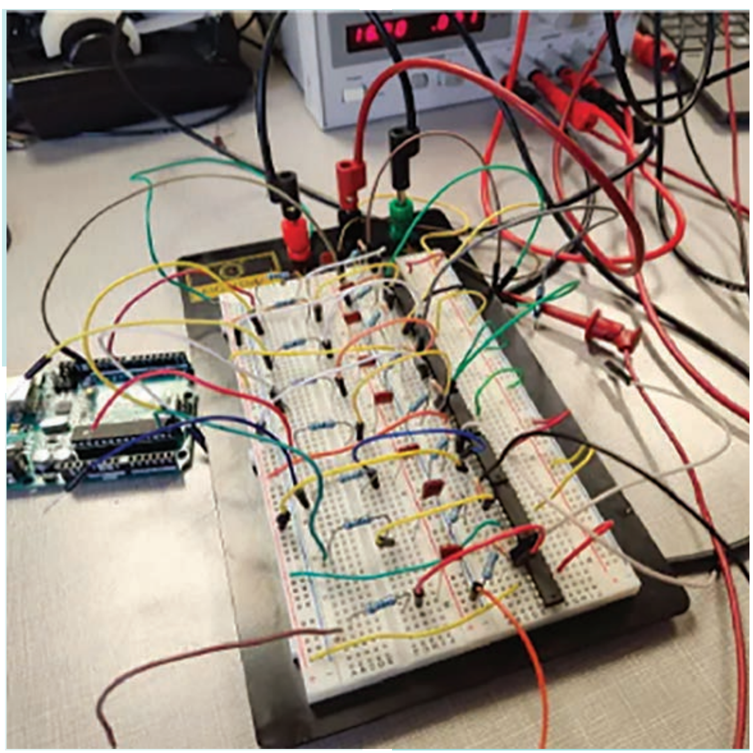

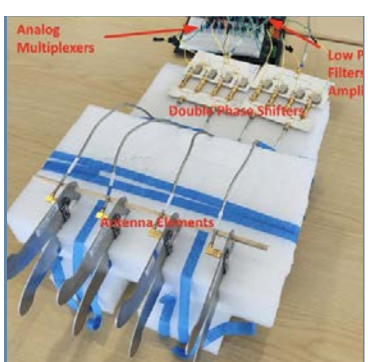

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From the EDITOR

Dear Colleagues:

The *Journal of Engineering Technology®* (*JET*) is entering an exciting new phase with the implementation of Digital Object Identifiers (DOIs) for all published articles, beginning with this issue. DOIs provide a unique, permanent identifier for scholarly work, ensuring stable access, enhanced citation linking, and greater discoverability. This advancement strengthens the credibility and long-term accessibility of research published in *JET*, further supporting our mission to bridge academic inquiry with real-world engineering applications.

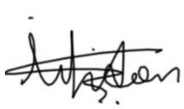
This issue features several impactful studies that advance both engineering technology education and applied research. One paper explores how a research project provided students with hands-on experience in radio frequency and radar systems, signal processing, and field-programmable gate array (FPGA) development, reinforcing practical skill development beyond traditional coursework. Another study focuses on enhancing student learning in geothermal cement engineering through the "1+1+1" educational model, which pairs undergraduates, graduate students, and faculty while integrating a portable testing instrument for experiential learning. Additionally, a paper highlights the benefits of engaging undergraduates in research on recycled plastic concrete, enriching their portfolios, fostering teamwork and leadership skills, and increasing interest in engineering technology disciplines. Another study assesses the impact of transportation-focused summer camps on students' knowledge and career interests while examining gender and ethnic differences in career awareness.

This issue also includes an editorial article that provides essential guidance for prospective authors on publishing applied research in *JET*. This paper aims to help researchers and educators prepare high-quality manuscripts that align with our journal's focus on integrating engineering technology education with industrial applications.

Looking ahead, our editorial team will host a special session at the 2025 ASEE Annual Conference in Montreal, Canada, focusing on best practices for preparing *JET* articles and highlighting the journal's impact. We invite you to attend this session and visit our journal booth to engage with our editorial team and learn more about opportunities for publication in *JET*.

As always, the editorial board looks forward to your contributions and continued support in advancing engineering technology education and research.

All my best,



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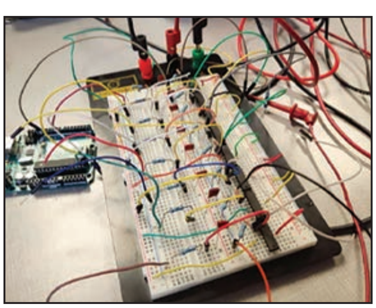

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COVER: Photos from "*Radar-Based Vital Sign Monitoring with Automated Beam Steering*."

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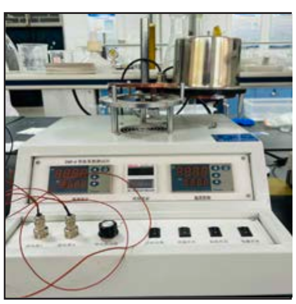

Announcements

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Exploring Transportation Career Awareness through University-Hosted Summer Camps

Maximus X. Huang and Maurizio Manzo

DOI: 10.18260/jet.42.1.1

Abstract

The US Department of Transportation (USDOT) has announced a strong need for diversified workforces in the transportation industry now and beyond the 21st century. Career awareness of choices and opportunities existing in the transportation industry for secondary school students is very important to help increase the number of students pursuing advanced degrees and careers in transportation-related fields, deliver STEM-capable workforces, and broaden the participation of women and minorities in transportation fields. Career seminars, university-hosted summer camps, and competitions are some of the common career awareness methods for secondary school students.

The objective of this study is to explore the effectiveness of university-hosted transportation-focused summer camps for transportation career awareness and diverse workforces. Based on data collected from the National Summer Transportation Institute (2022) and Summer Transportation Institute (2023) summer camps that were organized and hosted at the University of North Texas, it is observed that transportation-focused summer camp activities work very well for student transportation career awareness, which significantly improved students' familiarity with transportation knowledge and their interest in transportation careers. However, summer camp activities work significantly better for male students than female students and for Asian and White students than other students. Therefore, activities specifically designed to promote the involvement of female students, African-American students, Latino or Hispanic students, and Native-American students need to be considered for summer camp activities.

1. Introduction

The US has shown a strong need for a diverse workforce in the transportation industry now and beyond the 21st century. For example, for the highway industry, in January 2023, the roads and streets in the USA witnessed a significant surge in travel, with a 5.6% increase, totaling 13.2 billion additional vehicle miles compared to the same month in the previous year. This substantial growth is discernible in the seasonally adjusted vehicle miles traveled, which reached 272.5 billion miles, representing a 4.5% change over January 2022 and a notable 3.1% change compared to December 2022 (FHWA 2023). According to the Federal Highway Administration (FHWA), Americans' average daily vehicle miles of travel is 5.35 billion miles as of 2021 (FHWA 2021), while in Texas, the average daily vehicle miles traveled contributed to 772.7 million miles, with a grand annual total of 282.2 billion miles (Texas, n.d.). With the significant surge in travel and the continuously increasing vehicle miles traveled in the USA, there is a growing need for a substantial and skilled workforce to ensure the maintenance and upkeep of the roads and infrastructure. The conditions in other transportation industries, such as aviation, are similar to the FHWA. According to the U.S. Department of Transportation statistics, employment in the transportation and warehousing sector increased to 6.7 million workers in 2022, up by 8.2 percent from 2021 (USDOT 2022). Employment among civil engineers will increase by 11% between 2016 to 2026.

However, university enrollment trends suggest that growth in degrees in civil engineering will fall short of the projected 11% (Harper et al. 2018). To address this issue and to ensure a prosperous future for the transportation industry and its various components, it is imperative to increase the number of students pursuing STEM degrees and careers in transportation while simultaneously diversifying the pool of students entering these fields (Jasek 2020; Villatoro and Liou-Mark 2020). Career seminars and university-hosted summer camps and competitions are some common career awareness methods for secondary school students. The objective of this study is to explore the effectiveness of university-hosted transportation-focused summer camps for transportation career awareness and diverse workforces based on collecting and analyzing data from the National

Summer Transportation Institute (2022) and Summer Transportation Institute (2023) camps that are hosted at the University of North Texas.

2. Transportation Career Awareness

To explore the effectiveness of university-hosted transportation-focused summer camps for transportation career awareness and diverse workforces, the organized camp provides a 2.5-week summer program for middle/high school students (8-10th grades) in Dallas-Fort Worth (DFW) area to provide them the awareness of careers in the transportation industry, to encourage them to take transportation-related curricula, and to pursue advanced degrees and careers in transportation in the future. This research is part of the Summer Transportation Institute program supported by the Texas Department of Transportation and the US Federal Highway Administration. The objective of this research is to collect data and conduct analysis for the following research questions related to transportation career awareness and diverse workforces through summer education programs. Below are the research questions we would like to answer from this research:

1. Can summer camp activities, in a short time, effectively improve the familiarity with transportation knowledge among secondary school students?
2. Can summer camp activities, in a short time, effectively improve the interest in transportation careers among secondary school students?
3. For the diverse workforce, do gender and ethnicity impact career awareness results?

3. UNT Summer Transportation Institute (STI)

To answer the formulated research questions, in this study, there were designed activities that are included in the 2022 National Summer Transportation Institute (NSTI) and 2023 TxDOT Summer Transportation Institute (STI) programs; these activities include four categories: academic lectures, hands-on labs, field trips, and other activities. Other activities include orientation and campus tours, enhancement programs (meetings with student associations and the administrators of the College of Engineering), sports and recreation, etc. Those activities cover several transportation-related career types of TxDOT divisions, including aviation, bridge and highway/road systems, railroad transportation, maritime, transit, artificial intelligence, etc. Figure 1 summarizes the distributions of activities grouped by activity categories (in working hours) and by TxDOT transportation career types (in percentage), respectively. As shown, aviation-related activities take a large percentage. This is because of the well-developed aviation industry in the DFW area, which provides good sources of education.

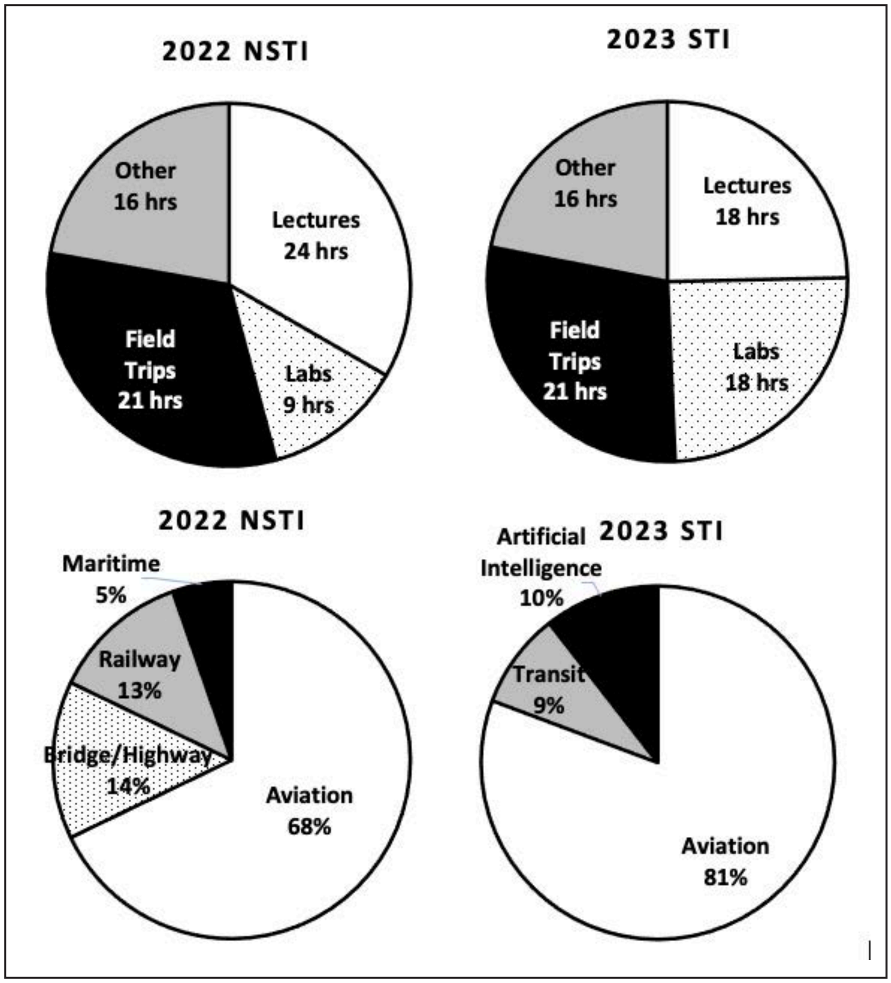

Figure 1. Distribution of student activities by activity categories (in working hours) and by TxDOT transportation career types (in percentage).

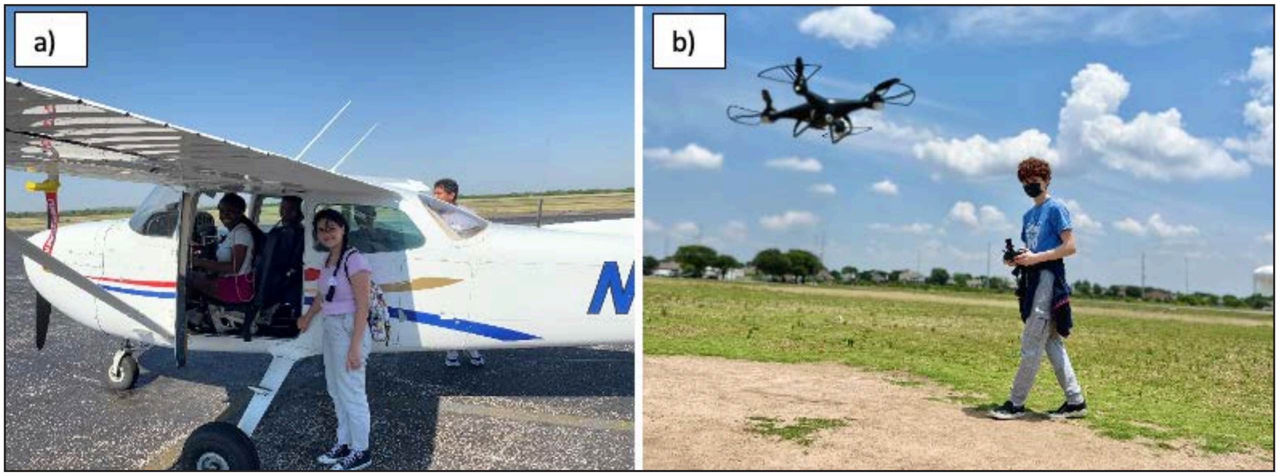

Figure 2. Example field trip and lab activities: a) US Aviation Academy field trip 2022; b) drone training lab 2023.

The UNT research team advertised the 2022 NSTI and 2023 STI summer programs to local public and private high schools by reaching out via email directly to the independent school districts (ISD) and school principals and distributing program flyers within the DFW area, including Denton ISD, Frisco ISD, Grapevine-Colleyville ISD, Plano ISD, Sanger ISD, Choctaw Nations, etc. Email applications were used for the 2022 NSTI and QR codes with online application forms were used for the 2023 STI.

Fifty-four and fifty-one prospective applications were received for the 2022 NSTI and 2023 STI summer programs, respectively. Twenty students were selected each year (2022 and 2023) by the research group using an application selection criterion, which includes middle/high school students in the 8-10th grades and a written statement regarding reasons for wanting to attend the 2022 NSTI or 2023 STI program, and how the program would benefit his/her academic career goals. Racial status was not considered in the application forms, as per TxDOT guidelines.

The UNT NSTI 2022 summer program was implemented from July 11th to July 27th, 2022, as scheduled. The UNT STI 2023 summer program was implemented from June 5th to June 21st, 2023, as scheduled. Figure 2 shows some participating students during selected field trips and lab activities. Student daily attendance remains at 95-100% for the 2022 NSTI and 75-90% for the 2023 STI program.

4. Survey, Data Analysis, and Discussions

4.1 Student Survey

At the beginning and the end of the 2022 NSTI and 2023 STI summer programs, the middle/high school student participants were asked to complete paper-based surveys. The surveys assessed students' familiarity with transportation knowledge (Q1 = Question 1), and interest in transportation careers (Q2 = Question 2). Numerical values are assigned to each answer choice of the question as "Very familiar = 5," "Familiar = 4," "Somewhat familiar = 3," "Know a little = 2," and "Know-nothing = 1."

All 20 students from the 2022 NSTI summer program responded to all three surveys (beginning, middle, and final); 17 of 20 students from the 2023 STI summer program responded to the beginning and middle surveys and 15 of 20 students responded to the final survey.

To answer research question #1 - Can summer camp activities in a short time effectively improve the familiarity with transportation knowledge among secondary school students? and question #3 - Do gender and ethnicity impact career awareness results? This research conducted analyses of the improvement (end value – beginning value) of Q1 transportation familiarity and Q2 transportation career interests for different genders and different ethnicity statuses, respectively.

4.2 Transportation Familiarity Improvement

Figure 3 shows the box and whisker plots of these improvements comparing males, females, all (male + female) including Asian, White, and Others, respectively. Table 1 summarizes the analytical statistics and the t-test results to show if an improvement is statistically significant compared to 0.

It can be observed that (1) the average overall improvement is 1.12 and P-value is 1.323E-07 < 0.10, which shows that the summer program activities can significantly improve the students' familiarity with transportation knowledge; (2) the average improvements in male and female students are 1.32 and 0.50, respectively, and the P-values of the improvements in male and female students are 9.549E-09 < 0.10

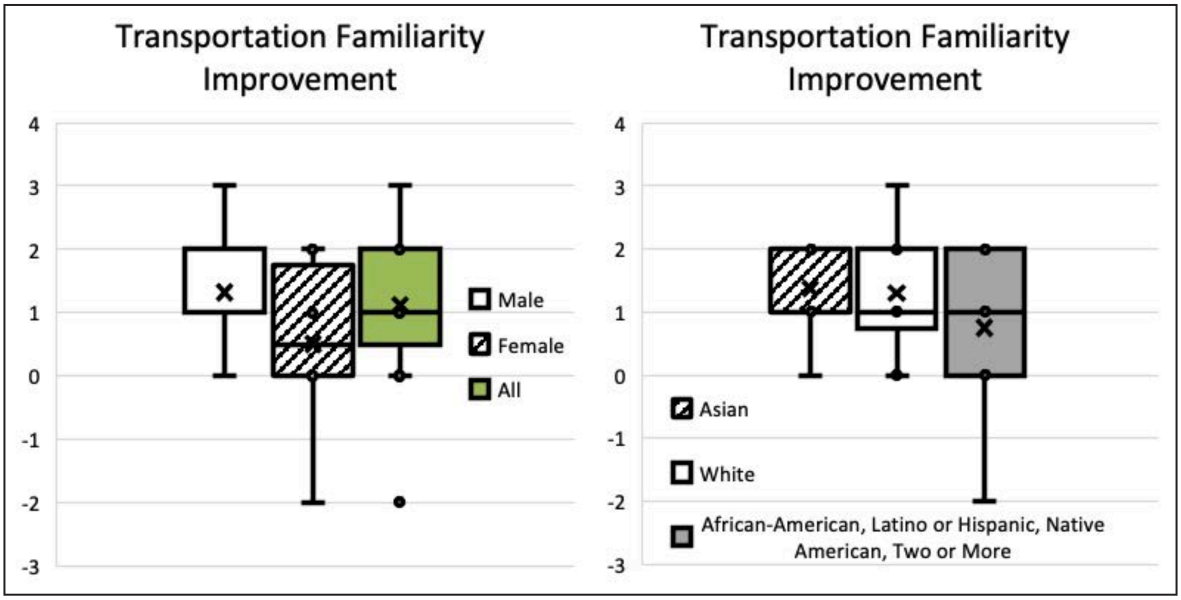

Figure 3. Box and whisker plots showing the improvement of students' familiarity with transportation knowledge.

and 0.1579 > 0.10, respectively, which show that the improvement for male students is statistically significant, but it is not significant for female students; (3) the average improvements in Asian, White, and Other (including African-American, Hispanic or Latino, Native American, Two or More) students are 1.36, 1.30, and 0.75, respectively, and the P-values of the improvements in Asian, White, and Other students are 2.655E-05 < 0.10, 0.0009479 < 0.10, and 0.02791 < 0.10, respectively, which shows that the improvements for all student ethnicity groups are statistically significant. However, the improvement is more significant for Asian and White groups than the Other group.

