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Board 373: Renewable Energy Systems Training (REST) Project Final Report

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Renewable Energy Systems Training (REST) Project Final Report

Abstract

Renewable energy systems are more efficient and environmentally friendly power generation solutions as compared to traditional fossil generators, and as a result have created a continuously expanding job market. The global investment in solar PV systems has gone through a mostly increasing trend in the past ten years, which implies that the solar PV market requires a significant number of Science, Technology, Engineering, and Mathematics (STEM) graduates specifically trained to handle the technical challenges and meet the job market demand. This project is funded through the Advanced Technological Education (ATE) program of National Science Foundation (NSF), and has been conducted at New Jersey Institute of Technology (NJIT) with the objective to train the required workforce for the solar photovoltaic (PV) job market through several activities that will provide benefits to university students, K-12 students, faculty members and instructors, and remote users all around the U.S.

In this paper, the five major activities of the project are explained, which include: (i) Design and development of the new laboratory entitled "Renewable Energy Systems Training (REST)" and the associated new course entitled "Solar PV Planning and Installation", (ii) summer workshops for K-12 students through Center for Pre-College Programs (CPCP) at NJIT, (iii) faculty development workshops for the instructors of other 2- and 4-year institutions, (iv) undergraduate research and senior design projects, and (v) development of a dedicated public website to include all the lecture notes, laboratory experiments, video recordings, publications, guidelines to develop similar courses, and other instructional materials. This paper summarizes and presents the comments and feedback from external advisory committee (EAC), external evaluator, faculty development workshop participants, K-12 workshop participants, and the students enrolled in the new course. It also explains the career placement, student retention, and community college transfer rates.

Project Activities

This NSF-funded project was initially planned for three years but was extended to four years due to the COVID situation. The project includes five major activities as listed in Table 1. In the subsequent sections, these activities and the project evaluation plan will be explained in detail.

Table 1. Project activities.

Activity	Description
(i)	Design, develop, and offer the new course and laboratory (renewable energy)
(ii)	Summer K-12 workshops through the CPCP at NJIT
(iii)	Faculty development workshops for the instructors of other 2- and 4-year institutions
(iv)	Undergraduate research and senior design projects
(v)	Develop a dedicated public website and include all the disseminated materials, lecture notes, laboratory experiments, video recordings, publications, guidelines to develop similar courses, and other instructional materials

Evaluation Plan

For the evaluation of the activities in this project, both formative and summative evaluations were performed. The formative evaluation is necessary to enhance the laboratory and curriculum development and implementation, by continuously collecting user feedback though early surveys and evaluations. The summative evaluation is necessary to determine to what extent the project objectives are met and what modifications are required, through end-of-course/workshop surveys and evaluations. For each of these surveys and evaluations, a standard rubric was prepared and provided to the participants with consultation with the EAC members to properly reflect the project activity objectives. These formative and summative measures are listed in Table 2.

Table 2. Evaluation plan including formative (F) and summative (S) measures.

Activity	Description	Evaluation Measure
(i)	New course and laboratory	Continuous consultation and feedback from External Advisory Committee (F & S); Early and end-of-term evaluations by students (F & S)
(ii)	K-12 Workshop	Survey of program participants (S)
(iii)	Faculty development workshop	Post-workshop survey (S)
(iv)	Undergraduate projects	Early/end-of-term evaluations by students (F&S)
(v)	Disseminated materials and dedicated public website	Continuous comments and feedback from EAC (F & S); Online surveys of intended users (S)

The external evaluator audited the implementation process through a document analysis approach. The analyses results and supporting evidences, which were collected and provided to the external evaluator, include the following: feedbacks from the EAC, aggregated summaries of early and end-of-term evaluations by students, professional development workshops materials, post-workshop survey results, aggregated results of surveys of outreach activities (summer camp programs) and collection of demographic data, list and examples of published papers, and all project reports. Moreover, any deviations from the original research plan were reported.

