

Education and Information Technologies

Online Technological STEM Education Project Management

--Manuscript Draft--

Manuscript Number:	EAIT-D-21-01534R6	
Full Title:	Online Technological STEM Education Project Management	
Article Type:	Manuscript	
Keywords:	STEM education; Cooperative/collaborative learning; Online learning; project management	
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Funding Information:	National Science Foundation (1950142)	Dr. Fangyang Shen
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Online Technological STEM Education Project Management

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Declarations.

Funding

The E-NEST project is supported by the National Science Foundation (Grant Number #1: NSF 1950142, \$1,444,398, May 1, 2020-April 30, 2025; Grant Number #2: NSF 1340007, \$1,418,976, January 1, 2014-December 31, 2019, PI: Fangyang Shen; Co-PI: Ahmet Mete Kok, Yi Han, Andrew Douglas, Hon Jie Teo; Project Manager: Janine Roccasalvo).

Conflicts of interest/Competing interests

The authors declare that they have no conflicts of interest or competing interests.

Availability of data and materials

All data analysed during this study are included in this published article.

Authors' contributions

FS and JR contributed to leading the project design and data analysis. All authors contributed to the infrastructure of the project and data analysis.

Acknowledgements

We would like to thank all faculty, staff and students who helped and supported the program at City Tech, BMCC and NSF. We also would like to give a special thanks to Professor Gordon Snyder for his help with the project's evaluations.

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ABSTRACT

With a strong demand for online education and project management in deeper scope and larger scale to better fit COVID-19 pandemic situation, exploring new knowledge of online education to make it more effective became vital with the new challenges of STEM education. To resolve the above problem, this paper focuses on various aspects of online STEM education project management where the Enhanced Noyce Explorers, Scholars, Teachers (E-NEST) three-tiered structure was implemented during the COVID-19 period. The City University of New York (CUNY) institutions, New York City College of Technology (City Tech) and Borough of Manhattan Community College (BMCC) used the three-tiered structure referred to as Explorer, Scholar and Teacher which incorporated advancements in teaching internships, professional development workshops and mentorships remotely. Built upon the theories of engagement, capacity and continuity (ECC) and team-based learning (TBL), this remote learning model and infrastructure had a positive impact on STEM education and project management. The technological tools utilized included Zoom, Google Meet, Microsoft teams, Blackboard Collaborate Ultra, Skype and SurveyMonkey. The results from qualitative and quantitative data including project evaluation, online surveys and focus group interviews demonstrate that the modified remote learning and management tools were effective. This indicated that the E-NEST model greatly supported student success and faculty in online learning and project management meetings.

The E-NEST STEM education project was compared to two other project management models along with the previous NEST curriculum. Faculty emphasized practicing project management proactively and utilized best practices of classroom and time management consistent with Project Management Body of Knowledge (PMBOK) and Project Cycle Management (PCM) guidelines. The comparisons attest that the E-NEST project developed excellent and innovative online platforms for student learning with project management and ECC and TBL applications.

Hereafter, this research can be used to constructively develop more online STEM education learning models and platforms and integrate new practice and technology globally. These ideas can contribute to future research that could be applied internationally to STEM education projects in K-12 and higher education institutions.

Keywords- STEM education; cooperative/collaborative learning; online learning; project management

1.- Introduction.

Before the COVID-19 pandemic, remote learning and project management existed, but it was not prominent until after the pandemic. As many schools and classrooms closed, online project management and learning became a required component of education curriculums. The rapid growth of remote learning arisen from the COVID-19 pandemic presented challenges to education systems worldwide in K-12 schools along with universities. With previous findings and knowledge of online education not being adequate to meet the huge demand of pandemic period learning, exploring new knowledge of online education to make it better fit to the post-pandemic situation became a necessity globally (Ali, 2020). How will we constructively develop project management and STEM education learning in educational computer systems throughout the duration of the pandemic period? With many universities facing unavoidable changes to remote studies, our pioneering program created an innovative model for remote project management and learning, which can be utilized by other programs in the USA and worldwide. As a result of the unanticipated rearrangement to remote learning, an online learning model was created to be employed in STEM education in higher education institutions. In this paper, we present an online STEM education project management strategy using the Enhanced Noyce Explorers, Scholars, Teachers (E-NEST) three-tiered structure (Shen et al., 2020) during the pandemic period. This structure was implemented at two City University of New York (CUNY) higher education institutions, New York City College of Technology (City Tech) and Borough of Manhattan Community College (BMCC) and is centered upon the theories of team-based learning (TBL) (Ruder, Maier & Simkins, 2021) and engagement, capacity and continuity (ECC) (Artis & Washington, 2021).