4.3 Transportation Career Interest Improvement

Figure 4 shows the box and whisker plots of the transportation career interest improvements comparing males, females, and all (male + female) and Asian, White, and Others, respectively. Table 2 summarizes the analytical statistics and the t-test results to show if an improvement is statically significant compared to 0.

It can be observed that (1) the average overall improvement is 0.33 and the P-value is 0.05087 < 0.10, which shows that the summer program activities can significantly improve the students' interest in transportation career; (2) the average improvements in male and female students are 0.44 and 0, respectively, and the P-values of the improvements in male and female students are 0.03070 > 0.10 and 0.5000 > 0.10, respectively, which shows that the improvement for male students is statistically significant, but there is no improvement for female students; (3) the average improvements in Asian, White, and Other students are 0.82, 0.30,

Table 1. Analytical statistics and the t-test results of improvement in transportation familiarity by genders and ethnicities.

	Gender			Ethnicity		
	Male	Female	All	Asian	White	Other
Mean	1.32	0.50	1.12	1.36	1.30	0.75
StDev	0.80	1.31	0.99	0.67	0.95	1.22
t-Test p-value	9.549E-09 < 0.10	0.1579 > 0.10	1.323E-07 < 0.10	2.655E-05 < 0.10	0.0009479 < 0.10	0.02791 < 0.10
Statistically Significant Improvement?	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**

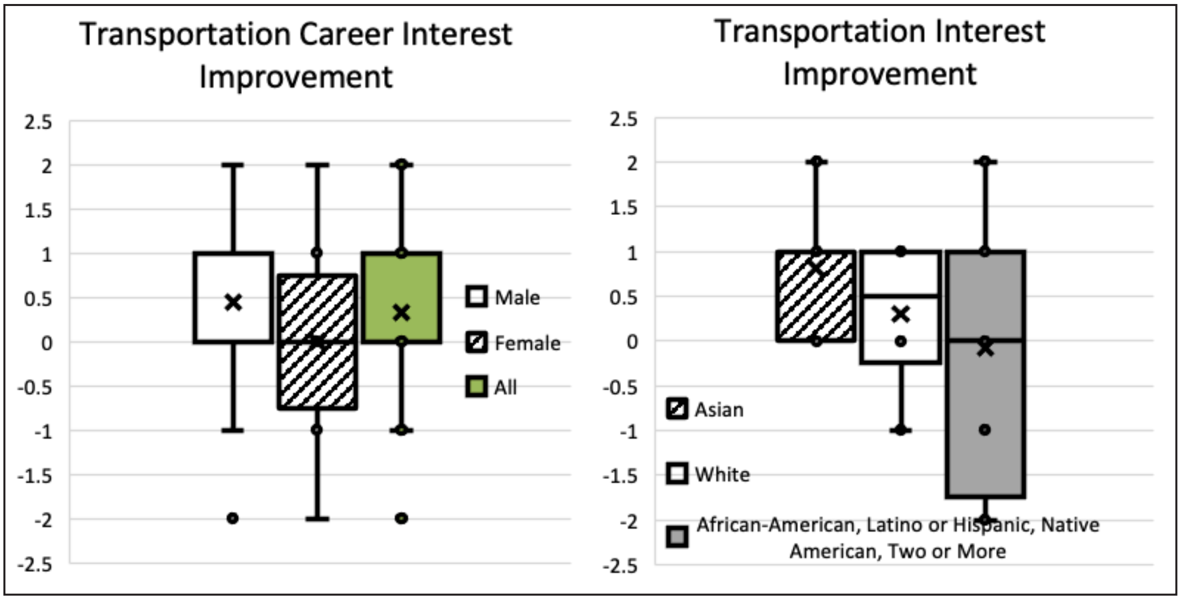

Figure 4. Box and whisker plots showing the improvement of students' interest in transportation careers.

and -0.08, respectively, and the P-values of the improvements in Asian, White, and Other students are 0.002366 < 0.10, 0.1394 > 0.10, and 0.4256 > 0.10, respectively, which shows the improvement for the Asian student group is statistically significant, but, it is not significant for the White group. The Other group's interest decreased.

5. Conclusion

The objective of this research was to collect data and conduct analysis for transportation career awareness and diverse workforces through summer camp activities. The following research questions and answers are summarized below:

1. Can summer camp activities, in a short time, effectively improve the familiarity withtransportation knowledge among secondary school students? Yes, transportation-focused summer camp activities can significantly (statistically) improve the students' familiarity with transportation knowledge.
2. Can summer camp activities, in a short time, effectively improve the interest in transportation careers among secondary school students? Yes, transportation-focused summer camp activities can significantly (statistically) improve the students' interest in transportation careers.
3. For the diverse workforce, do gender and ethnicity impact career awareness results? Yes, students' gender does have a significant impact on career awareness results. The improvement among male students is statistically significant and is significantly higher than among female students. And yes, students' ethnicity does have a signifi-

Table 2. Analytical statistics and the t-test results of improvement in transportation career interest by genders and ethnicities.

	Gender			Ethnicity		
	Male	Female	All	Asian	White	Other
Mean	0.44	0	0.33	0.82	0.30	-0.08
StDev	1.12	1.20	1.14	0.75	0.82	1.51
t-Test p-value	0.03070 < 0.10	0.5000 > 0.10	0.05087 < 0.10	0.002366< 0.10	0.1394> 0.10	0.4256 < 0.10
Statistically Significant Improvement?	**Yes**	No	**Yes**	**Yes**	No	No

cant impact on career awareness results. The improvement among Asian and White student groups is more significant and is significantly higher than among the Other student group (African-American, Latino or Hispanic, and Native American).

6. Future Research Direction

Transportation-focused summer camp activities worked very well for student transportation career awareness. However, it seems that these activities work better for male students, Asian, and White students. More specific activities designed for the involvement of female students, African American, Latino/Hispanic, and Native American students will be designed and added, such as involving student organizations such as the National Society of Black Engineers and the Society of Hispanic Professional Students.

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Maximus X. Huang

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Maurizio Manzo

Maurizio Manzo is an associate professor in the Department of Mechanical Engineering at the University of North Texas and the program director of the 2022 NSTI and 2023 STI summer programs. Dr. Manzo earned his PhD from Southern Methodist University, Dallas, Texas, in 2015, and both bachelor's and master's degrees in aerospace engineering from Italy. During his training, he has worked on different research areas of mechanical engineering such as experimental optics, photonics and sensing, and experimental fluid mechanics. He has authored several referred journal papers, and conference proceedings, and has 2 US patents (1 utility and 1 provisional). He is a member of the American Optical Society, the American Society of Mechanical Engineering, The Italian Association of Aeronautics and Astronautics, and the American Society for Engineering Education.

Exploring Physico-Mechanical Properties of Recycled Plastic Amended Cement Concrete

Shohana Iffat

DOI: 10.18260/jet.42.1.2

Abstract

Concrete is one of the most convenient construction materials to be utilized in primary and secondary constructions. One drawback of concrete is being heavy as it contains approximately 80% of aggregate. This pilot research focuses on utilizing recycled plastic waste as a percent replacement of aggregate to produce a lightweight concrete without adding further expense. At the same time, recycling waste is beneficial to our environment. Four concrete mixes were prepared in this research: one control mix without plastic, and three other mixes - one mix with 20%, one mix with 30%, and the last mix with 40% of coarse aggregate being replaced by plastic. Fresh concrete was examined through the slump and unit weight tests. Concrete specimens were cured at room temperature for up to 56 days and hardened properties were evaluated though compressive strength and dry density measurements. Concrete mix with 20% of recycled plastic exhibited comparable strength results after 7 days of curing. It could be hypothesized that recycled plastic added concrete is sustainable and inexpensive to construct many lightweight and secondary structures. Additionally, to enhance interests of freshmen and sophomores in engineering technology discipline, as well as to enhance their research experience at undergraduate level, faculties could involve them in such experimental research projects during summer or winter breaks.

1. Introduction

With the increasing demand for energy and materials, production of an environmentally friendly construction material has become a target for the construction industry in recent years. Not only the production of construction materials is alarming, but the amount of demolition, maintenance, and construction process generates substantial amounts of waste. This construction and demolition waste [Akanbi et al. 2018] disposal process is costly and challenging. Utilizing waste materials in concrete allows us to minimize the negative aspects of the production and disposal of construction materials. And utilizing waste products in construction is environmentally sustainable. The inclusion of waste materials often decreases the structural integrity of concrete and affects its durability. Despite these drawbacks, recycling waste in construction helps promote a circular economy and reduces the demand for new materials.

Aggregate plays a principal role in concrete which occupies 60-80% of the volume and 70-85% of the mass of concrete [Zhu et al. 2020]. Instead of collecting natural stones from quarries or sand from riverbeds, recycled waste could be utilized in manufacturing concrete for new constructions. Replacing natural aggregate with recycled plastic, which is one of the hardest materials in the ecosystem, helps to reduce plastic waste. Recycled plastic fibers or grains can be added to or replaced with normal aggregate to enhance concrete's durability [Ponmalar and Revathi 2022]. Substituting a portion of natural aggregate with plastic can lessen the need for quarrying and mining, and conserve natural resources. Incorporating plastic can lower the density of concrete [Dalhat and Wahhab 2016], leading to a lightweight structure [Almeshal et al. 2020]. Research revealed that the addition of plastic box waste particles [Adnan and Dawood 2021] improves the compressive strength of concrete and enhances ductility and stiffness. However, poor adhesion between plastic particles and the cement matrix [Mansour et al. 2024], resulting from the hydrophobic nature and smooth surfaces of plastics, decreases plastic's ability to bond effectively with cement paste. Dalhat and Wahhab [2016] found that a small quantity of recycled plastic added concrete exhibited enhanced compressive and flexural strength of concrete. Therefore, utilizing a small quantity of plastic waste in concrete not only strengthens concrete's performance but also reduces global warming, and it is a promising sustainable construction material.

Several research has been conducted on utilizing different types of recycled materials in concrete especially recycled fibers in concrete. Most of these waste materials were processed prior to applying to concrete

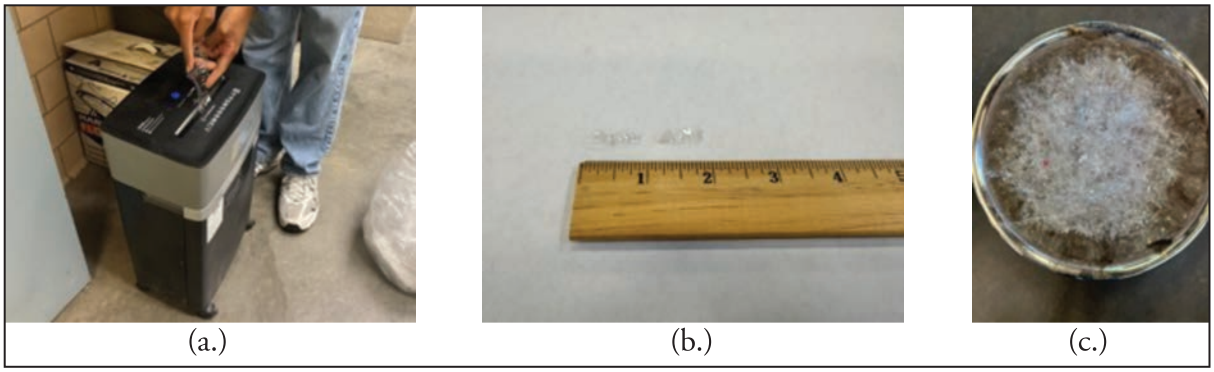

Figure 1. Plastic sample preparation: (a) shredding (b) measurement (c) shredded sample.

mix. In this research, the waste plastic particles were directly applied to the concrete mixes which is most convenient for real projects and is cost effective. Additionally, aggregate, which occupies the maximum volume of concrete, was partially being replaced with these lightweight waste materials which decreased the unit weight of concrete. Therefore, the resultant concrete was easier to handle and transport. In this way, the natural aggregate resources were preserved, and waste recycling is beneficial to the environment. In this research, 20%, 30%, and 40% of natural coarse aggregate were replaced by recycled plastic to make concrete. Cylindrical specimens were prepared and tested for compression after 7, 28, and 56 days of curing and concrete's strength was evaluated.

2. Methodology

2.1 Materials

2.1.1 Sources

Ordinary Portland Cement Type I-II, silica sand with specific gravity of 2.6, crushed stone with nominal maximum size of 19 mm and recycled plastic (polyethylene terephthalate, PET) were utilized in this research. Plastic water bottles were collected from recycled bins, lids and labels were removed, washed with water and air dried for about 24 hours. Then these bottles were split with scissors, and then using a paper shredder they were shredded into 50 mm x 6.25 mm x 0.003 mm portions. For this research, 1000 g of plastic fragments were prepared. Preparation of plastic samples are presented in Figure 1. Cement, sand and gravel were purchased from stores.

2.1.2 Properties

Sieve analysis was conducted on crushed stone according to ASTM C136 [2006] to obtain the grain size distribution, and the gradation curve is presented in Figure 2. Bulk density of plastic and crushed stone [ASTM C29. 2007], specific gravity and absorption capacity of crushed stone [ASTM C127. 2015], and moisture content of crushed stone and sand were obtained. The average tensile strength of three numbers of 13 cm x 5.2 cm x 0.003 mm PET plastic fragments was also obtained using a Universal Testing Machine (Figure 3) with a displacement rate of 0.5 inch/minute. The material properties are listed in Table 1.

2.2 Experimental Program

Four concrete mixes were prepared. One of these mixes was a benchmark with natural crushed stone and sand and without any waste plastic. The second, third, and fourth mixes were prepared with 20%, 30%, and 40% of natural crushed stone being replaced by plastic fragments, respectively. These concrete mixes could be conveniently utilized in the real construction scenario as no supplementary cementitious materials, admixture or no additives were

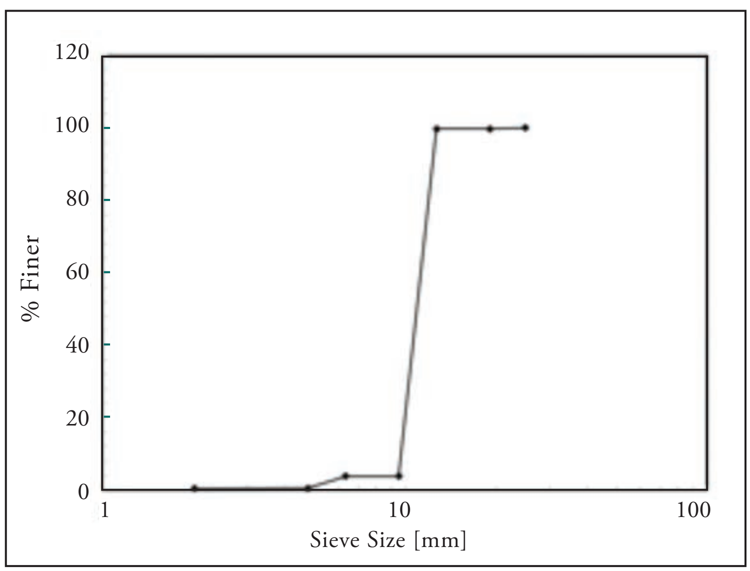

Figure 2. Grain size distribution of crushed stone utilized in concrete.

Figure 3. Tensile strength test of plastic sample.

Table 1. Material properties.

Specific Gravity	Absorption [%]	Moisture Content [%]		Bulk density [kg/m3]		Tensile strength [MPa]
Crushed Stone	*Crushed Stone*	*Crushed Stone*	*Sand*	*Plastic*	*Crushed Stone*	*Plastic*
2.745	0.42	0	0.58	85.91	1497.88	2150.97

consumed here. The design slump was 75 mm, and 28-day required compressive strength was 5000 psi (34.5 MPa). The mix design information is reported in Table 2.

The workability of each concrete mix was examined through slump test according to ASTM C143 [2012]. The unit weight of fresh concrete was estimated according to ASTM C138 [2017] and displayed in Table 3. From each concrete mix, three numbers of 100 mm x 200 mm cylindrical specimens were prepared for each test date. The cylindrical specimens were cast in the plastic molds, secured with lids, and were stored in a cabinet at a controlled temperature (80.7° ± 2.9° F) and relative humidity (58.7% ± 7%) for up to 56 days.

3. Results and Discussions

After 7, 28, and 56 days of curing, compressive strength of control and plastic added cylindrical concrete specimens was estimated according to ASTM C39 [2021], and the test setup is shown in Figure 4a. The variation in compressive strength of control and 20% of plastic added cylindrical samples with duration of curing is displayed in Figure 4b. In addition, 28-day compressive strength and dry density of control and different percentages of plastic added samples are reported in Figure 5a and Figure 5b, respectively.

From the compression test results of concrete shown in Figure 4b, it was observed that recycled plastic added concrete produced comparable compressive strength as conventional concrete after 7 days of curing, which indicates early strength gaining was not impacted undesirably by adding plastic fragments in concrete. However, after 28 and 56 days of curing, compressive strength of plastic added concrete was significantly lower than the conventional

Table 2. Mix proportions of four concrete mixes.

Ingredients	Control Concrete	20% Plastic added Concrete	30% Plastic added Concrete	40% Plastic added Concrete
Water [kg]	4.15	4.15	4.15	4.45
Cement [kg]	8.56	8.56	8.56	8.56
Sand [kg]	14.60	14.60	14.60	14.60
Crushed stone [kg]	19.52	15.61	13.66	11.71
Plastic [g]	-	220.56	330.83	441.11

Table 3. Unit weight of fresh concrete.