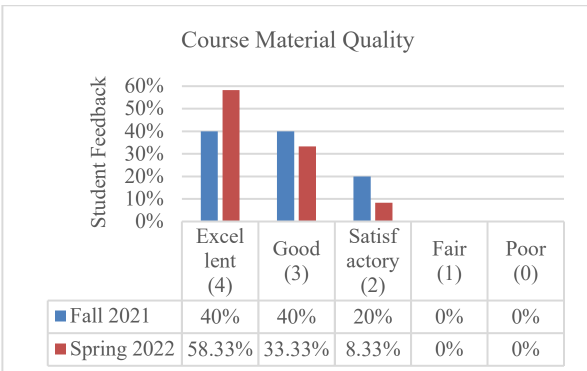
New Laboratory and Course Development and Student Feedback

The new Renewable Energy Systems Training (REST) laboratory was developed based on the equipment from Amatrol Inc. [1] as depicted in Figure 1.

(a) (b) (c) (d)

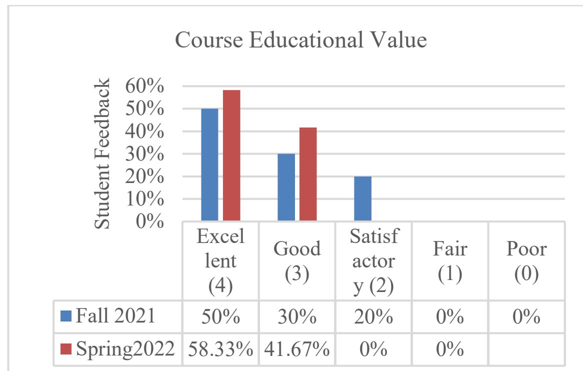
Figure 1. Laboratory equipment [1]: (a) Solar PV installation, (b) solar PV troubleshooting, (c) solar thermal troubleshooting, and (d) solar site analysis.

Associated with the new REST laboratory, the new course “Solar PV Planning and Installation” was developed based on the textbook [2]. The lecture notes cover the topics including: Solar radiation fundamentals, sun path characteristics, solar panel orientation, conducting site survey, solar PV fundamentals, solar PV installation and troubleshooting, solar thermal fundamentals, and solar thermal troubleshooting. The details of the course lectures and contents are presented in [3] and [4]. The new course was offered in the 2021-2022 academic year. Early-semester course evaluations were completed by the students in both semesters, Fall 2021 and Spring 2022. Moreover, end-of-semester course evaluations were completed, whose results for the four parts including “course material quality”, “course educational value”, “course level of difficulty”, and “instructor teaching effectiveness” are demonstrated in Figures 2, 3, 4, and 5, respectively.



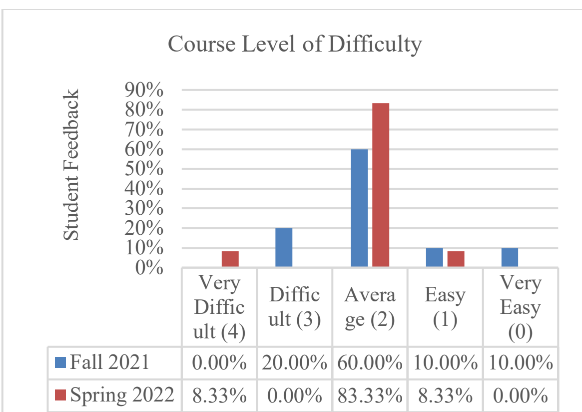
	Excellent (4)	Good (3)	Satisfactory (2)	Fair (1)	Poor (0)
Fall 2021	40%	40%	20%	0%	0%
Spring 2022	58.33%	33.33%	8.33%	0%	0%

Figure 2. Course evaluation (material quality): Fall 2021 (mean 3.20) and Spring 2022 (mean 3.50).