The demand for skilled professionals in STEM fields is growing which makes the retention of STEM teachers even more crucial (Sami & Medsker, 2021). The National Science Foundation (NSF) Noyce Scholarship program implemented at City Tech and BMCC assisted in resolving this problem by recruiting and retaining a large diverse pool of STEM education candidates from underrepresented groups. This NSF scholarship program provided explorers and scholars with the financial means to pursue a career in STEM teaching. Those students who were enrolled in classes full-time were given the opportunity to excel in their STEM education studies by decreasing the need for full-time employment while receiving their scholarship. Highly qualified scholars were recruited and retained with all Noyce scholars upholding a 3.5 GPA or higher in college coursework. City Tech and BMCC (CUNY) institutions adopted the three-tiered framework referred to as Explorer, Scholar and Teacher (Shen et al., 2020) in the National Science Foundation Noyce Scholarship program. Explorer-Scholar-Teacher incorporates the components of teaching internships, professional development workshops and mentorships, which consists of the modifications and re-development of engagement, capacity and continuity (Artis & Washington, 2021) and team-based learning (Ruder, Maier & Simkins, 2021) theories in the E-NEST project. The Computer Systems Technology, Mathematics and Career and Technology Teacher Education departments at City Tech along with the Computer Information Systems and Mathematics departments at BMCC collaborated to design this new remote STEM education curriculum. The curriculum design integrated cultural diversity along with modified project management and alternative distance learning approaches. Shen et al. (2020) described the preceding research model applied at City Tech and BMCC where both CUNY universities collaborated to expand STEM education opportunities in culturally responsive teaching. This was vital for STEM students and teachers-to-be. Teacher training involved the introduction of applying culturally responsive instruction in a variety of contexts within the classrooms. Focusing on the significance of culture in teaching and learning allowed students to expand their knowledge of different students with other backgrounds. Culturally responsive teaching internships, professional development workshops and mentorships were offered in Summer, Fall and Spring semesters.

City Tech, a Hispanic-Serving Institution (HSI), is the designated college of technology within one of the 25 CUNY campuses, the largest urban public university system in the nation. This college plays a major role in the production of STEM graduates both nationally and within the CUNY system. The college is ranked first in ethnic diversity among regional colleges in the northeastern US (U.S. News and World Report, 2021). The student body reported 148 different countries of origin. BMCC serves nearly 27,000 students in its credit (23,000) and noncredit (4,000) programs, making it the largest community college in the CUNY System. Over 90% of BMCC's student population is comprised of minorities and groups historically underrepresented in college. Close to two-thirds of its student body are women. BMCC ranks nationally among the top echelon of community colleges awarding associate degrees to minority students. Research tools consisting of project evaluations and comparisons, online surveys and focus group interviews were utilized. The results from all of the above qualitative data demonstrated that the STEM education remote learning and project management model was beneficial in teaching and learning for students and faculty. The use of a variety of technological tools allowed E-NEST faculty at CUNY institutions to successfully implement its project. There were several benefits of remote learning during the coronavirus pandemic period. This included the flexibility of work and learning environments, more efficient faculty meetings, greater accessibility for faculty and students and savings in commute times and facility costs. Student interviews and survey responses were able to be productively conducted via online platforms. Zoom, Google Meet, Microsoft teams and Blackboard Collaborate Ultra were the main platforms in remote learning classes, professional development workshops and teaching internships. The project evaluation and survey data indicated that the E-NEST three-tiered structure supported student and faculty success by using modified project management and distance learning approaches in STEM education. Hereafter, this research may be applied to other remote learning platforms internationally and contribute to future STEM education research in K-12 and higher education institutions.