Properties	Control Concrete	20% Plastic added Concrete	30% Plastic added Concrete	40% Plastic added Concrete
Unit weight [kg/m^3]	2384	2340	2319	2268

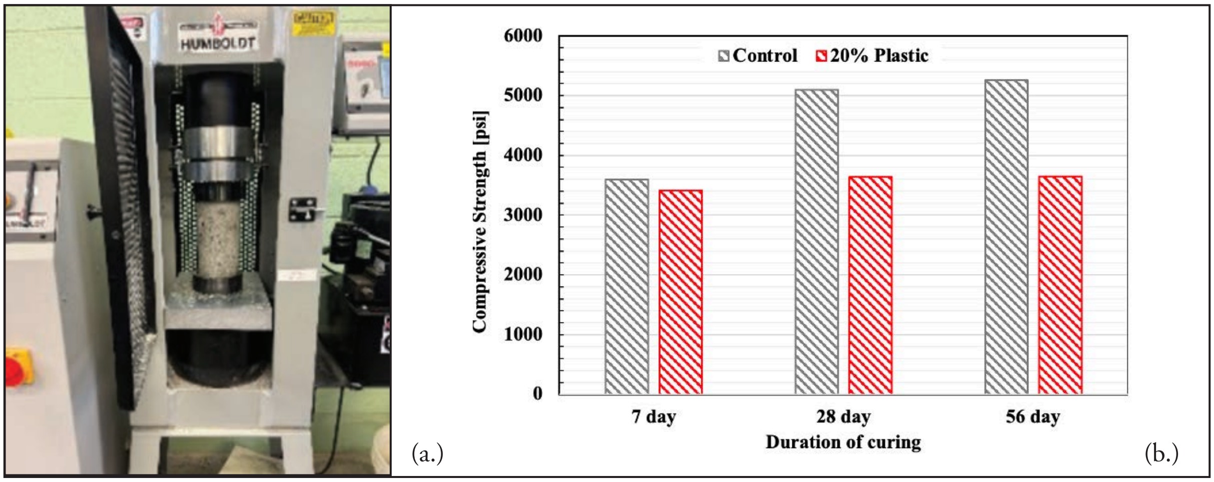

Figure 4. Compression test: (a) test setup (b) compressive strength after 7, 28 and 56 days of curing.

concrete, which signifies that plastic addition might impacted the production of cement hydrates, and adversely affected the interfacial transition zone in the cement concrete matrix, with duration of curing. The ruptured cylindrical samples of control and 20% of plastic added cylinders, displayed in Figure 6, suggest that plastic added samples resulted in less deteriorated failure as compared to the conventional concrete samples, though it yielded lower compressive strength. It was noticed from Table 1 that PET plastic has a tensile strength of 2150.97 MPa which is five times greater than that of mild steel. Due to this high tensile strength of added plastic fragments, a brittle failure of concrete was hypothetically prevented in compression.

It can be hypothesized that, due to lack of chemical compatibility between cement, aggregate and plastic [Naik et al. 1996, Mohammed et al. 2020], hydration was impacted by the presence of plastic particles inside the concrete. In addition, 20 to 40% of plastic added concrete were in range of 2.3 to 4.9% lighter than control concrete (Figure 5b) and these plastic fragments introduced lack of homogeneity in the concrete mix. In absence of 20 to 40% of coarse aggregate and in presence of plastic fragments, voids were generated inside concrete matrix after curing, which resulted in stress concentration zones while loading. As a result, 20 to 40% of plastic added concrete developed in range of 29 to 55% of lower compressive strength (Figure 5a) as compared to conventional concrete after 28 days of curing.

4. Educational Impact on Engineering Technology

Such experimental research has numerous impacts on engineering technology education and some of these potentials are listed below.

4.1 Innovations in Engineering Technology Education

Engineering students prefer reflective learning instead acting learning, while active learning e.g.,

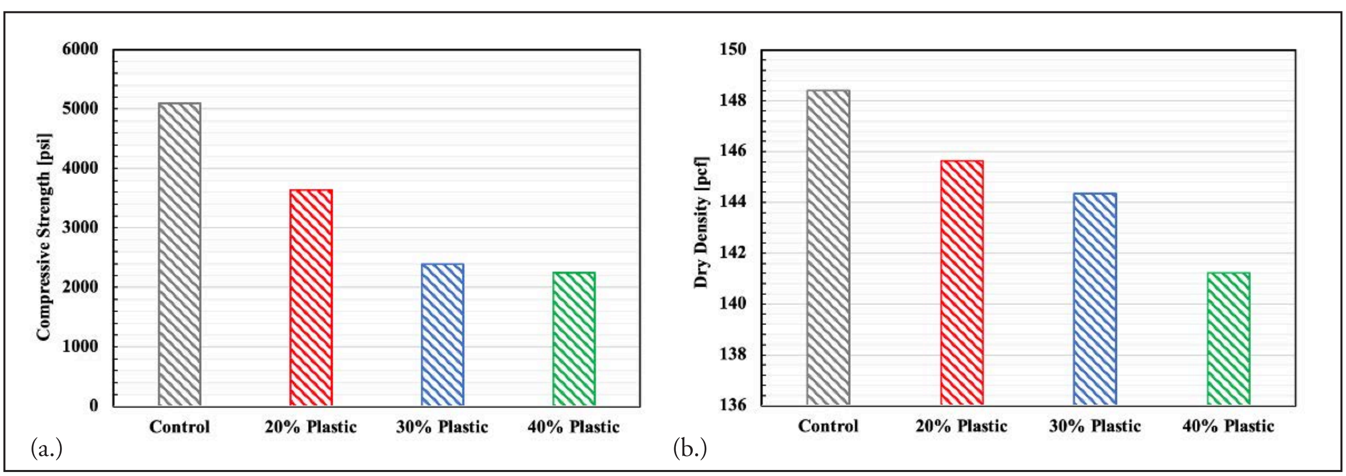

Figure 5. 28-day test results (a) compressive strength and (b) dry density.

Figure 6. Fractured specimens after 28-day compression test (a) control concrete (b) 20% plastic added concrete.

project-based learning offers enhanced understanding of basic engineering concepts [Prince 2004, Iffat 2023]. Involving students in such small projects could enhance their interests in engineering as well as could enhance their fundamental understanding of engineering concepts because hands on experiments in laboratories or fields always fascinate students more as compared to the classroom education. Additionally, students' teamwork skills could be enhanced which is essential for quality education [Uddin et al. 2024] and future leaderships.

4.2 Curricular Support to Engineering Technology Programs

Such small projects could be offered as technical elective courses where laboratory activities will be followed by the lecture. Students' performances could be evaluated through project reports and final presentations. Conducting experimental research works at undergraduate levels may enhance students interests in higher studies. As a result, relevant post graduate courses could be introduced to the program with advanced laboratory activities.

4.3 Enhancements to Student-Enrollment in Engineering Technology

This type of project-based courses will enhance students' enrollment in the engineering technology program while due to difficulties in understanding core engineering concepts in the first two academic years, many students transfer to many non-engineering disciplines. Additionally, student and faculty interaction, which is strategic for academic success of students [Yanik et al. 2021], could be enhanced through involving students in such experimental research projects conducted by faculty mentors.

5. Conclusions

From this experimental research, following decisions could be implemented:

- Early high strength after 7 days of curing was observed from 20% of plastic waste added concrete; however, no strength enhancement was experienced after 28 or 56 days of curing. After 28 and 56 days of curing, 20% plastic added concrete exhibited lower compressive strength compared to the control concrete.
- In this research, no supplementary cementitious materials i.e., fly ash, silica fume, or no admixtures were utilized to keep the construction expense minimal, and to ensure its quick application in real construction scenario.
- The recycled concrete was lightweight and less expensive as compared to conventional concrete. To reduce weight of large structures, these waste materials could be utilized in concrete in addition to some reinforcing agents and admixtures to offset the strength loss.
- As plastic fragments yielded high tensile strength, high flexural strength is hypothetically expected from recycled plastic added concrete.
- Recycled plastic added concrete could be utilized in low-rise residential buildings, partition walls of commercial spaces, curbs, sidewalks, driveways, road dividers and many other secondary structures. Uses of recycled plastic in construction will reduce the plastic waste and global warming.
- If undergraduate students are involved in such research projects, it enriches students' portfolios, boosts their teamwork-leadership skills, and finally, upgrades their interests in engineering studies. It is recommended to associate undergraduate students in research projects for all engineering technology disciplines, especially civil engineering

technology, architecture and construction management technology and mechanical engineering technology.

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Innovative Asphalt-Based Carbon Fiber Cement for Enhanced Geothermal Energy Efficiency-Impacts on Engineering Technology

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Abstract

Geothermal energy is currently being explored and developed on a large scale in response to the growing demand for global energy transition. High thermal conductivity geothermal reservoir cement is essential for raising effluent temperature, lowering development costs, and enhancing heat transfer efficiency. There is an urgent need to develop new cement systems with high thermal conductivity. The application effect of asphalt-based carbon fiber (ACF), a novel material with high thermal conductivity, in geothermal reservoir cementing is examined in this article. The findings show that by supplying reaction sites, raising the concentration of hydration products, and filling the structure's micropores, ACF facilitates the cement's hydration process. At the macroscopic level, this drastically reduces the heat transfer path and shows good heat transfer performance. Furthermore, this study's effects on research-based learning in engineering are thoroughly explained from four perspectives: undergraduate education, new instructional methods, new equipment, and student cognition. The use of G cement based on ACF in geothermal reservoir sections can improve cement heat transfer efficiency at a cheap cost and is anticipated to encourage the widespread growth of geothermal energy.

1. Introduction

With the increasing environmental issues brought about by fossil fuel consumption, geothermal energy has been widely used in power generation, heating/cooling, and agriculture for its advantages, such as stable and renewable heat sources, high energy utilization efficiency, and low carbon (Sun et al. 2024).

Geothermal resources can only be explored and developed by constructing a dependable injection-production wellbore in the formation. The most crucial engineering component to boost output and cut expenses is cementing, which is a crucial step in the construction of geothermal wells. It establishes the well's overall life cycle stability, service life, and production capability (Ahmed, Saeed, and Aman 2022). Enhancing the heat recovery efficiency of geothermal wells requires improving the cement materials" thermal conductivity in reservoir sections (Zhang and Li 2022).

Adding external materials is the most popular way to increase cement's thermal conductivity. It has been demonstrated that high thermal conductivity materials, such as steel, copper, and carbon-based fillers, can greatly increase the rate of heat transfer in cement, and accomplish the objective of increasing cement's thermal conductivity (Wei, et al. 2023; Bae, et al. 2023; Daza-Badilla, et al. 2024; Rasheed, et al. 2024). The natural flake graphite layer has a high thermal conductivity of 70~150 W/(m·K) due to its extremely active π bonds, which allow heat to be transferred by electrons. The cement's thermal conductivity rises to 1.8659 W/(m·K) when combined with iron powder and quartz sand in a 7.5:3:1 ratio (Hao et al. 2020). When the composite ratio of graphite, alumina, and steel slag powder was 7:1:3, the thermal conductivity in G cement peaked at 1.604 W/(m·K) (Ying et al. 2022). To forecast the thermal conductivity of geothermal cement, some academics have put forth mathematical models. Furthermore, it was proposed that the cement's heat conductivity is influenced by the water/cement ratio, porosity, the filler particle size and shape (Zhou et al. 2023; Yang et al. 2024).

In this study, it is impossible to overlook the detrimental effects of infill products on cement (Li et al. 2022; Wu et al. 2013). For instance, adding 7.5% graphite results in a 29% and 15% loss of compressive strength and fluidity, respectively. 15% graphite decreased compressive strength by almost 90%. On the other hand, these studies have not considered how high salinity geothermal fluids and formation temperature affect cement's hydration process and fundamental characteristics.

This study investigated using asphalt-based carbon fiber (ACF) to increase the thermal conductivity of geothermal cement. ACF costs only 1/3 as much as carbon fiber based on polyacrylonitrile-based carbon fiber and is produced from petroleum/coal tar pitch through processes such as modulation, spinning, non-melting, and carbonization. Additionally, ACF exhibits outstanding heat transfer performance, strength, and resistance to high temperatures. There are currently no reports on the use of ACF materials as thermal conductivity fillers in geothermal cementing.

This study aims to develop a novel high thermal conductivity geothermal cement based on the ACF and to promote efficient and low-cost geothermal energy development. At high temperatures or high salinity environments, the effects of ACF on thermal conductivity, compressive strength, fluidity, and density of G cement were evaluated. Then the mechanism of ACF's influence on cement was analyzed by polarizing microscopy, scanning electron microscopy (SEM), and X-ray diffraction.

2. Materials and Method

2.1 Materials

In this study, high sulfate-resistant G-grade cement was used, which was purchased from Qingyun Kangjing Building Materials Co., Ltd. (Dezhou, Shandong). This geothermal cement meets the high temperature and corrosion resistance requirements by strictly controlling the composition of its raw materials. S95 slag powder was purchased from Henan Dingnuo Purification Materials Co., Ltd. (Gongyi, Henan), made of blast furnace slag and obtained by drying, grinding, and other processes. The high-activity powder helps to improve the compressive strength of concrete, reduce the hydration heat, and reduce the early structural cracks. Asphalt-based carbon fiber powder (ACF) was purchased from Shenzhen Guosen Navigation Technology Co., Ltd., which is a powdery sample with a density of 1.76 g/cm3, a mesh number of 400, and a carbon content of ≥95%. AFC is a powder that has a resistivity of 1.5*10-3 ΩM, a diameter of 8-12 μm, and a high-temperature resistance of 450-2000 °C. The microstructure of ACF under SEM reveals rod-shaped fibers is seen in Figure 1. The unit pricing of major materials bought in small quantities are listed in Table 1; however, employing industrial-grade items bought in bulk is less expensive than that.

2.2 Methods

2.2.1 Preparation of cement

Preliminary experiments yielded the basic formula for cement: the ratio of cement and mineral powder was 6:4, and the water-cement ratio was 0.6. The experimental group consisted of cement mixed with 2.5%-20% ACF.

Three phases are involved in the preparation and curing of cement: 1. In the cement slurry mixer, the ash components (cement powder, S95 slag, and ACF) were mixed for two minutes. 2. To create the cement slurry, 60% solid mass water was added to

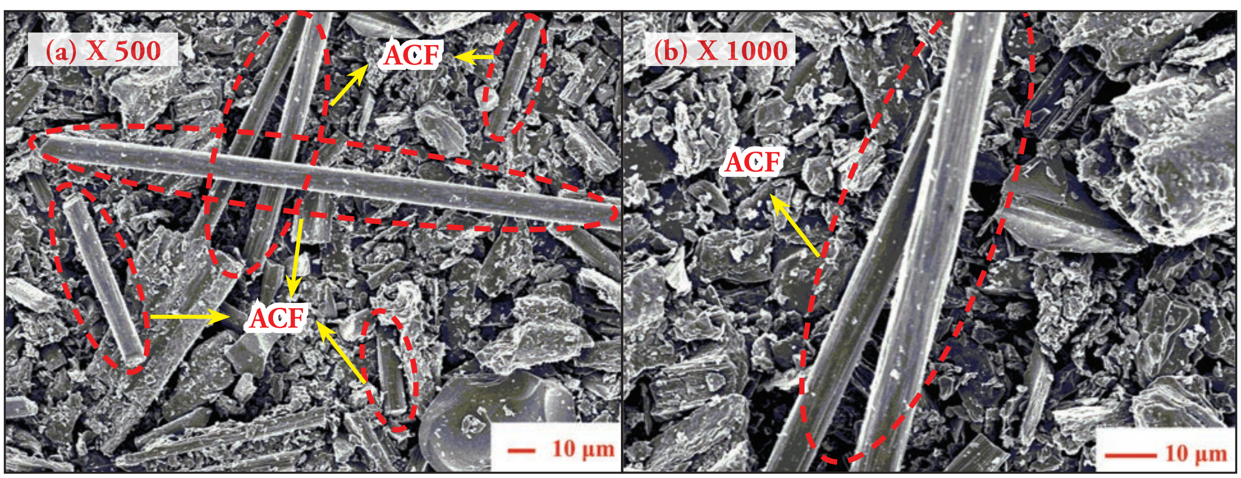

Figure 1. The SEM images of ACF: (a) magnify ×500; (b) magnify ×1000.

Table 1. Material cost.

Material	G cement	S95 slag	ACF
Unit-prices	4000 (¥/t)	5000 (¥/t)	150 (¥/kg)

the mixer, mixed for 120 seconds at low speed while the ash components were added gradually, and then agitated for another 120 seconds at high speed. 3. After pouring the cement slurry into the 40 mm x 40 mm x 40 mm triple test mold, it was cured for 72 hours at 40, 60, 80, and 100° C in a water bath. Additionally, the cement was cured in 2.5%, 5%, 7.5%, and 10% concentrations of salt water to simulate the impact of high-salinity geothermal water on cement.

2.2.2 Thermal conductivity testing of cement

Cement's thermal conductivity is tested using a DRP-2 type thermal conductivity tester, as seen in Figure 2(a). The principle is to heat the cement block through the heating plate and then move the heat through the tested block to the copper plate. The upper surface temperature (T1) and lower surface temperature (T2) create a steady temperature differential after the heat transmission is stable. T1 and T2 values were noted. Every 30 seconds, the temperature of the copper plate is recorded while it is left out in the open to cool naturally. Lastly, the analytical program is used to determine the sample's thermal conductivity. All of the temperatures in this study are expressed in ° C, and the thermal conductivity is expressed in W/(m·K). To guarantee accuracy, disc-shaped cement samples with a diameter of 13 cm and a thickness of 1 cm were prepared (Figure 2(b)).

2.2.3 Characterization of physical-chemical properties of cement

(1) *Foundation performance testing*. To characterize the compressive strength of cement, the WDW-600E microcomputer-controlled electronic universal testing equipment was used to record the maximum load. Calculate the mean of each group's three tests. Calculate the cement density by dividing the volume of the blocks by the mass of the demolded blocks. The truncated cone round mold method is used to assess the cement slurry's fluidity. (2) *Polarizing microscope test.* The pore/crack distribution in the cement sample was observed by a polarizing microscope (Model Olympus BX53P, Japan). Then, the statistical analysis was performed by using the Nano Measurer software. (3) *SEM test*. The cut cement sample was pasted on the copper tape. Then the gold spray and vacuum extraction were carried out. The surface characteristics of the cement samples were observed by using SEM (Model JEOL JSM-7610F Plus, Japan). (4) *X-ray diffraction test.* After grinding the test sample into a fine powder, the tablet was made by using a mold, and the X-ray diffraction instrument (Model Bruker D8-ADVANCE, Germany) was used for detection. The 2θ angle range of the test was 5°~70°, and the scanning speed was 10°/min.