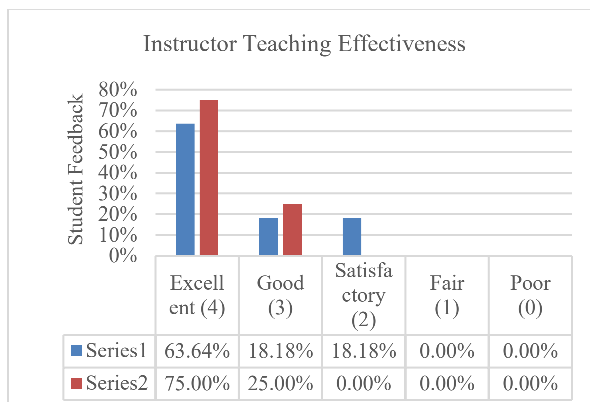
	Excellent (4)	Good (3)	Satisfactory (2)	Fair (1)	Poor (0)
Fall 2021	50%	30%	20%	0%	0%
Spring2022	58.33%	41.67%	0%	0%	

Figure 3. Course evaluation (educational value): Fall 2021 (mean 3.30) and Spring 2022 (mean 3.58).



	Very Difficult (4)	Difficult (3)	Average (2)	Easy (1)	Very Easy (0)
Fall 2021	0.00%	20.00%	60.00%	10.00%	10.00%
Spring 2022	8.33%	0.00%	83.33%	8.33%	0.00%

Figure 4. Course evaluation (level of difficulty): Fall 2021 (mean 1.90) and Spring 2022 (mean 2.08).



	Excellent (4)	Good (3)	Satisfactory (2)	Fair (1)	Poor (0)
Series1	63.64%	18.18%	18.18%	0.00%	0.00%
Series2	75.00%	25.00%	0.00%	0.00%	0.00%

Figure 5. Instructor evaluation (teaching effectiveness): Fall 2021 (mean 3.45) and Spring 2022 (mean 3.75).

Based on the student comments, the following changes have been made to the course and laboratory materials:

- Lecture notes are modified to provide more instructions on the scientific and engineering aspects of solar PV systems and design.
- The controller circuit and functionality are presented in more details to the students.

Summer Camp and K-12 Workshop

Summer camp workshops were offered to K-12 students through the CPCP at NJIT in Summers 2021 and 2022, which included lectures and hands-on experiments as depicted in Figures 6-(a) and (b), respectively. The following topics were covered in the lectures: preliminaries, current, voltage, and series parallel combinations; renewable versus nonrenewable energies; solar energy and solar PV systems; and hydro and wind energies.

(a) (b)

Figure 6. Summer camp and K-12 workshop: (a) Lecture and (b) hands-on experiments.

The electrical components for the K-12 workshop were purchased form Horizon Educational Inc. [5], based on which five hands-on experiments were provided to students as indicated in Figure 7.