The Robert Noyce Teacher Scholarship program's (National Science Foundation, 2021) main objective is to increase the number of certified STEM teachers on a national scale. This scholarship program has significantly helped high-need communities in urban areas such as in New York City. The Noyce scholarship support from the National Science Foundation grant at City Tech and BMCC has notably assisted prospective STEM education teachers to be able to achieve professional teacher certification in New York State in the E-NEST program. The process of preparing and teaching pre-service educators was reformed due to the ongoing COVID-19 pandemic. Some researchers in the education field analyzed the shift from conventional teaching methods to an online teaching

environment (Evagorou & Nisiforou, 2020). Using varied technological equipment to address activities' adaptations made by the pre-service teachers' helped improve student achievement. This research examined the critical need to prepare educators in how to teach online and to explore the specific pedagogical practices that are important in context to the subject being taught. In recent developments of distance learning, teacher guidance and professional development was identified during the pandemic where "emergency remote learning" was put into effect (Safi, Wenzel & Trimble Spalding, 2020). Teachers were trained on how to perform tasks of designing and delivering online structure via new technology platforms. Support included mini professional development conferences to facilitate and address the instructional needs of remote learning for all students. There was an increase in faculty communications to further guide teachers with online platforms. In (Ali, 2020), the analysis of the pandemic crisis conveyed that society needs to develop more flexible and resilient education systems in higher education online learning. This study evaluated e-learning and concluded that resources, staff readiness, confidence, student accessibility and motivation play an important function in information and communications technology integrated learning. Staff members used technological gadgets to enhance learning, especially during the COVID-19 pandemic. In other research, approaches for producing video was demonstrated for active learning to address the challenges of remote work due to the COVID-19 outbreak where educators lack guidance (Lipomi, 2020). Online platforms have recently become prominent and will continue to do so in upcoming years. Video and online platforms are native for students and should be utilized more widespread in universities to benefit a larger amount of learners with varied needs.

In (Ruder, Maier & Simkins, 2021), the theory of team-based learning was introduced to prepare and engage students more widely in their work. Students in teams work productively together and hold students accountable for their part in their education. The main objective in team-based learning is to ensure that students have the opportunity to practice using course concepts to solve problems. The development of interpersonal relations is concentrated on and used productively in a variety of learning activities. Previous research further explores the theory, team-based learning and describes how to implement it in classroom activities (Michaelsen, Sweet & Parmelee, 2008). Focusing on team assignments has been proven beneficial in student success with less of a focus on independent learning. The four fundamental concepts are groups, accountability, feedbacks and assignment design. First, students are divided into permanent groups. Students are then accountable for the quality of their individual and group work. All students acquire feedbacks regularly. Ultimately, group assignments, assessments and feedback were shown to improve academic learning and team development with peers. Prior research developed the trilogy of engagement, capacity and continuity (ECC) theory (Artis & Washington, 2021). Engagement encompasses the qualities of an awareness, interest or motivation in sciences and quantitative disciplines. Capacity includes the knowledge and skills to advance in rigorous subject matter. Lastly, continuity incorporates the opportunities, resources and guidance to support advancement. A variety of programs have applied each of the elements of engagement, capacity and continuity, but this educational theory integrates all three components. In order to maximize students' achievement, all components need to be intertwined.

Several studies have been proposed to build on project management approaches. In (Delisle, Jugdev & Thomas, 2001), strategies were introduced to address project management as a holistic discipline to achieve efficiency and innovation. The effectiveness of project management was maximized rather than practiced alternatively at a tactical and operational level. To determine success, a multidimensional construct was measured by effectiveness, efficiency and innovation performance metrics. Project management values ought to be aligned to the organization's strategic business priorities. Core competences were supported and protected by senior management in pioneering methods. Principally, project management teams were encouraged to learn and be receptive to change and learning. This has also been explored in prior studies. In (Crisan, Muresan & Ilies, 2010), the authors attest that project management has evolved increasingly becoming the primary method of adapting to change in organizations. The practice of project management can increase the probabilities of success in achieving project goals. It has progressed in guidelines and international standards that are generally accepted by organizations. These guidelines and standards include transfer of knowledge, better communication, process quality and team work, time and cost savings, efficient and objective audits and improved monitoring and controlling of projects. Project Management Body of Knowledge (PMBOK) guidelines are widely utilized in the United States of American. The five process groups are: Initiating, Planning, Executing, Controlling and Monitoring and Closing. Project Cycle Management (PCM) guidelines are generally used in European countries. The five phases are: Programming, Identification, Formulation,

Implementation, Evaluation and Audit. Although both project management models include best practices, the PMBOK is applicable in all types of organizations.

All of the factors in these previous distance learning and project management studies can be used to modify and enhance the STEM education project management model. This study investigates the students' observations of the impact of the three-tiered infrastructure of project management and E-NEST programs using the enhanced theories of team-based learning and engagement, capacity and continuity in online learning. The following research questions guide this study:

- RQ1: What are the students' perceptions of the three-tiered infrastructure of project management and implementation of the E-NEST program?
- RQ2: What components of team-based learning and engagement, capacity and continuity theories are integrated in remote learning?
- RQ3: How do the students evaluate their early teaching experiences considering the support and resources provided in the Noyce program?