3. Results and Discussion

3.1 Thermal Conductivity of ACF Cement

Figure 3 illustrates the addition of ACF significantly increases the thermal conductivity of cement at various temperatures. The thermal conductivity of ACF cement first rose and then fell as the ACF concentration rose from 2.5% to 20%. The best reinforcement effect is seen at 7.5% ACF. At 40°C, 60°C, 80°C, and 100°C, the thermal conductivity of 7.5% ACF-cement rose by 50%, 280%, 96.2%, and 100%, respectively, in comparison to the control group. The cement cost rose as the concentration of ACF grew, but the rise in heat conductivity steadily reduced as

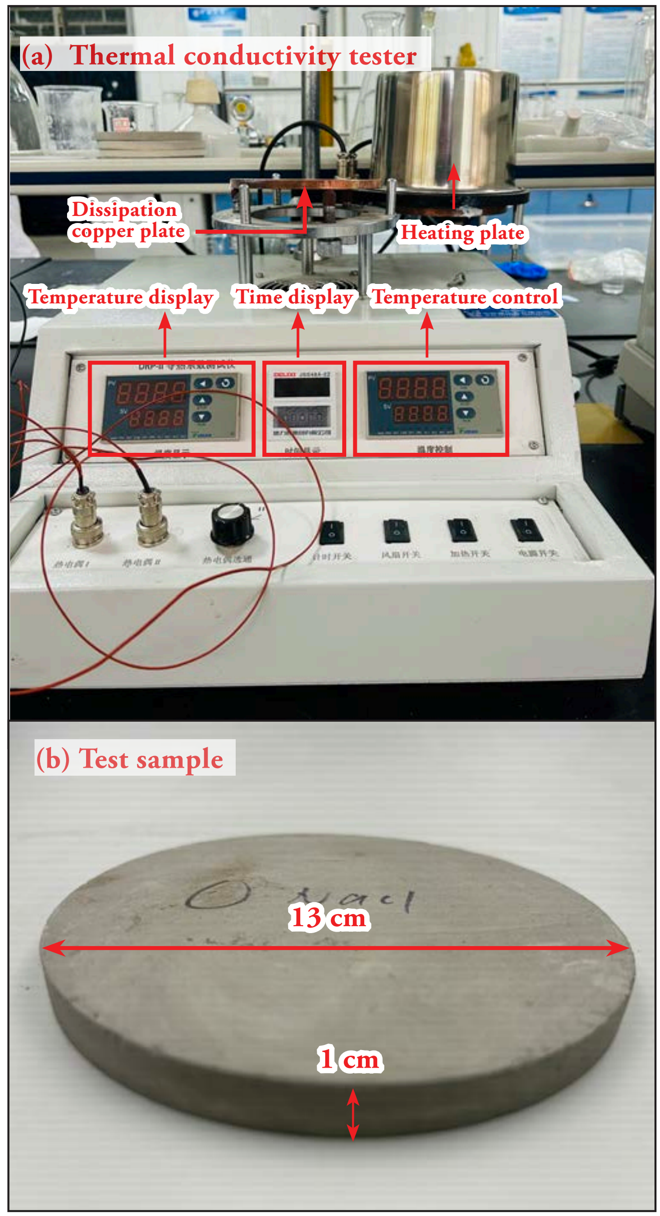

Figure 2. Thermal conductivity tester (a) and test sample (b).

a result of the pore-forming property of ACF. The negative effect of 12.5-20% ACF is more than the positive effect for ACF cement cured at 40° C, which causes the cement's thermal conductivity to rise negatively. In conclusion, 5-10% ACF greatly increased the thermal conductivity of G-cement at T<60 °C, whereas 5-12.5% ACF is advised at T≥60 °C. 7.5% ACF is the best option when taking application cost and heat conductivity into account.

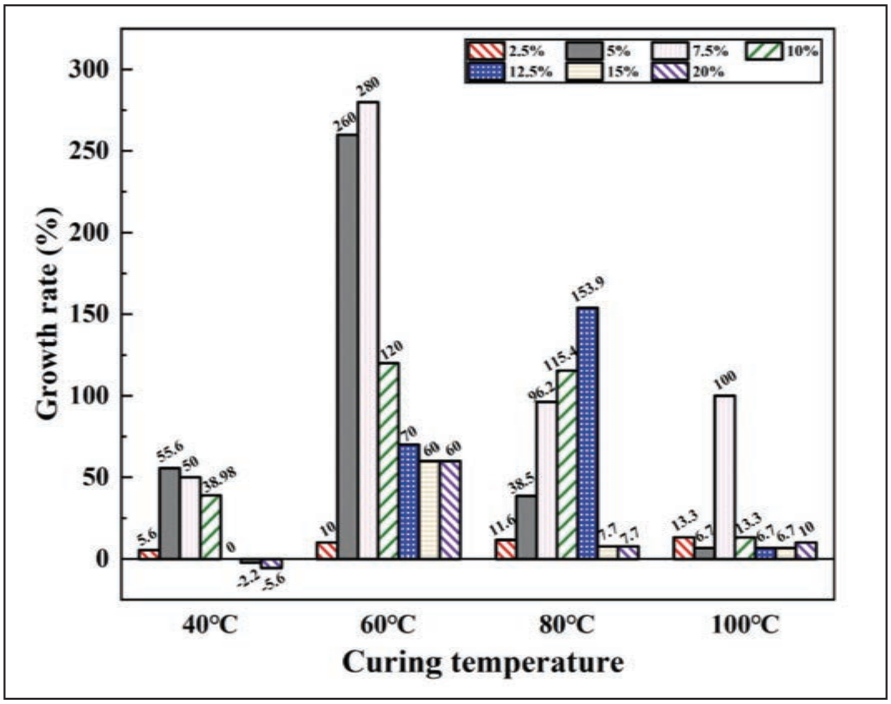

Figure 3. The growth rate of thermal conductivity of 2.5~20% ACF-cement cured at different temperatures.

3.2 ACF' Influence on the Compressive Strength, Density, and Fluidity of Cement

The stability and service life of the geothermal well are determined by the cement's compressive strength. It should not be less than 10.3 MPa. Figure 4(a) illustrates the compressive strength of 2.5-20% ACF cement varies within the range of 10.6-20.1 MPa as the ACF increases, meeting the standard's requirements. Based on the recommended concentration, 7.5% ACF has a compressive strength higher than 11.8 MPa.

Mastering the variation of cement density helps to match the right reservoir pressure. Figure 4(b) shows that ACF decreased the cement's density. After 40-100° C curing, the control group's density varied between 1.462 and 1.689 g/cm³, whereas the 2.5-20% ACF cement's density varied between 1.307 and 1.662 g/cm³. As the ACF increased, the density steadily dropped. Geothermal reservoirs are typically fractured structures with low pressure, making the ACF cement more suitable for low-pressure geothermal fields due to their reduced density.

Fluidity has an impact on cement pumping. ACF's inclusion somewhat decreased the cement's fluidity, as seen in Figure 4(c). Nonetheless, the cement fluidity varied between 17.3-22.5 cm at 40-100 °C, consistently fulfilling cementing standards. In short, the impact of ACF on the basic properties of G cement is acceptable.

3.3 Comparison of ACF and Reported Thermal Conductive Fillers

ACF has been proven to successfully increase cement's thermal conductivity while maintaining its fundamental qualities, as indicated in Table 2. The thermal conductivity rose by 280% after 7.5% ACF was added to the G cement, yet the strength and fluidity still met all API requirements. The cement's thermal conductivity rose by 151% when 6% graphite was added; nevertheless, the fluidity and compressive

Table 2. Comparison of the effects of thermal conductive fillers on cement properties.

Sample	Thermal conductivity	Compressive strength	Fluidity
7.5% ACF	Increased by 280%	Increased by 14%	19.8cm
6% Graphite (Li et al. 2022)	Increased by 151%	Decreased to ~2MPa	<6cm
10% Composite graphite (Yu et al. 2020)	Increased by about 18%	<6MPa	<6cm

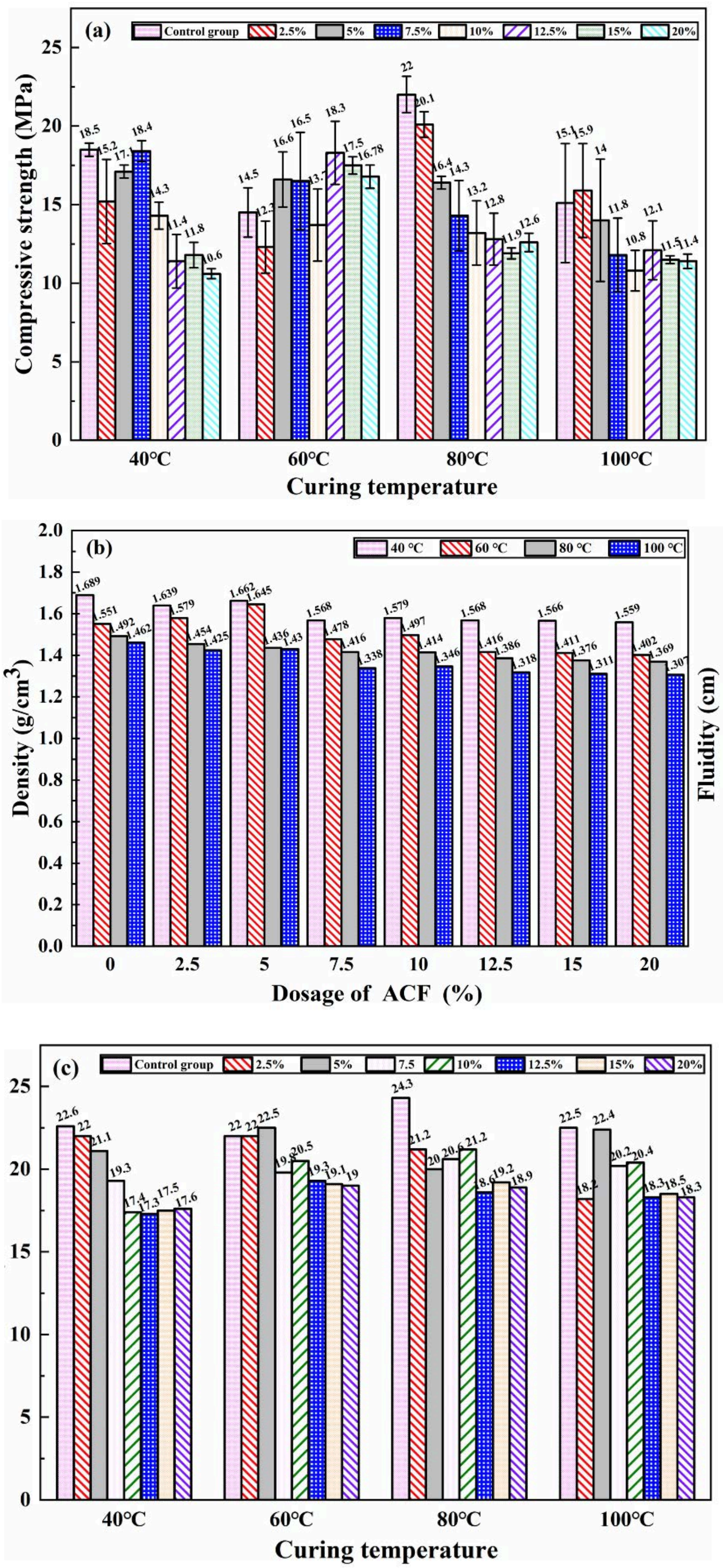

Figure 4. The effect of 0~20% ACF on the performance of cement under different curing temperatures: (a) compressive strength; (b) density; (c) fluidity.

strength dropped to about 6 cm and 2 MPa, respectively. Cement's mechanical qualities and fluidity were significantly diminished by graphite powder, making it challenging to pump underground or preserve wellbore stability.

3.4 The Salt Resistance of ACF Cement

Geothermal resources are located in large sedimentary basins, and the majority of formations contain salt rock layers and carbonate rocks. High concentrations of Na^+, Cl-, and even hot brine are caused by soluble minerals dissolving in subterranean hot water (Zhang et al. 2024). As shown in Figure 5, tests were performed on G cement and 7.5% ACF cement cured at 80°C with a 2.5%-10% NaCl solution.

Figure 5(a) shows that the thermal conductivity of ACF cement progressively drops as the concentration of salt ions rises. Nonetheless, ACF cement consistently has a higher thermal conductivity than the control group. Compared to the control group, the thermal conductivity of ACF cement increases by 199.7%, 50.1%, 117.3%, and 51.5% in 2.5%, 5%, 7.5%, and 10% NaCl solutions, respectively. In fluids with a high salinity, the thermal conductivity effect of ACF cement is noticeably improved. Figure 5(b) demonstrates that the compressive strength of 7.5% ACF cement varies between 14.09 and 16.47 MPa when the concentration of NaCl rises from 0 to 10%, consistently satisfying the needs of geothermal cementing. The compressive strength decreases by 1.3% at a rate of 7.5% NaCl. The influence of salt solution on the cement compressive strength is relatively small, especially for the ACF cement. In short, ACF cement has good applicability in high salinity geothermal formations.

3.5 Mechanism Analysis of Thermal Conductivity Enhancement of the ACF Cement

3.5.1 Observation of scanning electron microscope (SEM)

The G cement has a significant number of micropores, as seen in Figure

6(a). Microcracks were also discovered. The control group had a lower thermal conductivity as a result of these loose pore configurations.

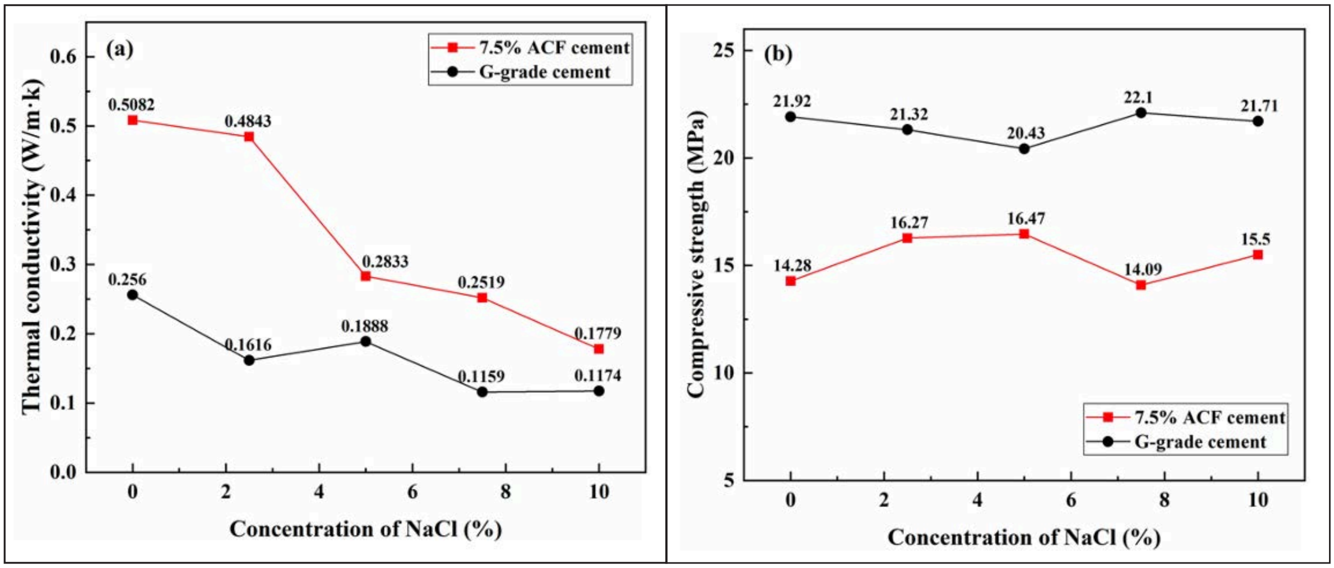

Figure 5. Thermal conductivity of cement cured with 80 salt water: (a) thermal conductivity; (b) compressive strength.

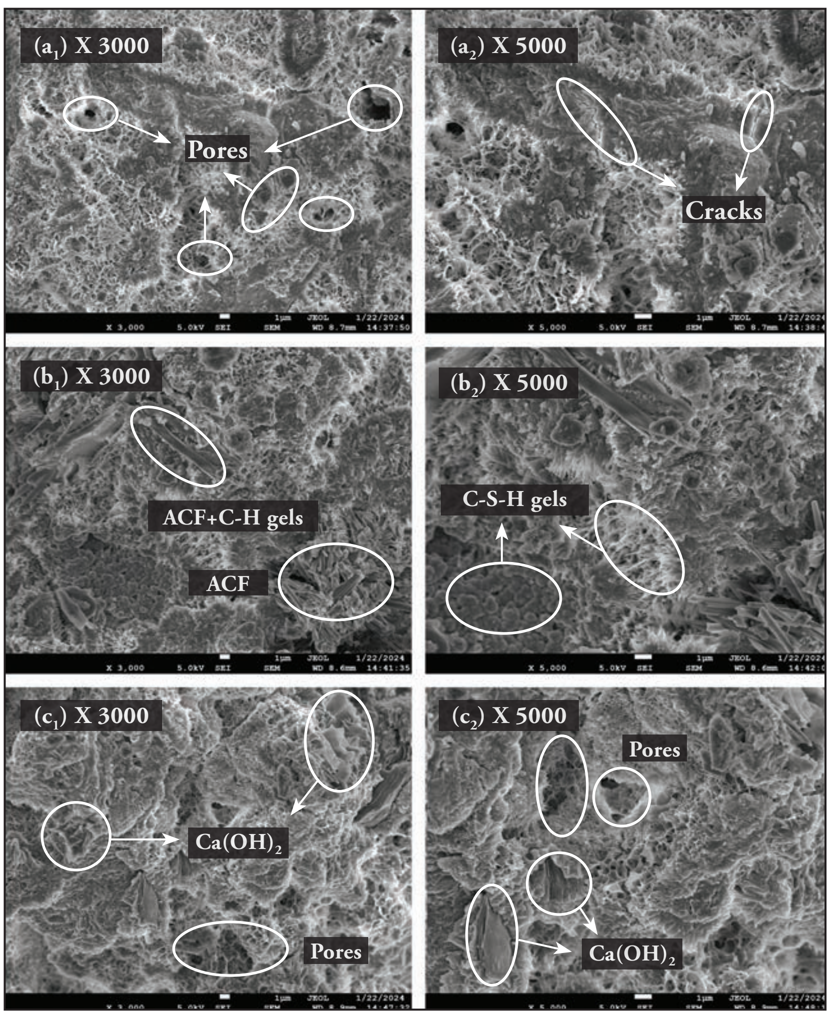

Figure 6. SEM images of cement: (a) G cement; (b) ACF cement; (c) ACF cement +NaCl.

Numerous spherical particle structures and fibrous spatial network structures, which are C-S-H gel, can be found in ACF cement (Fig. 6(b)). By efficiently filling in the spaces left by the un-hydrated cement particles, these gel formations create a dense microstructure (Haiyue et al. 2023). ACF particles exist in cement in two forms: well-dispersed ACF can provide a site for the formation of C-S-H gel, which is surrounded by a tightly stacked structure. High-compactness cement composed of high thermal conductivity materials corresponds to a significant increase in thermal conductivity. However, microscopy examinations have indicated that when ACF fibers are not completely dispersed, a grass-like ACF structure may form in cement. This could result in the production of large-diameter pore structures and a reduction in cement strength.