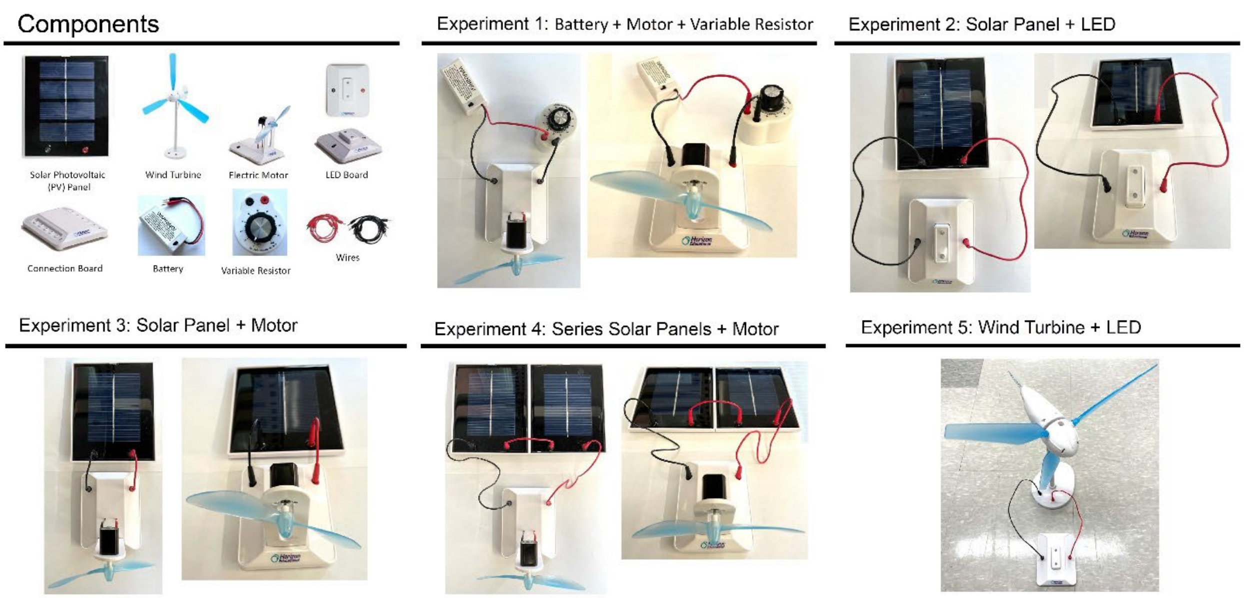


Figure 7. Electrical components [5] and five hands-on experiments for K-12 workshop.

The demographic information of the K-12 students is presented in Table 3.

Table 3. Demographic information of the K-12 workshops.

Year	Total Students	Male	Female	Asian	African American	Hispanic	Caucasian
2021	12	9	3	3	5	4	0
2022	20	6	14	4	7	2	7

The samples of comments and notes from the K-12 students are as follows:

- "The workshop was very fun and it bestowed upon me the wondrous world of electricity! I wholeheartedly look forward to the next one!"
- "Learning about these energy sources was not a first, but you definitely expanded my knowledge on the topic. One new thing that I learned was that you could use water streams as a renewable energy source."
- "I truly enjoyed the hands-on experiments as well as the videos, they were fun and filled with interesting information."
- "I loved learning about solar panels and renewable energy. I had a lot of fun working and experimenting with the many different gadgets, and it was interesting to see how they all interacted with each other."

Faculty Development Workshop

The faculty development workshop was offered in Summer 2022 as demonstrated in Figure 8. This one-day workshop included the following lecture topics: certification programs and electrical codes and standards; solar panel ratings and types and parts of PV systems; load analysis, site survey, and PV array sizing; financial overview and benefits; how to design and develop a similar course and laboratory at other institutions; and how to plan for budget, equipment, and course materials. The workshop also covered the following hands-on activities: connecting and operating a stand-alone AC PV system, troubleshooting a stand-alone AC PV system, and designing a residential PV system using online tools. A total of 16 participants from all around the U.S. attended the workshop, and the post-workshop survey and evaluations are summarized in Figure 9.

Figure 8. Faculty development workshop.

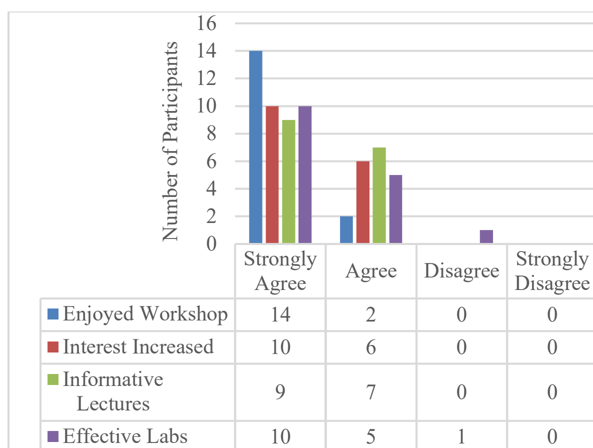


Figure 9. Faculty development workshop evaluation summary (total participants: 16)

Undergraduate Research and Senior Design Projects

The new laboratory developed in this project has been used for undergraduate research and senior design projects to help with the students' academic progress. The following opportunities have been provided to the undergraduate students at NJIT:

- Undergraduate Research (one student, completed): "Laboratory Development for Microcontroller Communication". In this project, multiple microcontrollers were connected to cooperatively simulated a renewable energy system, which is computationally too expensive for one microcontroller.
- Undergraduate Research (one student, completed): "Laboratory Development for Solar PV Troubleshooting Learning System". In this project, laboratory experiment videos were developed and recorded for the online module of the new course entitled "Solar PV Planning and Installation".
- Senior Design Project [6] (four students, completed): "Solar-Powered Speed Radar Measurement, Display, and Logging System". In this project, a solar PV system was designed to power a speed control system including a radar sensor, camera, microprocessor, and data logging system (Figure 10).
- Senior Design Project (five students, in progress): "Solar-Tracking PV System Design and Development". In this project, a PV system is designed and developed with the capability to track the sun based on two degrees of freedom for optimal performance.

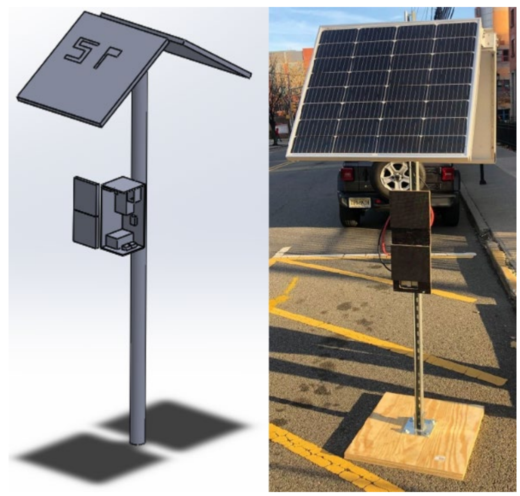


Figure 10. Solar-powered speed radar measurement, display, and logging system.

Website Development

The new website http://research.njit.edu/rest has been created and publicized for use by all universities and colleges, and is being continuously updated. This website includes:

- Overview and scope of the project, partner institutions, external advisory committee, and other collaborators inside and outside NJIT.
- The textbook, lecture notes, and laboratory equipment and recordings, which have been developed and used for the REST laboratory and the associated new course.
- The information and instructional materials, which have been developed and used for K-12 and faculty development workshops.
- The undergraduate research and senior design projects, which have been conducted in the REST laboratory.
- The publications including journal and conference papers.
- An online feedback form for the users to anonymously provide their suggestions for continuous improvement.

External Advisory Committee (EAC)

The EAC included the industry partners from S&C Electric Company, Energy Vault, GE Power, and SunLight General Capital, who reviewed all the materials developed for the new course and laboratory, and provided comments and feedback for modification and enhancement. The feedback which was provided to the EAC included the following four questions:

1. Lecture notes: Do they provide the knowledge required in the field? What additional topics/materials can be added to improve and enhance them?
2. Laboratory experiments: Do they provide the skills required in the field? What additional experiments can be added to improve and enhance them?
3. Evaluation (quizzes, tests, review questions, project): Do they provide an effective evaluation of the students? What additional evaluation modules can be added?
4. Please provide your overall evaluation of the new course and laboratory, and any other comments and suggestions for improvement.

All of the EAC's comments and feedback about modifications to the course and laboratory materials were implemented. Their major comment was to add a laboratory experiment on PV sizing and siting by using a website or software. This comment was addressed and implemented accordingly by adding three additional laboratory experiments, which are summarized in Table 4 and explained in detail in [7].

Table 4. Additional labs in response to the EAC comments and feedback.

PV Sizing and Siting	
Lab A	Perform load analysis using the "Whole House Load Calculation" in the following website: https://gensizer.assurancepower.com
Lab B	Perform PV system design using the following website: https://pvwatts.nrel.gov
Lab C	Perform PV site survey using the website in Lab B.