The remainder of this paper is structured as follows; Section 2 discusses the methods related to the research problem; Section 3 presents the results and discussion of the E-NEST remote learning model; and Section 4 describes the conclusions and future research.

2.- Methods

The primary goal of the E-NEST project is to continually improve and enhance the existing three-tiered structure which will create a STEM teacher preparation pathway in computer science and mathematics disciplines and lead to New York State licensure in teaching. The Robert Noyce Scholarship program implemented at City Tech and BMCC created the E-NEST model which consists of the following enhanced three tiers: Noyce Explorers, Scholars, and Teachers. (1) Noyce explorers include associate-level STEM students; (2) Noyce scholars include baccalaureate-level students in computer systems technology or mathematics majors; and (3) Noyce teachers consist of post-baccalaureate students whom will receive mentoring and support as they begin their career as STEM teachers and complete their mandatory teaching years. CUNY faculty along with New York City Department of Education cooperating teachers helped mentor students throughout the process. Ultimately, this will lead to an increase in retained scholars and teachers. Due to the current pandemic, a number of revisions were made to E-NEST remote teaching and learning and project management using the new three-tiered infrastructure to successfully implement the STEM education project consisting of the modifications and re-development of engagement, capacity and continuity (Artis & Washington, 2021) and team-based learning (Ruder, Maier & Simkins, 2021) theories.

Figure 1 below depicts the participant flow throughout the E-NEST program over a five-year timeframe. Students will progress through the stages (tiers) to become mathematics and technology teachers in New York City where there is an increasingly growing demand for STEM teachers. In the first and second years, Tier I Noyce explorers include approximately 700 associate-level STEM students who participate in the various student activities described in the figure during the internship and summer programs in addition to teaching internships at New York public schools. In the third and fourth years, Tier II Noyce scholars include over 25 baccalaureate-level students in computer systems technology or mathematics majors who continue to participate in teaching internships at New York City public schools, summer programs, professional learning workshops and mentorships. In the fifth year, Tier III Noyce teachers comprises of over 20 post-baccalaureate students who will receive mentoring and support as they begin their career as STEM teachers and complete their mandatory teaching years.

Participant Flow - E-NEST Program

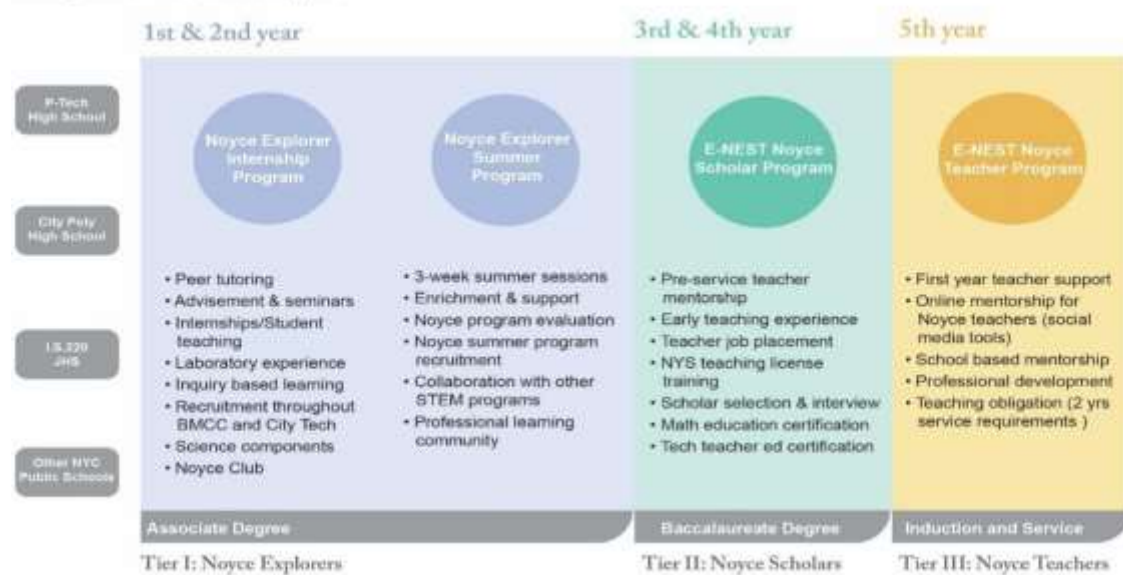


Figure 1. E-NEST Program Participant Flow

2.1.- Research model and procedure.