ACF cement cured with NaCl solutions is depicted in Figure 6(c). It shows a lot of irregular plate-like Ca(OH)2 crystals. The decrease in cement's thermal conductivity is caused by a considerable increase in the number of micropores as compared to Figure 6(b).

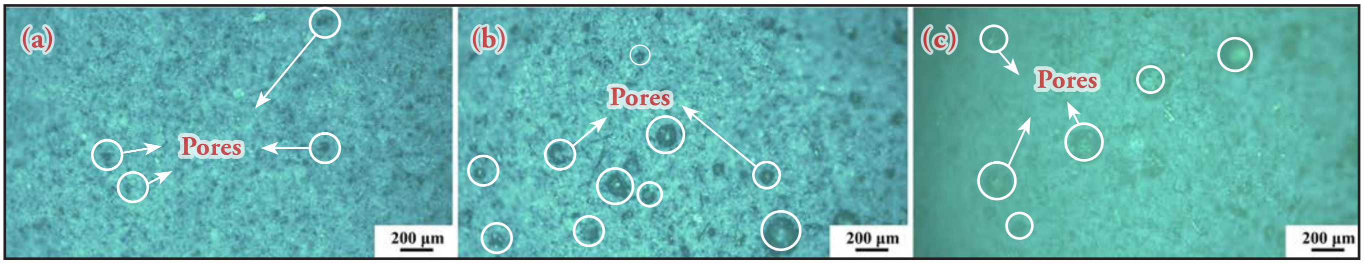

Figure 7. Microscopic images of cement: (a) G cement; (b) ACF cement; (c) ACF cement+NaCl.

3.5.2 Observation of polarizing microscope

The cement's large-diameter pore structure (d > 10 μm) was investigated using a polarizing microscope, as shown in Figure 7. Statistical analysis of about a thousand pores in several microscopic pictures was summarized in Figure 8 and Table 3.

The distribution of pore sizes follows the normal distribution pattern. A Gaussian function is used to fit the pore size distribution curve. The expectation value (μ) of the Gaussian function is consistent with the average diameter, and the variance (σ^2) indicates the distribution's central tendency. The distribution is more concentrated when the variance is less. In the ACF cement, 92.3% of pores are scattered between 10.0 and 70.0 μm, whereas in the G cement, roughly 93.4% of pore diameters are distributed between 12.5 and 32.5 μm. The σ^2 of ACF cement was 98.5% higher than that of G cement. The expectation and average diameter of G cement were 21.88 μm and 23.22 μm. The expectation and the average diameter of ACF cement were 30.38 μm and 40.22 μm. Hence, ACF increased the content of large-diameter pores. The loose structure corresponds to a lower compressive strength, which explains the data in section 3.2.

The average pore diameter of ACF cement cured at 10% NaCl is 50.64 μm. 90.5% of pores are found in 30.0-110.0 μm. Accordingly, the large-diameter pore structure in ACF cement is not significantly impacted by the NaCl solution, and the cement can sustain a steady compressive strength, which is in line with the findings in section 3.4.

3.5.3 Analysis of X-ray diffraction (XRD)

The hydration reaction is the key to the cement stone product obtained from cement hardening. As shown in Figure 9 (a-d), the hydration products of cement were investigated by XRD. The diffraction peaks at 11.6° and 34.4° are the analogous hydrotalcite phase (Ht). The strong peak at 18° was attributed to Ca(OH)2. The peaks of 21.6°, 31.5°, and 47.4° were attributed to C-S-H gel. ACF cement does not produce any new hydration products in comparison to G cement.

Table 4 shows the statistical calculation of the peak intensity in the XRD curve based on the integrated area. It is evident that ACF cement's Ht peak is consistently greater than G cement's. The Ht phase can effectively fill pores, preventing cementitious materials from shrinking and fostering long-term performance improvement (Yonghui et al. 2023). The C-S-H gels in ACF cement also had larger total integration areas than the control group. This suggested that ACF can serve as a good nucleation and growth site for C-S-H gel, thereby increasing the amount of C-S-H gel in hydration products. C-S-H gel fills the micropores, improving compactness and shortening the cement's heat transfer path. The addition of NaCl inhibited the hydration process of cement. The $Ca(OH)_2$ peak value of ACF cement cured with

Table 3. The pore size data of cement.

Sample	Range of pore diameters (μm)	Average diameter (μm)	Expectation (μm)	Variance (σ^2)
G cement	10.36~62.67	23.22	21.88	6.57
ACF cement	11.33~222.06	40.22	30.38	13.04
ACF cement+NaCl	18.14~270.13	50.64	38.99	5.50

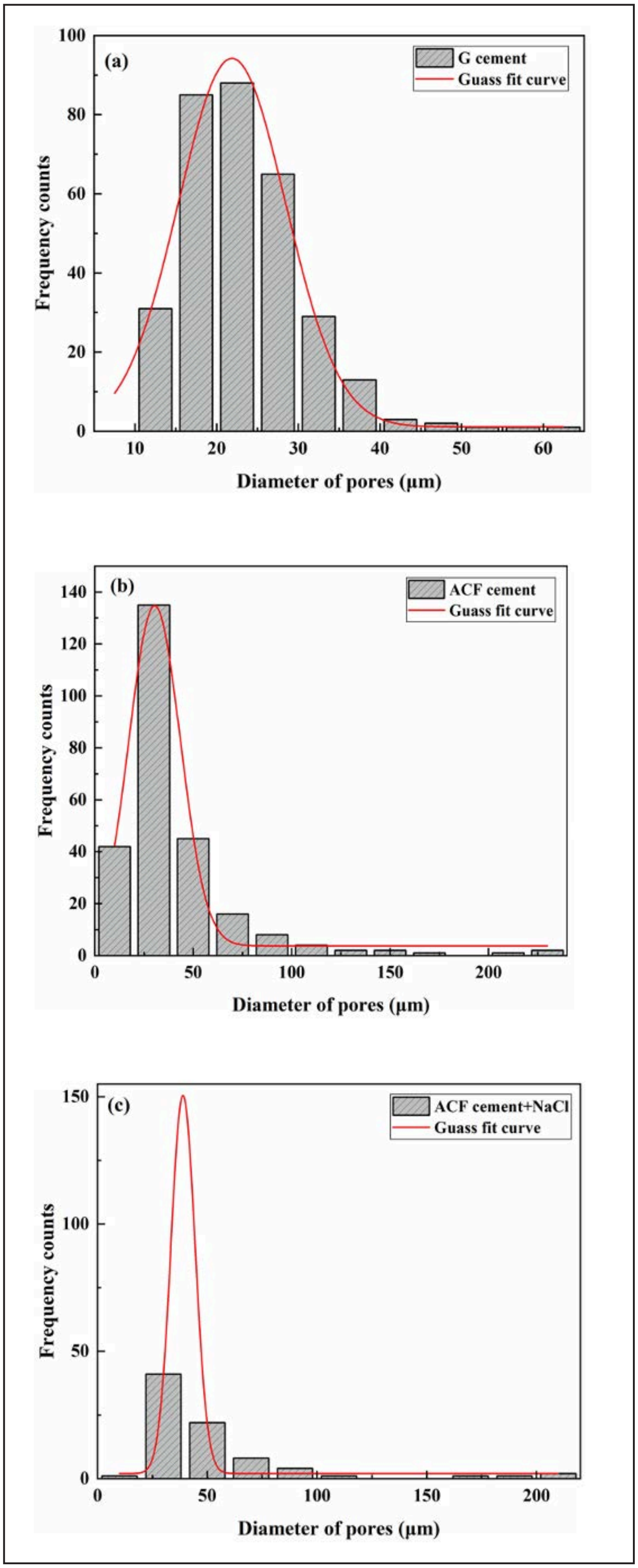

Figure 8. Pore distribution: (a) G cement; (b) ACF cement; (c) ACF cement+NaCl.

10% NaCl was reduced considerably. This suggests that the quantity of C-S-H gels has decreased, and the microstructure is generally loose.

3.5.4 Analysis of thermal conductivity mechanism

The mechanisms can be summed up as follows: As illustrated in Figure 10(a), the fibrous ACF material is susceptible to developing a grass-pile structure as a result of uneven mixing, which raises the cement's large diameter pore count. The cement's density and compressive strength are decreased by these big pores. Srengthening the ACF cement's microstructure and preparation method should resolve this issue.

On the other hand, by offering locations for hydration reactions, ACF accelerated the cement's hydration process and raised the amount of hydration products. C-S-H makes up the cement structure's micropores, minimizes microcracks, and produces a dense microstructure. In inorganic non-metallic materials, phonon conduction is the primary method of heat conduction. ACF greatly reduces the heat transfer path, raises the total heat transfer per unit time, and exhibits good heat transfer performance at the macro level, as seen in Figure 10(b).

3.6 Educational Impact of the Research Study for Engineering Technology Field

The following effects of this study on research-based education in engineering technology were observed:

(1) Student cognition: Despite having finished foundational courses, students' knowledge and comprehension of the subjects, as well as their acceptance of their understanding as they approach professional life, are still limited, according to this study. Course-based undergraduate research experiences (CUREs) are interventions that expose students to graduate-level research into specific engineering phenomena (Kribs 2022). Students will gain a deeper understanding of the cutting-edge theories and foundational information in their field by working independently to complete experiments. Effectively avoiding the problem of students losing interest and enthusiasm for learning quickly due to the content being too profound and tasteless (Zhan et al. 2022; Phillips et al. 2023).

(2) The application of research findings in teaching: Although the mechanical and physicochemical characteristics of concrete are generally introduced in teaching, it is unclear how these relate to engineering. Understanding the materials and techniques

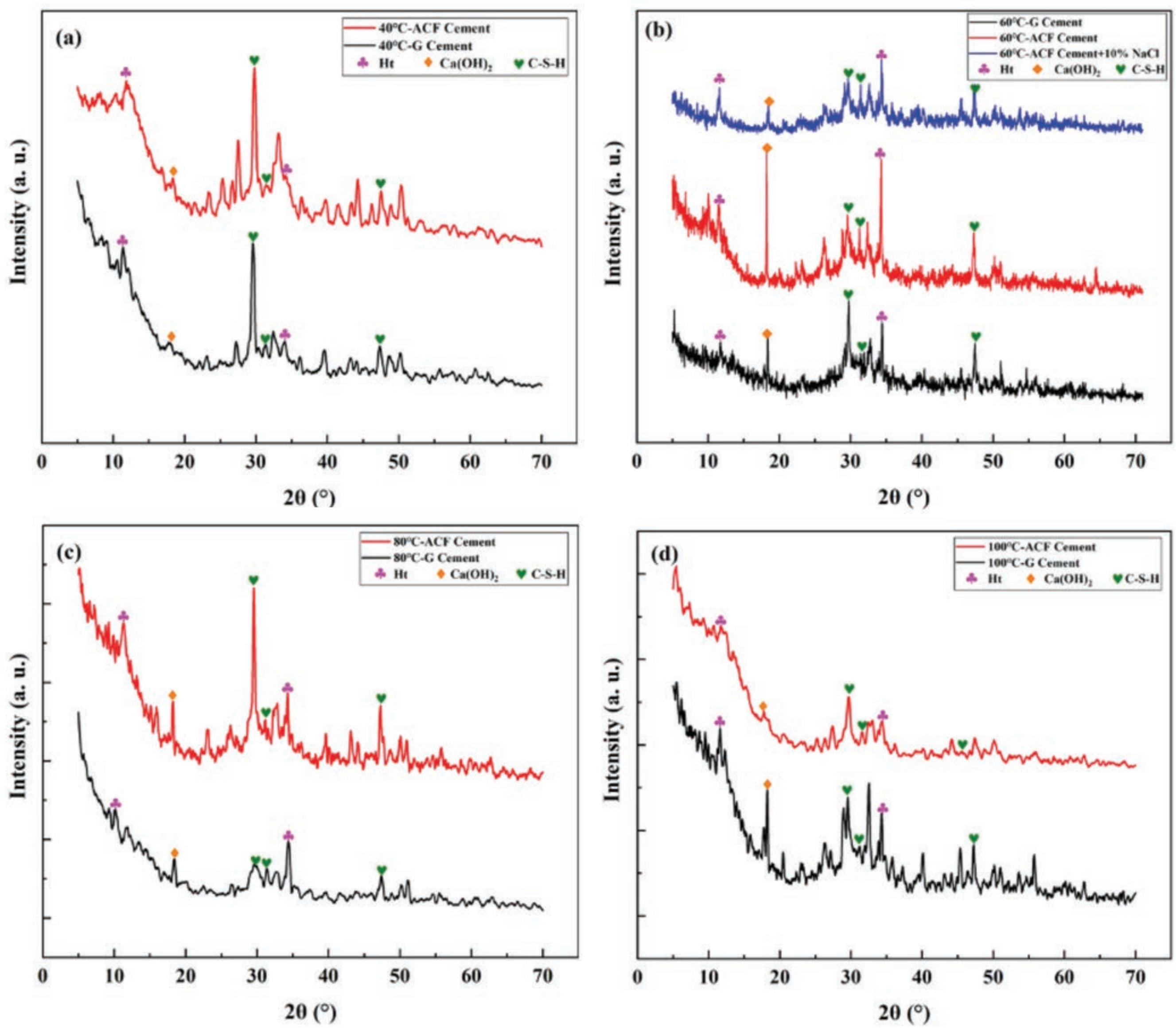

Figure 9. XRD curves of cement samples cured at different temperatures: (a) 40° C; (b) 60° C; (c) 80° C; (d) 100 ° C.

Table 4. Integral area of characteristic peaks in XRD curve.

T (ºC)	Sample	Ht		C-S-H gels			
		~11.6°	~34.4°	~29.6°	~31.5°	~47.4°	Total
40	G cement	76.81	35.82	71.67	27.33	29.98	128.98
	ACF cement	167.63	184.72	55.71	48.51	45.24	149.46
60	G cement	22.99	32.83	65.88	15.22	26.55	107.65
	ACF cement	67.86	51.98	69.42	31.79	34.69	135.9
	ACF cement +10% NaCl	27.17	27.89	44.67	24.23	24.81	93.71
80	G cement	37.88	29.56	65.54	27.52	26.03	119.09
	ACF cement	98.96	41.38	106.88	23.18	39.46	169.52
100	G cement	51.84	21.00	26.37	16.58	17.37	60.32
	ACF cement	85.97	23.22	48.01	21.87	25.34	95.23

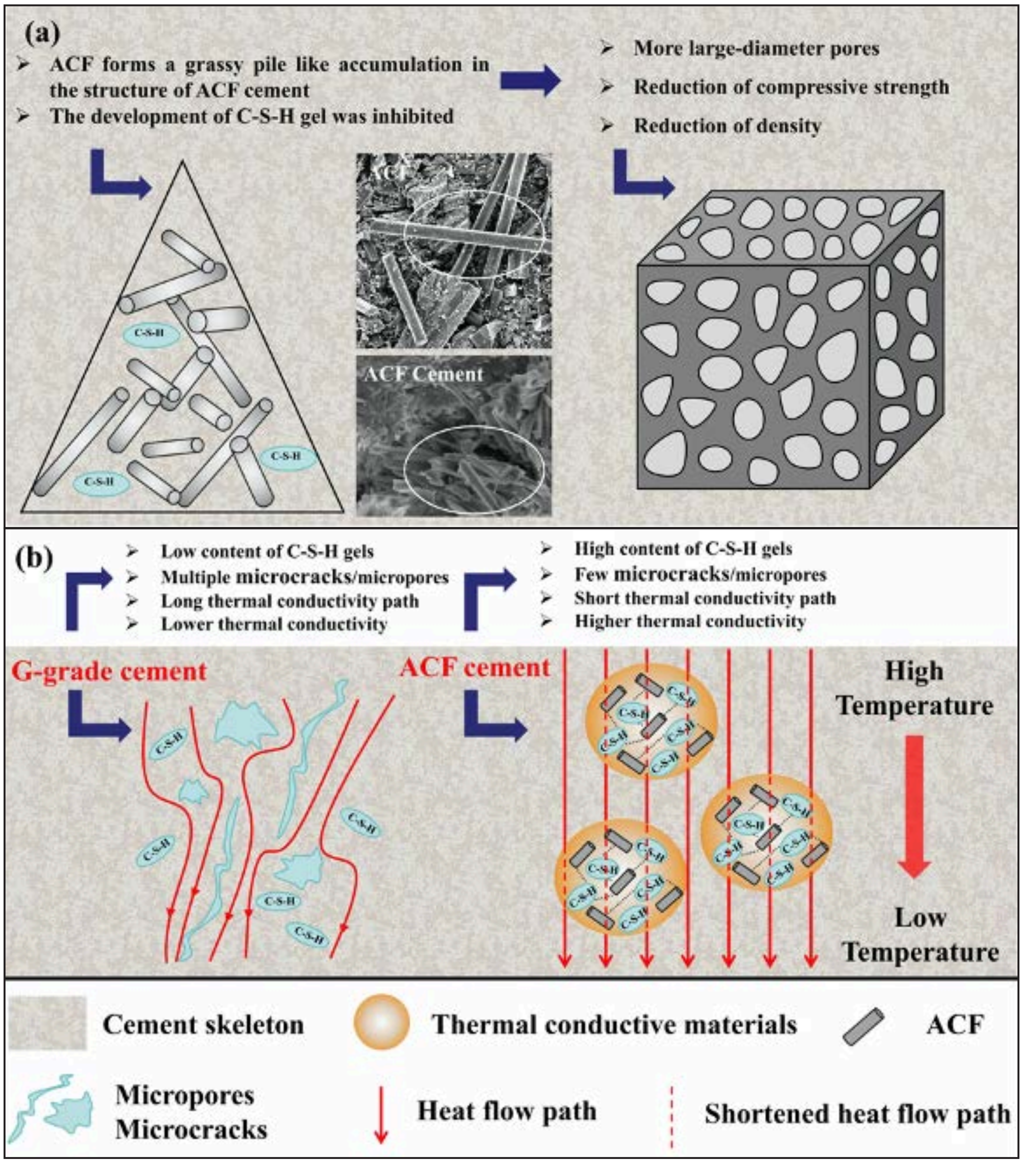

Figure 10. Mechanism analysis of the influence of ACF on the thermal conductivity and strength of G cement: (a) influence on the strength; (b) influence on the thermal conductivity.

that can be utilized to control the attributes and the governing principles is similarly challenging. In future teaching projects, this study can be used as a case to illustrate the data sources and analysis techniques of cement performance changes, and help students develop inquisitive thinking skills.

(3) New educational components: The sandwich education model, which is dominated by multiple factors, has been successfully applied in guiding graduation design, practical course reform, Chinese international education, and other fields (Hailang et al. 2021; Jianling 2014). This project has implemented the effective "1+1+1" educational model, which consists of an undergraduate student, a graduate student, and a professional teacher. They were tasked with developing research directions, directing the use of equipment, and gathering data, respectively. The key to this model is for teachers to help assist students in solving experimental funding. On the other hand, in the "1+1+1" mode, regular group discussions of three people have been proven effective, ensuring that the guiding teacher has a grasp of the progress and direction of the experiment.