The EAC's positive responses to the question #4 above are listed below:

- "In general, the course is very thorough and covers all aspects of work with Solar PV."
- "I find the course materials very broad and sufficient, and lab setup well-designed to serve the job market demand. I don't have any suggestion for improvement other than mentioned earlier in previous comments."
- "I am very impressed by the quality and practicality of the course material, very well fit for a renewable technician training program. The use of audio narration and integrated videos for the lectures made them easy to follow and understand for both in class and remote students. The use of multimedia further helps keep students engaged with the lectures. The lab procedures are very illustrative and detailed, and use of video recordings as supplementary material further helps navigating through the course material. The lab experiments and practices are chosen to train the students for practical installation and maintenance problems and how to proceed in each troubleshooting scenario. This course can be used as a role model for similar technical educational programs."

Career Placement, Student Retention, and Community College Transfer Rates

In the past few years, NJIT and the School of Applied Engineering and Technology (SAET) at NJIT have been actively promoting courses in the field of renewable energy systems, including the new course "Solar PV Planning and Installation" developed in this NSF-funded project. Consequently, the career placement rates of NJIT and SAET graduates in renewable energy industries have been on the rising edge as demonstrated in Table 5 and Figure 11. These rising trends are displayed by dashed lines in Figure 11, while the impact of COVID-19 is also observed.

Table 5. Career placement data for NJIT and SAET: Numbers of all graduates reported employment in any industries and those employed in renewable energy industries.

Year	SAET		NJIT	
	Students Employed in Renewable Energy	**Total Students Reported Employment**	**Students Employed in Renewable Energy**	**Total Students Reported Employment**
2017	6	108	55	1551
2018	1	63	36	1500
2019	9	137	71	1858
2020	3	113	65	1902
2021	7	133	75	1900

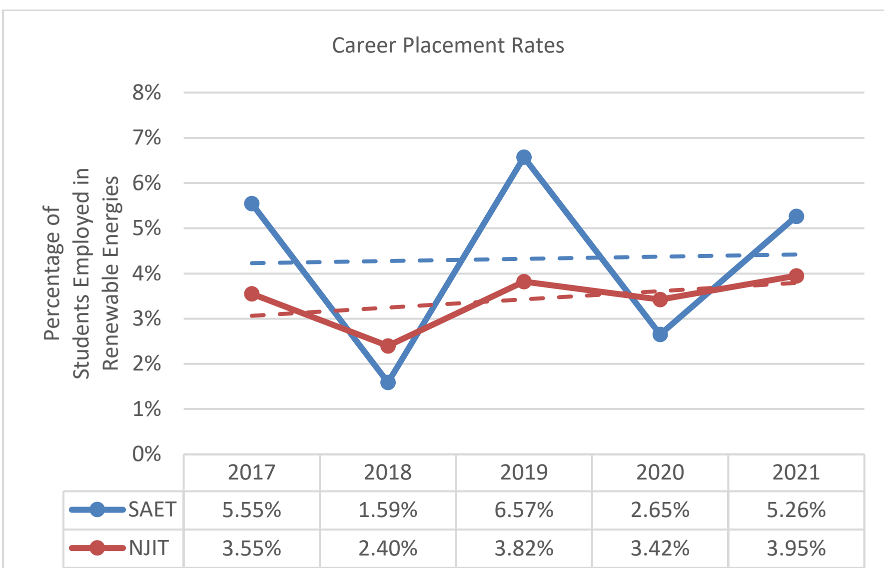


Figure 11. Career placement rates: Percentage of the students with employment in renewable energy fields as a fraction of the overall students reported employment in any industries.

The SAET and Electrical and Computer Engineering Technology (ECET) program at SAET have been actively offering applied courses and developing new courses that fit well with the industry demands in a wide range of domains including renewable energy system, such as the new course "Solar PV Planning and Installation" developed in this NSF-funded project. These efforts have significantly impacted the SAET and ECET student retention rates as well as community college student transfer rates, which are demonstrated in Tables 6 and 7, and Figures 12 and 13, respectively. It can be observed in these figures that the retention and community college transfer rates have been impacted by COVID-19. The retention rate for the ECET program (home to the new course "Solar PV Planning and Installation") had been in the range of 92%-100% before it went down to 73% due to COVID-19, after which it went up to 88%.