(4) Research method: In this investigation, the conventional concrete thermal conductivity sample in the construction field was creatively reduced to a 13 cm diameter disc model by using a portable thermal conductivity tester. Its remarkable reliability was confirmed by experimental results. Promoting this device in undergraduate teaching is beneficial for fully utilizing limited platform resources, expanding the practical scope of college students, and improving experimental efficiency.

3.7 Industrial Impact of the Research Study

According to research, ACF can significantly increase geothermal cement's thermal conductivity, which could have a variety of effects on the manufacturing sector:

(1) This finding contributes to the economic enhancement of geothermal systems' extraction efficiency. This boosts the competitiveness of manufacturing companies that use geothermal energy by reducing energy costs and increasing energy consumption efficiency. Given the growing use of geothermal energy in manufacturing, it is reasonable to assume that more manufacturing businesses will adopt this technology to lessen their reliance on conventional energy sources, cut carbon emissions, and achieve green production.

(2) The application of ACF in construction materials, geothermal energy, and other areas will increase market potential and profit margins for businesses, supporting the manufacturing sector's diversification. Manufacturers will increase research and development, encourage technological advancement, and upgrade the ACF material industry to fulfill the need for high-performance ACF materials in geothermal energy. Simultaneously, manufacturers will focus on environmental protection throughout ACF's production, use, and recycling life cycle and support the green development of manufacturing to support the sustainable development of ACF materials.

4. Conclusion

This work investigates the new thermally conductive filler ACF, which is resistant to high temperatures and salt. While preserving fundamental performance requirements, it shortens the heat transmission path, compensates for the micropores in cement by encouraging the hydration process, and greatly improves the heat transfer properties of geothermal cement. The significance of cementing engineering in the development of geothermal energy has been reinforced by this study, which expands the use of cementing cement. It is anticipated that this research will eventually lead to the low-cost enhanced geothermal energy recovery goal in cementing engineering. Next, an eco-friendly organic solvent will be taken into consideration to optimize the ACF cement preparation process, which is anticipated to decrease the creation of grass pile structures and increase the cement's compressive strength.

Finally, the impact of this study on the geothermal industry, especially the manufacturing industry, has been revealed. The study's effects on undergraduate education and student cognition were examined, and the feasibility of the CURE intervention measure was confirmed. A new "1+1+1" educational component was explored. The application effect of a portable testing instrument in undergraduate teaching trials was also examined.

Acknowledgments

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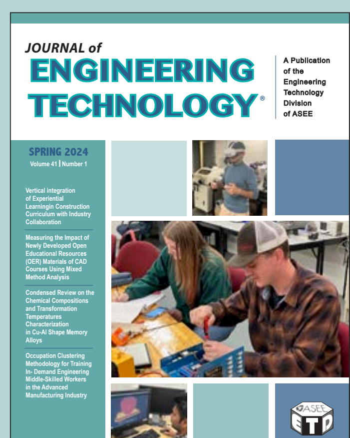

Radar-Based Vital Sign Monitoring with Automated Beam Steering

Daniel Gore, Daniel Petronchak, Felipe Valencia, Gavin Young, Nithish Warren and Athina Petropulu

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Abstract

Hospitals monitor an infant's vital signs after birth to quantify the status of its body during incubation. This is often done by adhesively connecting biometric devices to every infant in the hospital nursery. However, if the need for physical connections were to be eliminated and a single device is used to monitor every incubator, infants can experience increased comfort and vital sign monitoring costs largely decrease. To solve this problem, a team of five undergraduate students participated in an ongoing research project that is developing a wireless multitargeted vital sign monitor (VSM), and as their capstone design project developed hardware that automated the VSM deployment. This paper discusses the automated VSM design, along with educational outcomes for the students. The team's project relies on a double phase shifter (DPS) phased array to repeatedly steer a radio frequency (RF) beam between desired targets to gather their vitals wirelessly. A plain phased array could be used in this context; however, its ability to target a beam at a precise location is limited. Equipping the antenna array with DPS produces a highly focused beam that can localize closely spaced targets. After targeting the beam, a receiver records the infant's heart rate and breathing rate. To automate the beam design process, a programmable controller was implemented to drive the control voltages at each phase shifter. Doing this causes a shift in the beam's direction, which depends on the location of a target and unwanted neighboring targets. Finally, using fast Fourier transforms (FFTs), the frequency information of the infant's vitals is recovered. To test the system's effectiveness, an experiment was conducted on two human targets. The device successfully recovered each target's vital signs, which demonstrates its promising applications in medicine.

1. Introduction

Hospital nurseries commonly monitor infant vital signs by connecting biometric monitors to newborns through their incubators. While this procedure produces accurate readings, the hardware setup is costly and potentially uncomfortable for the newborn. Cost issues become a visible concern if one sums the prices of all the biometric monitors in an incubator and multiplies the result by the total number of incubators in a hospital nursery. Typically, the net expense can surpass tens or hundreds of thousands of dollars, depending on the size of the nursery (Tarus 2023).

When considering other issues, including incubator sensors breaking over time and needing to be replaced, and the issue of newborns experiencing discomfort from the sensors surrounding their body, clearly the efficiency of many infant VSMs can be improved (Rajalakshmi 2019). Therefore, instead of putting a collection of costly sensors in a large array of incubators, a cost-friendly approach would be to have one wireless device that scans infants individually and provides a corresponding health report. Such a device would eliminate the potential issues associated with wired monitors, as well as costs due to installation, continuous electronic servicing, and occasional replacement. To develop such a device, a team of five undergraduate students at Rutgers University leveraged remote sensing using radar (Xu 2023; Li 2009) for their capstone design project.

In the context of radar-based sensing, the team relied on phased array technology (Jeffrey 2009). Phased arrays are multi-element antennas that can steer beams of RF energy in different directions (Mailloux 2018). Depending on the application, beams generated by a phased array can be used as an adjustable channel to transmit information to any target inside of it. For example, if a transmitter wanted to send a message to three receivers, and the locations of those three receivers are known to the transmitter, then the transmitter could sequentially steer the beam to the three receivers and individually send them a message. However, this works under the assumption that the receivers are spaced far apart from each other. In the situation where targets are closely spaced together, the beam can overlap across multiple targets, making one-on-one communication between the transmitter and receiver difficult to isolate (Xu 2022).

For the purposes of a nursery, it can be assumed that incubators are spaced close together due to indoor capacity requirements for hospitals (Humphreys 2022). As a result, a highly focused beam must be generated to ensure stable communication between infants and the transmitter. Many plain phased arrays are unable to accommodate such a requirement, which drives the need for a new technological implementation. To combat this problem, the team turned to double phase shifter (DPS) technology.

Typically, phased arrays have one phase shifter per antenna element to steer the beam. The transmitter can preset the phase at each phase shifter to pull the beam in a certain direction, while also distributing power within the beam, suppressing its side lobes (Stoica 2015). For targets that are far apart from each other, one phase shifter per antenna is enough to establish isolated communication between one transmitter and one target. However, since multiple targets are spaced closely together in a nursery setting, the power distribution in the beam should be condensed into a narrow region. This is where DPS comes in: by adding two phase shifters at each antenna, the distribution of power within the beam becomes much narrower. As a result, a single target in the main beam will be localized, while neighboring targets are suppressed to nullify undesired interference (Stuckman 1990; Vouras 2011). Figure 1 exemplifies this process, where one-on-one communication is easier to achieve among closely spaced targets.

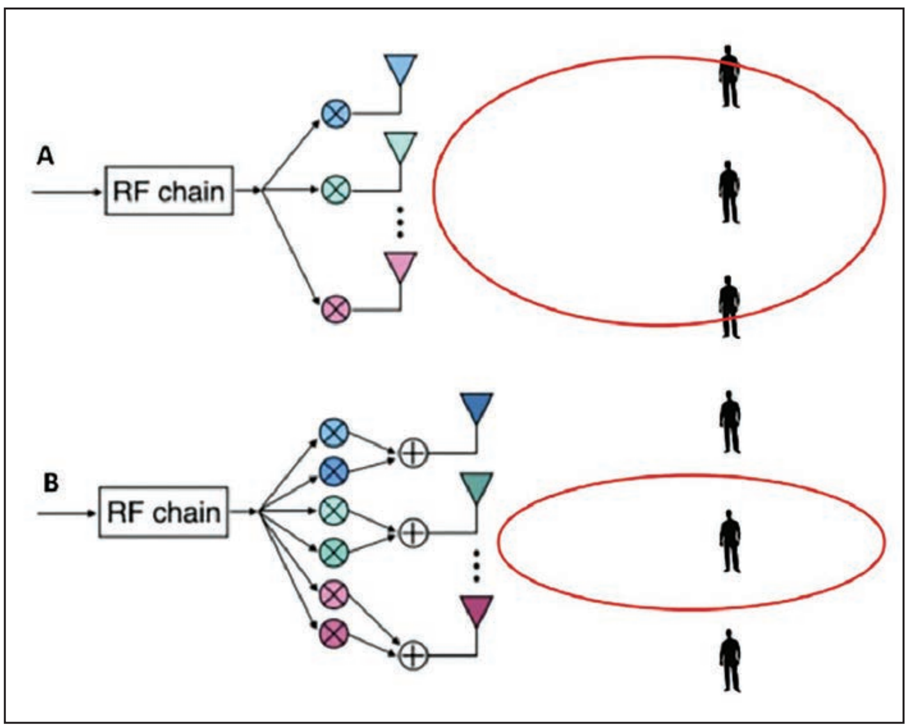

Figure 1. (a) Example beam of a plain phased array on closely spaced targets; (b) example beam of a DPS phased array on closely spaced targets.

To adopt this technology into an infant monitoring system, multiple contributions were necessary. Firstly, with the help of Dr. Michael Wu's group at Rutgers University, the team was able to integrate a custom 4-element DPS phased array into the system design (Xu 2024). Then, using a DPS algorithm developed by Xu (2023), custom circuitry and software was designed to control the two-phase shifters at each antenna element of the DPS phased array.

The system design of the multitargeted VSM is explained in section 2 of this paper, where aspects of hardware and software development, experimental results, and costs are discussed in detail. Section 3 highlights the educational outcomes for the team members after completing the project. Finally, section 4 discusses the overall sensibility of the monitoring system and its future direction for future capstone projects.

2. Methods and Results

The objective of the team's capstone project is to create a remote infant monitoring system by automating the beam steering capabilities of DPS. To complete the design, numerous hardware and software considerations needed to be made. In this project, two main questions regarding hardware were scrutinized. First, what kind of controller can be used to steer the beam? Since the phased array has 8 analog phase shifters, the controller must efficiently convert digital commands into analog voltages. Second, what kind of driver circuitry is required between the controller and the phase shifters? Most controllers nowadays operate on 5V or less, which is problematic because the phase shifters being used in the DPS phased array require control voltages up to 15V.

At the software level, another two questions are left to be explored regarding the signal processing back end of the system. First, how does the phased array know where to steer the beam? To enable beam-

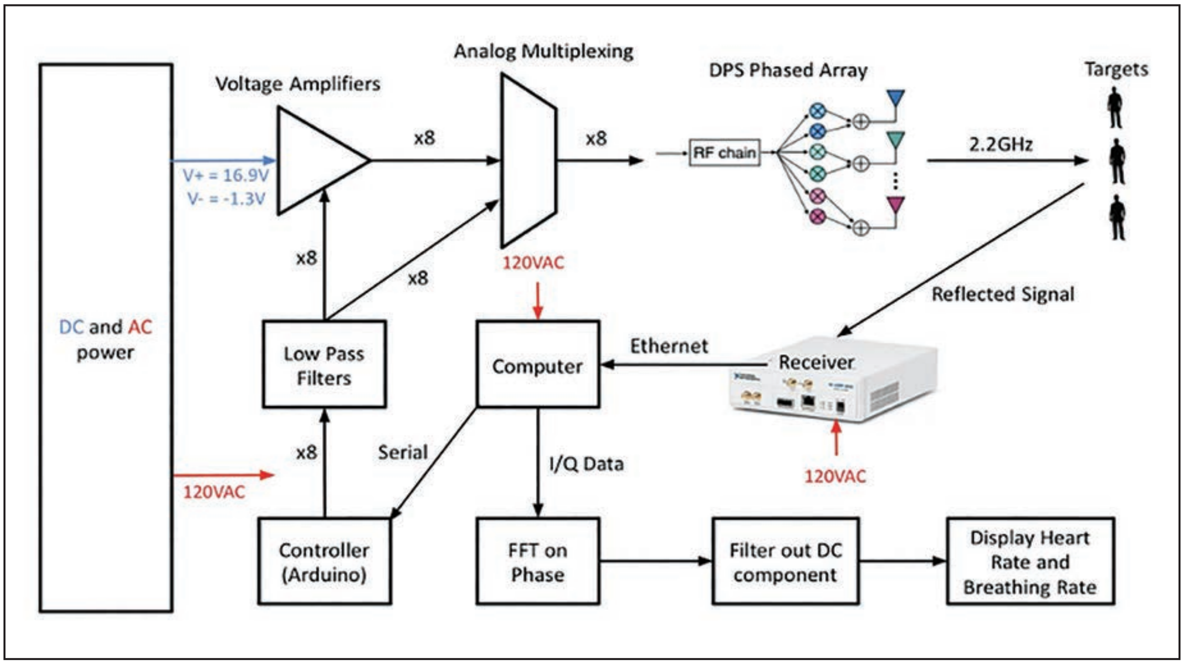

Figure 2. Proposed solution for wireless vital sign monitoring.

forming, the controller must change the DC control voltage at all 8 phase shifters, each of which is meticulously calculated by a DPS optimization algorithm (Xu 2023). Second, how is vital sign information processed? To extract frequency information from received data, a processing algorithm employing the Fourier transform should be implemented.

With these four questions in mind, the team developed the system in Figure 2. The DPS phased array acts as a transmitter, which localizes a target and directs a 2.2GHz pulse at them. The receiver recovers the reflected pulse, which is a modulated 2.2GHz carrier that contains frequency information about mechanical vibrations in the stationary target's body. The recovered data is then sent into a computer, which runs an FFT to recover the frequency components of the echo. Each FFT is expected to contain two peaks: one corresponding to the target's heart rate and one corresponding to the respiration rate. From there, a filtering stage is added to remove any DC components in the data before displaying the vital signs of the corresponding target. Finally, once the vital signs of the first target are recovered, the controller will determine which target to monitor next and steer the beam accordingly. To do this, the controller will send 8 voltages into separate amplifiers, which act as drivers for the individual phase shifters.

The following subsections of this paper scrutinize the subsystems in Figure 2. Section A describes voltage controller design for communication between the computer and the phased array. Section B describes the receiver used for data recovery of the echo signals. Section C describes the control software that enables beam steering. Section D describes the post-processing software used to extract the respiration rate and heart rate from the receiver. Section E details the results of an experiment conducted with the monitoring system on two human targets. Finally, section F will discuss the costs associated with the prototype.

2.1. Controller and Amplifier Design

To design a voltage controller that would automatically steer the beam by changing eight analog phase shifter voltages (Mini-Circuits 2024) on the phased array, the team designed a system that maps digital inputs to unique analog voltages. At the control port for each phase shifter, a voltage V_{ps} between 0V and 15V can be applied to change the phase of the input. Since most microcontroller outputs V_c can only produce $0V \le V_c \le 5V$, an amplifier stage between the controller and phase shifters must be designed to produce a DC voltage gain of at least 15/5 = 3. Given the constraints of a variable 5V input supply and the required 15V (maximum) output, the system in Figure 3 was implemented. The PWM source is generated by an Arduino Mega. Since the analog output of the Arduino's PWM pins is pulsed with a duty cycle κ, a low pass filter was added to convert the pulsed signal into a DC voltage with a value of 5κ.

After the filter, an amplification stage converts the output range of the PWM pin from 0V-5V to 0V-15V. To do this, an inverting amplifier was designed

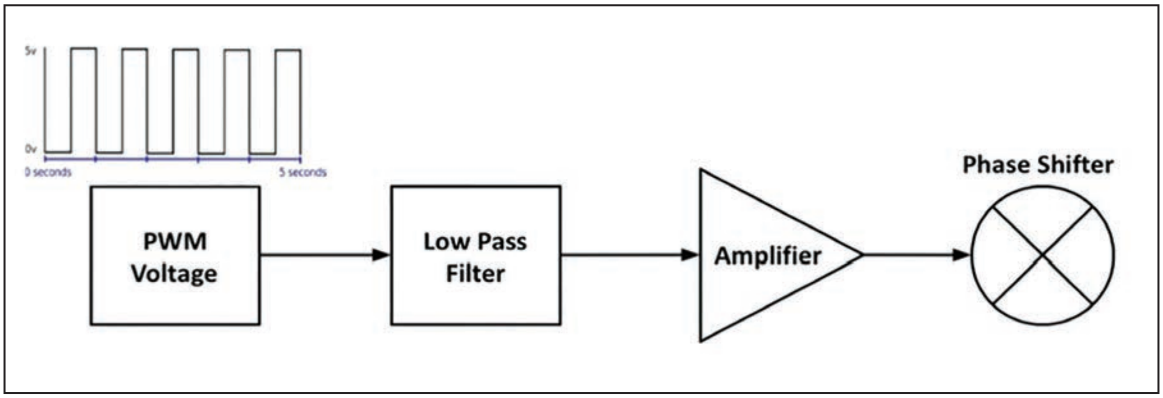

Figure 3. Voltage conversion from PWM to 0V-15V DC.

such that

$$V_{out} = 15 - GV_{in} \quad (1)$$

Where G represents the gain of the amplifier. Given an input of 5ĸ, it follows that

$$V_{ps} = 15 - \frac{5Ga_{in}}{2^N - 1} = 15 - \frac{Ga_{in}}{51} \quad (2)$$

Where N = 8 bits and $0 \leq a_{in} \leq 255$ are the PWM settings on the Arduino. Figures 4 and 5 represent the integration of equation 4 into a hardware setup.

The schematic in Figure 4 contains a 1kΩ resistor in parallel with the 3.3nF capacitor, which is a low pass filter. The resulting DC output gets passed into an inverting amplifier with a transfer function like that in equation 1 (Solomon 1974). G is decided by the parallel network of the 1kΩ resistor and the 2.2kΩ feedback resistor, which were tuned to maximize the gain of the amplifier. To check the gain during tuning, the team probed the red dot in Figure 4 and repeatedly produced V_{ps} vs. a_{in} plots, like the one in Figure 5. In the end, the best outcome was:

$$V_{ps} = 15 - 0.0547a_{in} \quad (3)$$

With a 16.9V positive supply and -1.3V negative supply on the LF347 operational amplifier (Texas Instruments 2024). Equation 3 provides the phase shifters with a 1V-15V control range, meaning 0V-1V is not included in the output range. This is due to the output swing of the amplifier being limited to 14V. As a result, a 2-1 analog multiplexer (Analog Devices 2024) was added to the circuit. Since the output range on the filter is 0V-5V, digital control can be used to determine which output must connect to the phase shifter control port. Whenever 1V-15V is required, the MUX will tie the amplifier output to the phase shifter control port; otherwise, the MUX bypasses the amplifier. Note that for most beams, the phase shifters often use voltages higher than 1V, so the MUX component may be optional.

2.2 . Receiver Configuration

After the controller tells the phased array to steer a beam in a unique direction, the signal will reach a stationary target and reflect off it. As a result, the receiver will pick up the vibrations of any moving object inside the beam, namely a beating heart and lungs (Diao 2009). It is imperative for the system to extract these vibrations in the form of frequency information. To do this, the team used a USRP-2920 (National Instruments 2024), which is a software defined radio (SDR) that can transmit and receive data simultaneously. In the context of a radar-based heart monitor, the device gener-

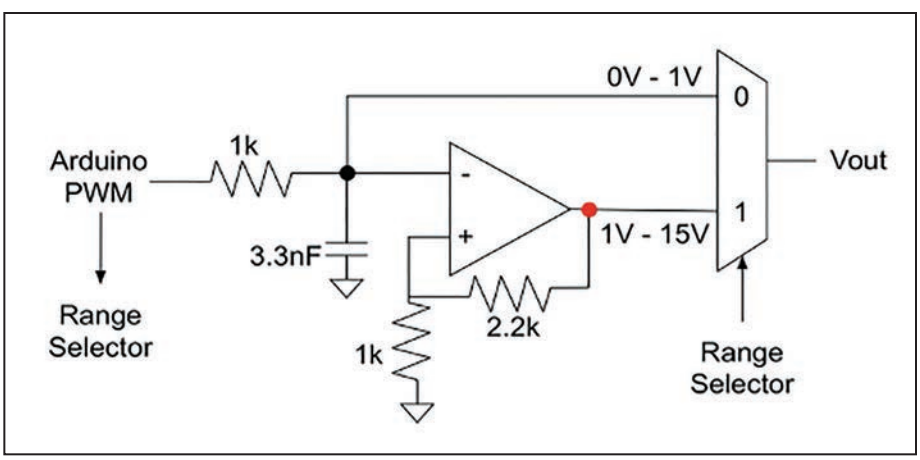

Figure 4. RC filter and amplifier design with range extending multiplexer.

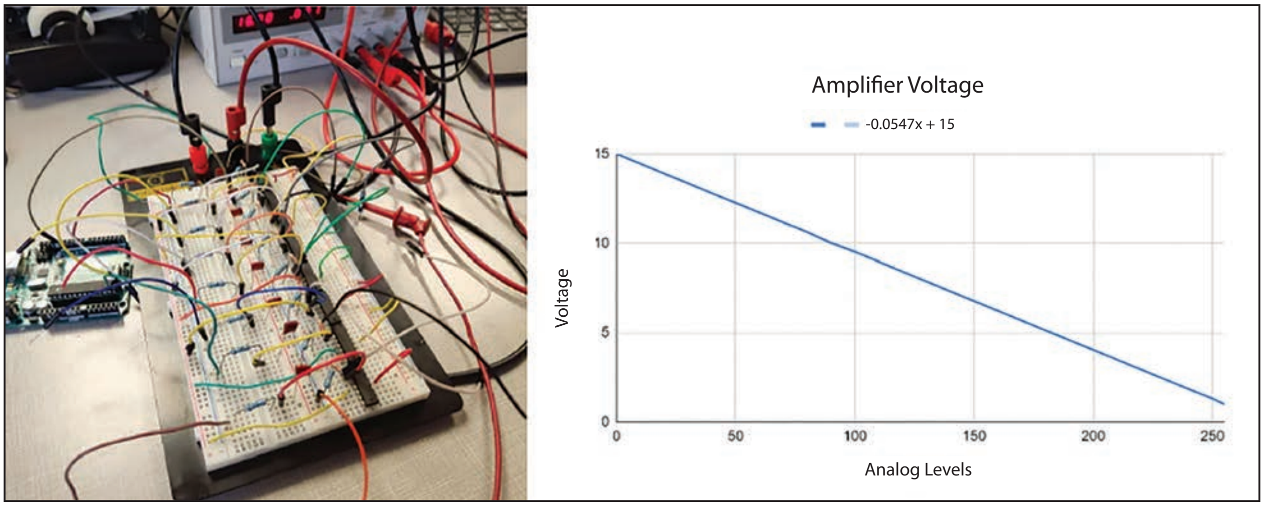

Figure 5. (Left) Implementation of Figure 4 without multiplexers and (Right) Sweep of the output control voltage.

ates a 2.2GHz signal that is passed into the phased array, while also reading echoes caused by the beam encountering a target.

The LabView code uploaded to the USRP consists of two scripts. The first script is used to generate a 2.2GHz signal through the internal RF front end. The second script implemented a real-time receiver, which takes I/Q (real/imaginary signal) recordings of the surrounding environment and exports the data into a csv file. To configure the USRP's I/Q recording outputs for post processing on a computer, several settings in LabView were adjusted. The desired I/Q rate was set to 100,000 samples per second. Since the monitoring time was set to 10 seconds per target for a total of N targets, a recording of one full sweep must be 10N seconds and contains 10^6 N samples. Finally, the post processing steps in subsection D were taken to extract the breathing rate and heart rate of the desired target.

2.3 . Voltage Control Software

To preset specific analog outputs on the Arduino's PWM pins that feed into the amplifiers, the team found a way to compute each voltage from a set of given input angles (i.e., target locations). To do this, the Arduino must compile the DPS algorithm developed by Xu (2023), which converts a target angle and a set of unwanted neighbors (or nulls) into a voltage vector v with 8 entries. If T represents all the closely spaced targets, the algorithm will run at least $|T|$ times since each target has a unique voltage configuration. For the k-th target in T, the target angle can be defined as T_k and the nulls as $N_k = \{T_z : T_z \neq T_k\}$ where $z = 1,2,\ldots,|T|$. Therefore, for every k-th target, the corresponding voltage configuration $v_k = DPS(T_k, N_k)$ where DPS is the DPS algorithm developed by Xu (2023).

Next, the team wanted to introduce automated switching functionality to the phased array by making the code multitargeted. To implement this, the user can enter multiple target angles in an array T. Since the DPS algorithm was originally developed to output one set of voltages, it was modified to output a matrix V^* of voltages. For each k-th target, the k-th row of V^* equals the corresponding voltage configuration $v_k = DPS(T_k, N_k)$.

$$V^* = [v_1, v_2, \ldots, v_{|T|}]^T \quad (4)$$

Upon calculating V^*, the eight voltages are loaded into the Arduino as PWM signals and then converted into analog equivalents with the amplifier design in Figure 4. This process is fully depicted in Figure 6, which visualizes the controller implementation across Python and C++. Since the Arduino does not have enough memory to support the computational load of the DPS algorithm, all computations are conducted in Python while control commands are written in C++ and called over Python's "PySerial" library.

2.4. Post Processing Software

After the 2.2GHz echo passes into the receiver, it is processed through the USRP's digital back end and converted into I/Q data. The data is then exported into Excel, which is processed to gather the heart rate and breathing rate of the target. To recover frequency information on the I/Q recordings, it is necessary to analyze the phase θ of the I/Q data $x[n] = I + jQ$.

$$\theta[n] = tan^{-1}\left(\frac{Q}{I}\right) \quad (5)$$

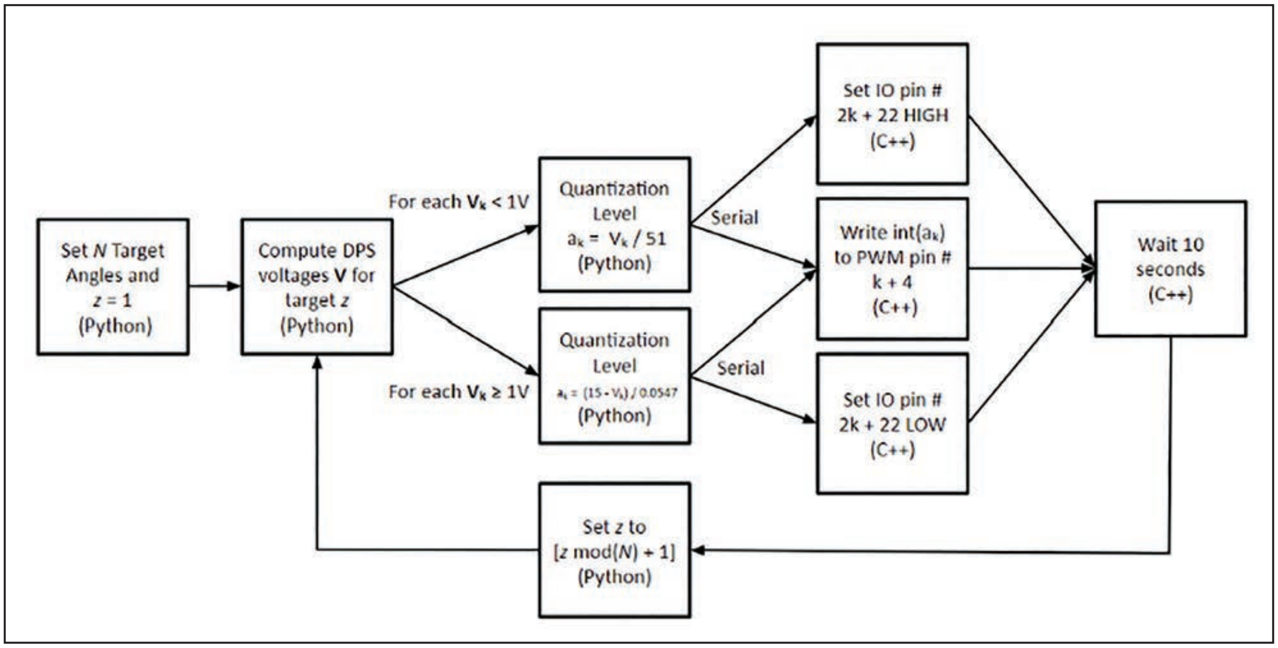

Figure 6. Voltage control algorithm for the hardware depicted in Figure 7.

Since a Doppler shift is formed by the 2.2GHz signal reflecting off the target, the frequency of vibrations in the target's body will be related to the phase of the echoes reflecting into the receiver. Therefore, by using the Fast Fourier Transform (FFT) on $\theta[n]$, the resulting X $[k]$ will contain peaks at frequencies corresponding to the target's heart rate and breathing rate.

$$X[k] = \sum_{n=0}^{N-1} \theta[n] e^{\frac{-j2\pi kn}{N}} = \sum_{n=0}^{N-1} tan^{-1}\left(\frac{Q}{I}\right) e^{\frac{-j2\pi kn}{N}} \quad (6)$$

Where N is the size of the I/Q recording (Patole 2017).

Once the FFT is generated, the Python code will locate the vital sign-related peaks inside the FFT. Since 60bpm=1Hz and the high end of heart rates is about 180bpm, the heart rate peak is expected to be between 1Hz and 3Hz, while respiration rate peaks should be between 0.1Hz and 0.5Hz (Taylor 2022).

Furthermore, the issue of DC components needed to be considered. Since the USRP's I/Q export considers the entire frequency spectrum from 0Hz, a peak at 0Hz is expected due to the 2.2GHz signal having a DC offset. Since the DC component is at a much higher power level relative to the surrounding peaks, any surrounding activity gets suppressed. Therefore, the DC component must be removed by suppressing the magnitude of the peak at 0Hz to the noise floor X_0, such that $X[k = 0Hz] = X_0$.

2.5. Experimental Results

After implementing the system, students conducted a real-time test to assess the viability of the wireless VSM. Figure 7 depicts all the subsystems in Figure 2 being interconnected, which includes the DPS phased array, the receiver/signal generator, a custom voltage controller, power, and a computer for post-processing.

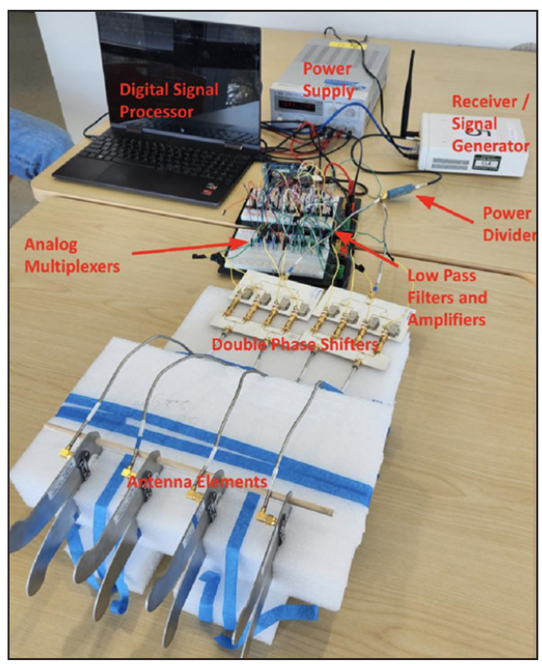

Figure 7. Full vital sign monitoring system.

To assess the system's viability, the test in Figure 8 was conducted (using IRB protocol HRP-503a). Two human targets sat 1.5 meters away from the VSM. One was located 20° off the centerline, while the other target was located at -20°. To steer the beam between targets #1 and #2, the control algorithm in Figure 6 configured the phase shifter voltages to produce the beam patterns in Figure 9. Notice that because of DPS, the sidelobes in both beam patterns are heavily suppressed at the nulls, while the main beams are optimized to nearly 0dB at the targets.

After taking 10 second I/Q recordings of each stationary target and processing the data, the FFT plots in Figure 10 were generated. By analyzing the FFTs, it is estimated that target #1's estimated breathing rate was 0.24Hz or 14.4bpm, while target #2's estimated breathing rate was 0.17Hz or 10.2bpm. Furthermore, target #1's estimated heart rate was 1.28Hz or 77bpm, while target #2's estimated breathing rate was 1.03Hz or 62bpm. Even though clutter is displayed in both plots, the vital signs peaks are noticeably larger, making the vitals relatively easy to see. Note that both targets were instructed to take deep and very slow breaths in an attempt to improve the breathing rate magnitude on the FFT spectrum. These results were calibrated with a smart watch, which can be attached to the target's wrists for monitoring with contact. The system deviated from the smart watch by at most 10% across three total trial runs, which implies that the monitoring system is relatively accurate.

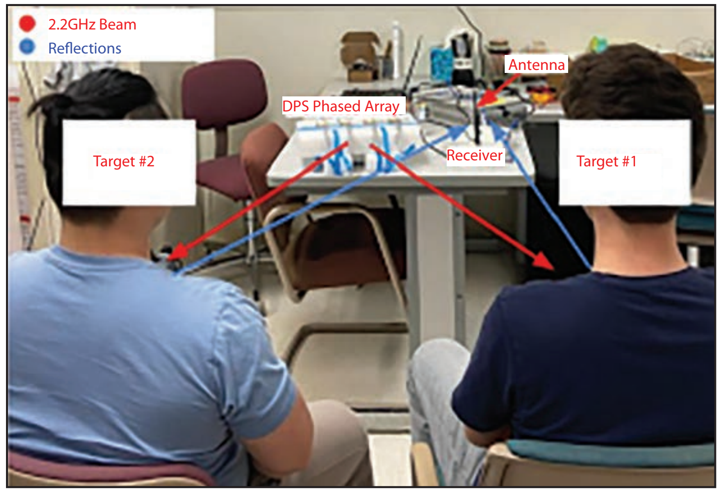

Figure 8. Test on two human targets.

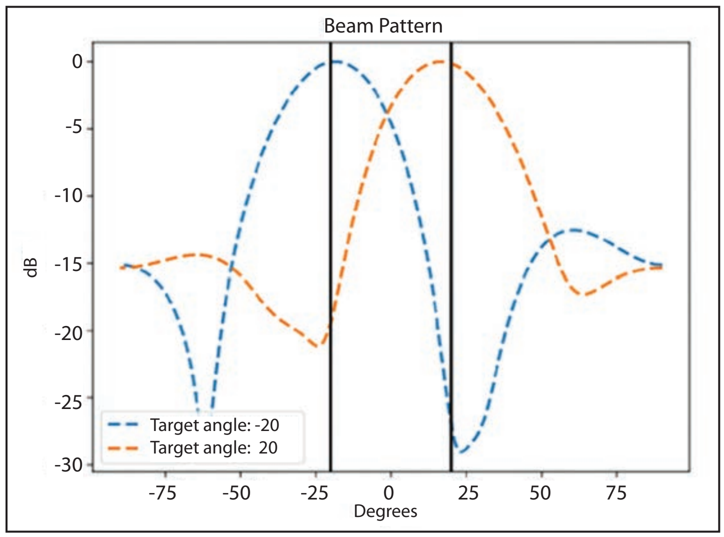

Figure 9. Beam patterns for targets #1 and #2.

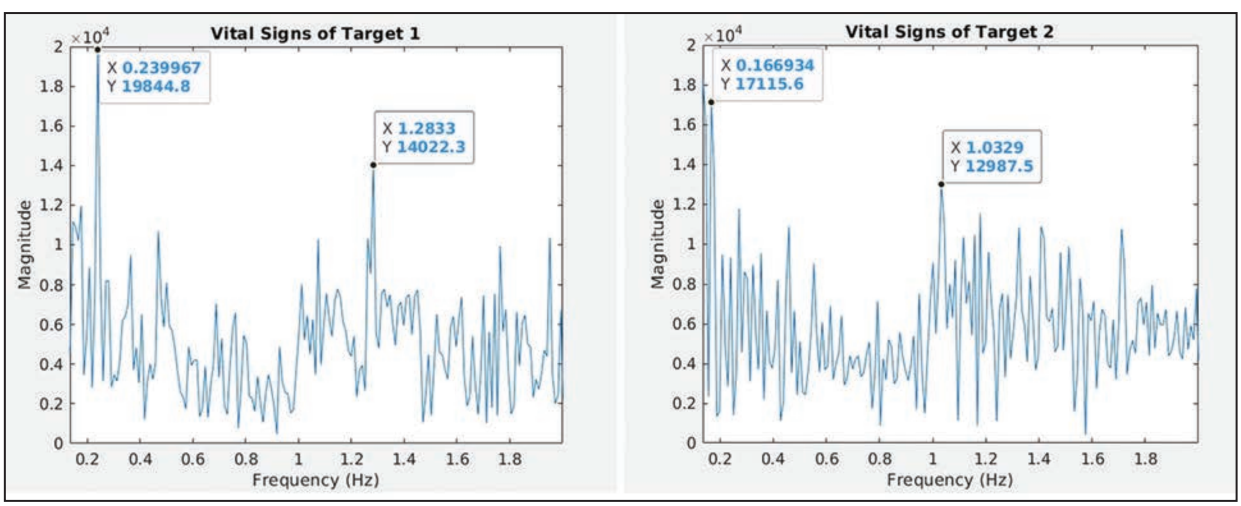

Figure 10. Frequency spectrum of target #1 (left) and #2 (right).

Table 1. Differences in cost between the prototype and a PCB implementation.