Table 6. Student retention data for SAET and ECET: The total numbers of new freshmen and those returning to school.

Year	**SAET**		**ECET**	
	New Freshmen	**Returning to School**	**New Freshmen**	**Returning to Program**
2017	24	20	4	4
2018	29	26	13	12
2019	129	83	12	12
2020	56	39	15	11
2021	105	68	16	14

Table 7. Community college transfer data for SAET and ECET: The numbers of all undergraduates and those transferred from community colleges.

Year	**SAET**		**ECET**	
	Undergraduates	**Transfers**	**Undergraduates**	**Transfers**
2017	74	60	18	14
2018	89	74	22	20
2019	100	78	26	23
2020	69	51	25	19
2021	80	67	26	20

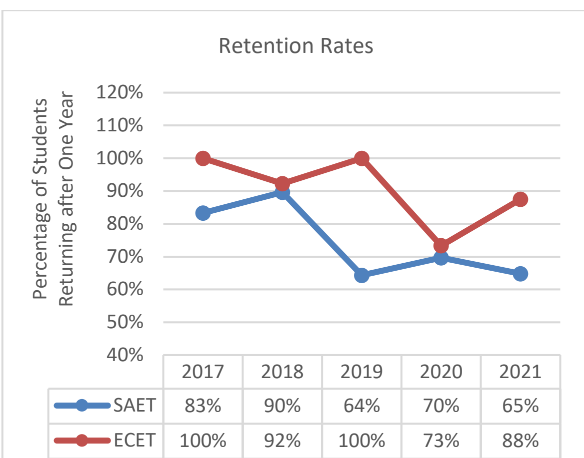


Figure 12. Student retention rates: Percentage of the students returning after one year as a fraction of the overall admitted and enrolled students.

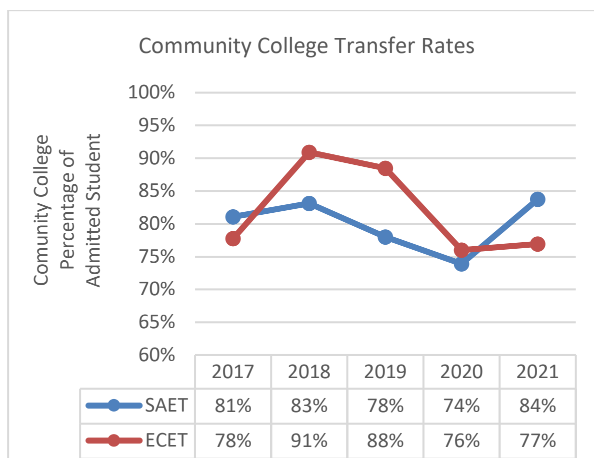


Figure 13. Community college transfer rates: Percentage of the students transferred from community colleges as a fraction of the overall admitted and enrolled students.

External Evaluator and Progress Report

The external evaluator independently evaluated this project and authored annual external evaluation reports including results and improvement recommendations, to which the project team responded. Based on the assessment plan in this project, the data from this project were collected as per Table 2 and provided to the external evaluator, who then provided third-party independent feedback and evaluation on the methods, results, and interpretations. The summary of annual progress reports for the four years of the project are presented in Tables 8-11, which include all the five activities (i)-(v) specified in Table 1.

Table 8. Progress report summary, Year-1 (2019-2020).

Activity	Progress Summary
(i)	• Conducted comprehensive research on the potential vendors and ordered laboratory equipment. • Met with EAC for consultation about the laboratory equipment.
(ii)	• N/A
(iii)	• N/A
(iv)	• N/A
(v)	• Attended ATE-PI Conference, Washington, DC, Oct. 23-25, 2019. • Worked with the external evaluator and compiled the year one project evaluation report.
External Evaluator: “Based on the external evaluator’s review of the provided evidence, the project investigators have made adequate progress in their first year of implementation.”	