Prototype	PCB Implementation
Phase Shifters: \$32 per (x8)	Phase Shifters: \$19 per (x8)
Antennas: \$30 per (x8)	Antennas: \$15 per (x8)
Multiplexers: \$5 per (x8)	Multiplexers: unnecessary
Amplifiers: \$0.56 per (x8)	Amplifiers: \$1 per (x8)
RF Transceiver: \$5,500	RF Transceiver: \$150
Arduino Mega 2560: \$42	FPGA: \$10 per
Breadboarding costs: \$5	PCB fabrication costs: \$10 to \$100
Digital Signal Processor: \$800	DSP Conducted on Controller: \$0
Power divider: \$1000	IC Power Divider: \$20
Power Supply: \$500	Power Supply: \$20
Rough Total: >\$8000	Rough Total: >\$500

2.6. Costs

To visualize the costs of the prototype, each subsystem in Figure 2 was listed out in the left column of Table 1. Understandably, the prototype costs are high because of expensive SDR hardware, namely the \$5,500 USRP2920. The right column in table 1 illustrates the team's approach to reduce the VSM's cost. The clearest method of cost reduction would be to choose a cheaper receiver, preferably one that is small enough to fit onto a printed circuit board (PCB). Changing the controller into an FPGA (field programmable gate array) would also help, both in terms of cost and computational power. For mass production, cheaper amplifier and power regulation ICs can be used in the design of a single PCB. In this, the overall system cost drops to around \$500, which is more than an order of magnitude cheaper than the current prototype.

3. Educational Outcomes

The capstone design team for this project consisted of four electrical engineering students and one computer engineering student, all of whom were graduating seniors. The makeup of the team was determined by the students' mutual interest in working with each other. Upon grouping together, the students picked their advisor, Dr. Athina Petropulu, because of their unanimous desire to gain experience in signal processing and wireless communication systems. Once the advisor-capstone team connection was formed, students were tasked with developing a project topic. The advisor initially proposed her lab's DPS technology and its potential applications in VSM to the team; however it was up to students to decide how to apply DPS in their own unique project idea. After about a week of deliberation, the team decided to follow through with a multitargeted infant monitoring system, given the need for improved infant VSM in nursery settings. Since the capstone design course at Rutgers University requires students to complete the project within 2 semesters, team members unanimously agreed that the project scope was feasible enough to design and test within the required timeframe.

Upon completing the 2-semester long project, team members were surveyed by the team leader (Daniel Gore) to assess the educational outcomes of the project via an in-person meeting. No specific list of questions was followed; rather, the team members engaged in a conversation that the team leader was able to generate meeting notes from (like many project tag ups in industrial settings). Once the meeting notes were fully compiled, the team leader was able to make numerous determinations. For starters, students agreed that working on this project broadened their knowledge on electronic circuitry, specifically RF circuits, and signal processing. In terms of hardware, three team members gained hands-on experience with amplifiers, phased arrays, SDR, and test engineering. The other two team members who centered more towards software gained experience in concepts such as C++ for Arduino control, algorithm design in MATLAB and Python, and FFTs. Overall, the team learned new skills in five total software programs to make the VSM work: C++ (via the Arduino IDE), Python, MATLAB, LabView, and Excel. Team members also learned how to apply information from their undergraduate classes, ranging from introductory circuit design to more advanced topics including digital signal processing and analog electronics. However, much of the needed theory for this project is not typically taught in undergraduate courses, so for concepts in radar engineering, team members relied on literature review.

In the end, all five students admitted to developing skills and interests in RF engineering and radar, signal processing, or testing at the systems level. These developments paid off for the team, as the project won first place (out of 52 teams) at their department's capstone exposition and a distinguished "Best in Research" prize. Regarding the effects of its success on a department-wide level, this project set an example for future capstone projects whose teams want to compete for first place. By applying innovative technologies like DPS that have little to no known documentation, or by integrating multiple advanced concepts into one system, judges at capstone design expositions may express increased interest in their evaluations of a project.

4. Conclusions and Future Work

This paper has discussed the integration of DPS technology into a VSM. During the project life cycle, the team developed a multitargeted VSM with a custom analog controller and beam steering backend to wirelessly collect a target's heart rate and breathing rate. Experimental results illustrate the device's efficacy on human subjects, which motivates future efforts to scale down the device size for improved performance and lower cost. In terms of the system's future development, the team began organizing the design of an all-in-one PCB. The new device will integrate a FPGA, DC amplifier circuitry, and RF front end on a single board. The FPGA will act as a programmable PWM controller that feeds a similar analog frontend to steer the beam on the phased array, and a digital signal processor will compute the vital signs of each measured target with an FFT. Using duplexing techniques, the onboard RF transceiver will act as a pulse recovery system in receive mode to recover each target's vitals, and a telemetry hub in transmit mode to send the recovered vital sign information to a computer for display purposes. Finally, power amplifiers will be added at the output ports of the DPS hardware to ensure that the FFTs produced by the board are less noisy than the results in Figure 10.

As development continues with the VSM, not only is the team convinced of its practical potential in pediatrics, but also its positive effects on their educational journey in becoming well-rounded electrical engineers. All five team members developed a foundational understanding of RF and radar concepts with little theoretical background, and instead relied on hands-on learning and literature review which was conducted only when it was necessary. Less niche skills, including those in Python, MATLAB, and signal processing, were also developed; however most students had an introduction to such concepts from prior courses. For future senior design teams who wish to continue the VSM development, team members will be able to learn the same skills at a much faster pace now that documentation of the VSM prototype already exists. This will allow students on future teams to gain additional knowledge within a two-semester-long timeframe while working on the same effort, namely in RF PCB design and implementing digital signal processing algorithms on FPGAs.

Acknowledgements

We would like to thank Dr. Athina Petropulu and Dr. Zhaoyi Xu for their tremendous support and guidance as we worked to implement a prototype for our project. We would also like to thank Dr. Michael Wu, Donglin Gao, and Shuping Li for lending us the DPS phased array and providing tips on how to use it properly. Finally, we would like to acknowledge the NSF for funding the development of DPS through EECS-2033433.

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Felipe Valencia

Felipe Valencia, a 2024 Rutgers Electrical Engineering graduate, earned his EIT certification before starting his career as an electrical engineering analyst at Kimley-Horn. During his studies, he honed skills in circuit design, machine learning, and sustainable energy solutions. Currently, his work focuses on renewable energy, including solar and battery storage systems.

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Gavin Young graduated from Rutgers University with a degree in Electrical and Computer Engineering and a minor in Mathematics in May 2024. He is currently pursuing a master's degree in electrical engineering with a focus on electronic devices, circuits, and systems. At the same time, Gavin works as an electrical engineer at Peraton Labs.

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Nithish Warren, a computer engineer, specializes in high-performance computing and AI. He holds a Computer Engineering degree from Rutgers University and is currently pursuing an ML/AI master's degree. Interested in scalable computing and deep learning, Nithish joined iCIMS as a software engineer with the aim to innovate in enterprise AI, GPU acceleration, and cloud-based architectures.

Athina Petropulu

Athina Petropulu is distinguished professor of Electrical and Computer Engineering at Rutgers University. She is Fellow of IEEE and the American Association for the Advancement of Science. She was 2022-2023 president of the IEEE Signal Processing Society and editor-in-chief of the IEEE Transactions on Signal Processing. For further information please see https://en.wikipedia.org/wiki/Athina_Petropul.

Highlights on Crafting an ASEE-JET Article

Ismail Fidan, Mathew Kuttolamadom and Jyhwen Wang

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Abstract

The Journal of Engineering Technology® (JET), *published by the Engineering Technology Division of American Society for Engineering Education (ASEE), is a leading platform for advancing research, innovation, and best practices in engineering technology education and application. The journal focuses on integrating cutting-edge technologies into real-world industrial challenges, fostering industry collaboration, and enhancing hands-on learning methodologies. With a strong emphasis on applied research,* JET *bridges the gap between academic inquiry and practical engineering solutions. This article provides essential guidance for prospective authors, presenting submission requirements, manuscript expectations, and key considerations for successfully publishing in* JET.

1. Background

The *Journal of Engineering Technology (JET)* ("Journal of Engineering Technology®" n.d.) is a peer-reviewed journal published by the Engineering Technology Division (ETD) of the American Society for Engineering Education (ASEE) ("ASEE" n.d.). The focus of the journal is to disseminate timely advancements, innovations, and research findings in the field of engineering technology practice and education. The journal has been published in hard copy since 1984. It has also been published via the Scholastica Publishing platform at jet.scholasticahq.com since 2024. Electronic copies of the journal are available through the ASEE ETD website ("*JET* Digital Version" n.d.), ProQuest Central ("ProQuest" n.d.), and EBSCOhost Applied Science & Technology Full Text ("EBSCO n.d.). *JET* is indexed by the Science Citation Index Expanded (SCIE) of the Web of Science, which is a product of Clarivate Analytics ("Web of Science Core Collection Clarivate" n.d.). Web of Science is valued for its rigorous journal selection criteria, ensuring that only high-quality content is indexed. Overall, *JET* articles are of high quality and prestigious since they are selected and published after a rigorous peer-review. This short article provides helpful guidance for deciding and preparing to publish in the ASEE-*JET*.

2. Coverage

Manuscripts submitted to the journal are framed around a diverse group of topics. However, their coverage is expected to be either on engineering technology education and/or practice. Some of the major topics covered along with (already published) representative articles are listed in Table 1. Manuscripts that involve fundamental research and/or physics-based modeling are not appropriate for being published in *JET*. Some of our recommendations for suitable *JET* topics include

- Hands-on and science-based solutions (and case studies) to industrial problems
- Best practices in STEM fields accomplished via engineering technology practices.
- Holistic reviews presenting and advancing the engineering technology field.
- Educational innovations in engineering technology curricula, practical development, and implementation
- Assessment and evaluation of the engineering technology degree programs.

3. Requirements for a Regular *JET* Paper

JET publishes high-quality, original research on contemporary topics in engineering technology. Submissions should demonstrate the application of existing technologies to novel industrial challenges or present innovative teaching methodologies that incorporate current industry practices. Manuscripts submitted to *JET* must focus on the applied, practical implementation, adaptation, and advancement of engineering technology. Manuscripts should demonstrate how engineering technology is effectively integrated into education and industry, fostering hands-on learning, skill development, and professional growth.

Table 1. Selected *JET* articles: A reference for future authors.

Topic	Sample JET Article
Innovative Teaching	Teaching the Internet of Things (IoT) (Mullett 2023)
Accreditation	ETAC ABET and EvaluateUR-CURE Findings from Combining Two Assessment Approaches as Indicators of Student Learning Outcomes (Grinberg and Singer 2021)
Diversity, Equity, and Inclusion	Supporting Women in Engineering Technology Programs (Dell 2019)
Workforce Development	Building an Engineering Technology Workforce (Taraban et al. 2018)
Applied Research	A Holistic Approach for Deciphering the Operation of Planetary Gear Train Systems (Davis 2018)
Capstone Projects	Technical Risk Management as the Connectivity in a Capstone Design Course (Hylton 2006)
Laboratory Development	Development of Modular Fixturing Lab Kits to Enhance Design for Manufacturing Learning (Cook 2020)
Distance Learning	Designing a Microcontroller Training Platform for Active Distance Learning Engineering and Technology Students (Hsiung 2009)
Industry Collaboration	Vertical Integration of Experiential Learning in Construction Curriculum with Industry Collaboration (Zahraee et al. 2024)
Non-Technical Skills	On Engineering Technology Education: BS to PhD (Barbieri 2012)
Innovative Pedagogy	Purdue Mission to Mars: Recruiting High School Students into a Polytechnic College (Turner 2016)
Classroom Activities	Introducing Engineering Students to Microfluidics and 3D Printing Using Hands-On Activities (Dogan 2023)
Active Learning	Active Learning: Increasing Construction Management Students' Technical Competencies through Concrete Formwork Exercises (Martin 2019)
Curriculum Design	Creating a New Engineering Technology Program Using the UbD Approach (Sundheim 2018)

JET does not accept purely theoretical research, news articles, opinion pieces, trade articles, or lengthy thesis and dissertation write-ups, as its mission is to bridge the gap between academic research and practical engineering applications. Submissions should align with applied and industry-relevant topics (see Table 1 for examples) that demonstrate real-world impact and innovation in engineering technology.

All manuscripts undergo a rigorous peer review process, ensuring relevance to the engineering technology discipline and its academic curricula. The journal is published by ASEE, which holds the copyright for all published materials unless otherwise specified. Manuscripts submitted to *JET* must be original and not under review by another journal. If a manuscript has been previously published in another journal or conference proceedings, it must be at least 70% distinct from the original version to be considered for publication.

Authors should carefully review the *JET* author guidelines and format their manuscripts accordingly before submission ("*JET* Author's Guide" 2020). Manuscripts must be submitted via the "Submit via Scholastica" link on the *JET* website ("*Journal of Engineering Technology*®," n.d.). Each submission requires a $10 processing fee.

Upon acceptance, the corresponding author will receive detailed formatting instructions, including requirements for graphics and author biographies. To support publication costs, authors are required to pay page charges of $75 per published journal page (approximately 750 words per page).

4. What is New?

In addition to standard manuscript submissions, the *JET* editorial board invites authors to contribute Short Papers, aimed at showcasing recent advancements and innovative practices that enhance the teaching and learning of engineering technology. *JET* seeks manuscripts that demonstrate unique and substantive contributions to the engineering technology field. Short Paper submissions should present novel ideas, technologies, or methods and should include preliminary assessment and evaluation results that highlight their impact on educational practices. The expected length of the submissions is approximately 2,500 words. Manuscripts focused solely on theoretical or fundamental research, without a **clear** educational context, will not be considered.

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The Production Editor collaborates with the manuscript and copy editors to ensure that each issue of JET is published on time, meets the highest quality standards, and is free of errors. This position also plays a vital role in maintaining the journal's online presence and supporting the peer-review process.

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If you have any questions, please contact:

Ismail Fidan, PhD, Editor-in-Chief, *Journal of Engineering Technology®*
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Style Guide for Authors

Review of Submitted Papers

Papers submitted to the *Journal of Engineering Technology*® are reviewed for their contribution to the advancement of the field of engineering technology. Membership status in the Engineering Technology Division of ASEE does not influence the review process. Material submitted should not be under consideration by another publication.

Unsolicited manuscripts should be sent to the manuscript editor, who will make an initial decision on the paper's suitability for review. Papers are then sent to two or more reviewers who represent a cross-section of the Engineering Technology Division membership interests. Both solicited and unsolicited papers are reviewed. At least two to three months must be allowed for reviewing. Articles are accepted with the understanding that they may be returned to the authors for revision on the reviewers' recommendation, and edited by the staff for the sake of clarity and conciseness. Alterations appear on galley proofs that authors receive before publication.

Writing an Article

Articles published in the Journal of Engineering Technology® are expected to be clear, informative, and accurate. Organize your material carefully, and make sure the significance of your work will be apparent to readers outside your own area of interest. Avoid specialized jargon and wordiness. Readers will skip a dull article or one they cannot understand. Standards of good usage can be found in The Chicago Manual of Style, and Skillin's Words into Type. See manuscript requirements printed elsewhere in this issue.

Appropriate Topics for Journal Articles

Some appropriate topics are:

- Applied Technology and High Technology
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- Applied Research: Case Situations Methodology and Results
- Specific Engineering Technology Disciplinary Interests
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- Measurement and Evaluation of ET Programs
- Women/Minorities in ET
- Personnel Practices and Administration

Papers are accepted for publication in one of three general interest areas. The interest areas mentioned here are examples, and are not meant to be all-inclusive:

Major Articles: Reviews of new developments or trends of broad significance to Journal readers; descriptions of a current problem or approach of interest to more than one engineering technology discipline; reviews and comparisons of programs and teaching methods, with supporting data; studies of an aspect of the practice, history, philosophy, or administration of engineering technology. (Average length: 8-11 pages*)

New Ideas: Succinct communications of ideas that have been applied to the practice or teaching of engineering technology with evaluation of their effectiveness. (Average length: 5-6 pages*)

New Findings: Brief reports of recent studies pertaining to engineering technology practice or education, emphasizing results and implications. (Average length: 4-6 pages*)

*Paper lengths stated here refer to standard (8-1/2" x 11") pages, typed with double spacing and 1-inch margins throughout, averaging one table or figure for every three pages of text.

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Errata

JET Spring 2024 - Volume 41-1

The second paper title had a typo and should have been—

"Measuring the Impact of Newly Developed Open Educational Resources (OER) Materials of CAD Courses Using Mixed Method Analysis"

and should have listed the following as authors—

Mohammad Moin Uddin, Keith V. Johnson, Leenderdt Craig, and Ashley D.R. Sergiadis

Ashley Sergiadis designed and implemented the surveys which were adapted from Bliss et al. (2013) and Sergiadis et. al (2022) with additional questions about equity and inclusion adapted from Open Oregon Educational Resources. She also contributed significantly by identifying relevant OER materials, ensuring copyright compliance, and publishing resources on Digital Commons.

Sergiadis, A.D.R., Clamon, T., Smith, P., & Young, J. (2022). Two peas in a pod? Support for open and affordable course materials through an awards program and e-textbook reserves. Oral presentation at Charleston Conference. https://www.fulcrum.org/concern/monographs/v692t899x

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Title

M423-Navigating the Journal of Engineering Technology: Insights and Opportunities

Session Description

The session will highlight the journal's mission, scope, and submission process while offering practical guidance on manuscript preparation, peer review expectations, and strategies for successful publication. Attendees will gain valuable insights into how the journal serves as a platform for applied research and instructional innovations in engineering technology and how they can contribute to and benefit from the journal's growing community.

Speakers

Dr. Ismail Fidan
Tennessee Technological University

Ismail is the Editor-in-Chief of the Journal of Engineering Technology. Currently, he also serves as the Production Editor for the journal. Ismail is a Professor at Tennessee Tech University.

Dr. Mathew Kuttolamadom
Texas A&M University

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All papers will be subject to double blind peer review, with decisions made on the basis of accept, minor revision, or rejection. Each submitted paper should follow the author guidelines detailed at https://engtech.org/jet/authors-guide/

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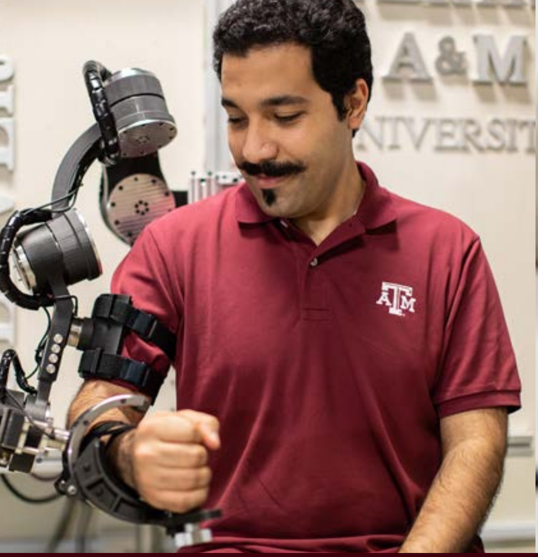

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