Table 9. Progress report summary, Year-2 (2020-2021).

Activity	Progress Summary
(i)	• Received and set up the laboratory equipment. • Designed and developed the laboratory experiments and lecture notes. • Developed the course syllabus and got approval from the Committee on Undergraduate Education (CUE) at NJIT and County College of Morris (CCM).
(ii)	• N/A
(iii)	• N/A
(iv)	• N/A
(v)	• Attended and demonstrated at ATE-PI Conference (Virtual), Oct. 19-23, 2020. • Met with EAC for feedback about the laboratory and course materials. • Worked with the external evaluator and compiled the year two project evaluation report.
External Evaluator: “Based on the external evaluator’s review of the provided evidence, the project investigators have made adequate progress in their second year of implementation.”	

Table 10. Progress report summary, Year-3 (2021-2022).

Activity	Progress Summary
(i)	• Offered the new course at NJIT in Fall 2021 and Spring 2022, and at CCM in Spring 2022.
(ii)	• Planned, developed materials, and offered K-12 summer workshop (virtual), July 13, 2021.
(iii)	• Planned, developed materials, and offered faculty development workshop, June 21, 2022.
(iv)	• Advised undergraduate research including one student.
(v)	• Attended and demonstrated at ATE-PI Conference (Virtual), Oct. 18-22, 2021. • Published and presented the paper [3] at ASEE Conference for Industry and Education Collaboration (CIEC), Tempe, Arizona, Feb. 9-11, 2022. • Published and presented the paper [4] at ASEE Annual Conference and Exposition, Minnesota, Minneapolis, June 26-29, 2022. • Worked with the external evaluator and compiled the year three project evaluation report.
External Evaluator: "Based on the external evaluator's review of the provided evidence, the project investigators have made adequate progress in their third year of implementation."	

Table 11. Progress report summary, Year-4 (2022-2023).

Activity	Progress Summary
(i)	• Offered the new course at NJIT and CCM in Fall 2022 and Spring 2023.
(ii)	• Planned, developed materials, and offered K-12 summer workshop (in-person), July 19, 2022.
(iii)	• N/A
(iv)	• Advised undergraduate research including one student. • Advised two capstone senior design projects (one in progress) including nine students.
(v)	• Attended and demonstrated at ATE-PI Conference (Virtual), Oct. 20-21 and 26-28, 2022. • Published and presented the paper [7] at ASEE Conference for Industry and Education Collaboration (CIEC), North Charleston, South Carolina, Feb. 8-10, 2023. • Published and presented the current paper, "REST Project Final Report", and the papers [6] and [8] at ASEE Annual Conference and Exposition, Baltimore, Maryland, June 25-28, 2023. • Published the journal papers [9], [10], and [11]. • Created and set up the website (http://research.njit.edu/rest). • Worked with the external evaluator and compiled the year four project evaluation report.
External Evaluator: "Based on the external evaluator's review of the provided evidence, the project has reached the proposed project goals and objectives."	

Conclusions

In this paper, the NSF-funded REST project outcomes are presented, which include several activities conducted at NJIT as follows. The new laboratory and course were designed, developed, and offered to engineering technology students at NJIT and CCM. The laboratory at NJIT was also used for undergraduate research and senior design projects, and K-12 and faculty development workshops. The workshop participants' comments and evaluations are summarized and included in this paper. The project was developed in close collaboration with industrial partners, who provided comments and feedback to enhance the quality of lectures and laboratory experiments, which are explained in this paper. Moreover, this paper includes the project's public website, which was developed to disseminate all the course and laboratory materials, products, and results of this project. In addition, the career placement, student retention, and community college transfer rates are demonstrated. Finally, the annual progress reports, which were evaluated by the external evaluator, are summarized.

Acknowledgement

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