As classes on campus shifted to remote learning due to COVID-19, the E-NEST project management team from City Tech and BMCC universities developed a three-tiered structure of online learning and project management for STEM teacher preparation. Modifications of the STEM education curriculum was used beginning in Spring 2020 due to the project not being held in person. With multiple years' NSF Noyce project implementation, the E-NEST project team correspondingly revised project management meetings, teaching internships and professional development workshops using varied technological tools, emails and phone conferences.

The E-NEST program utilized and provided enhancements on the theories of engagement, capacity, and continuity (ECC) (Artis & Washington, 2021) and team-based learning (TBL) (Ruder, Maier & Simkins, 2021).

1. Engagement. The online instruction of the Noyce program was highly engaging and motivating for learners during stimulating teaching internships, professional development workshops incorporating cultural diversity and mentorships. Professional development workshops involving cultural diversity focused on the importance of learning about the diverse backgrounds of students.

2. Capacity. As students maximized their capacity in STEM education, they progressed from beginner level explorers to intermediate level scholars and then, moved forward to advanced level teachers. From a wide range of STEM education instruction, students were able to increase their knowledge and skills to advance in rigorous subject matter.

3. Continuity. Students were given the opportunities, resources and guidance to support advancement in the Noyce remote learning program creating excellent Noyce explorers, scholars and teachers. While continuing in the remote learning program, students' academic endurance accumulated as they advanced through their coursework.

Teachers can apply ECC to assess the individual needs of students and use information acquired to modify the curriculum (Jolly, Campbell & Perlman, 2004). The E-NEST curriculum was supplemented with lessons about current events in small group discussions. By supporting and guiding all cultural groups of students, a more collaborative, engaging environment was created in the online classroom. Noyce remote meet-up events were also organized to motivate students in the E-NEST program and give them more opportunities to socialize with other interns. Team-based learning was also used widespread throughout e-learning on digital platforms and incorporated into the E-NEST curriculum of summer workshop activities, project management development and teacher

certification training. Presenting learning activities in a highly-structured course format provides students multiple opportunities to express their understanding and receive feedback from peers (Ruder, Maier & Simkins, 2021).

Evidence-based best practices of cooperative learning, reciprocal teaching, whole-class interactive teaching and visual presentations allowed students to conceptualize and apply new information gathered. Students were given multiple STEM education hands-on learning activities which promoted critical thinking and assured readiness. Team-based learning activities maximize student preparation and participation, giving students' responsibility for their own learning (Arshad, Savita & Zulkifli, 2020). ECC and TBL was applied throughout coursework where teams collaborated and progressed in their studies through professional development workshops, remote teaching internships and peer and faculty mentorships. Breakout room and chat functions were essential to encourage TBL in remote learning. Students were given the opportunity to practice using course concepts to solve problems and given peer evaluations, assessments of learning and ongoing feedback on group assignments. The implementation of peer evaluations was found to be useful for student feedback and communication (Michaelsen, Sweet & Parmelee, 2008). Students worked cooperatively in small groups to share ideas and reflect upon STEM teaching internships. Working in teams deepened the learning experience and promoted active learning (Offenbeek, 2001). The use of cooperative learning groups stimulated academic learning and team development with peers in more of a capacity than just independent learning.

The use of remote teaching and learning will continue to grow in the next decades. While some courses will revert back to being implemented on university campuses, other remote learning will continue to stay as modern technology keeps improving. Technology has become more accessible in current times as costs have become less allowing increased digital opportunities for students. As digital technology surges in classrooms in the United States, exploring how to integrate technology with STEM education curriculums was most valuable to the E-NEST project. Digital technology enhanced online learning and increased the accessibility and effectiveness of both project activities and project management. Four key apps, Zoom, Google Meet, Microsoft teams and Blackboard Collaborate Ultra along with Skype and Cisco Webex apps helped ensure the use of technological tools was purposeful. These digital apps gave Noyce explorer and scholar interns the opportunity to transition easier during the summer workshops and Fall and Spring teaching internships each semester at City Tech and BMCC. Other apps such as Dropbox, Google Drive and OneDrive helped engage students and provide hands-on materials.

The project management team utilized online platforms which were suitable to assist in communicating Noyce program objectives and activities of remote teaching internships and professional learning. Pre-service teachers were given opportunities to apply knowledge in STEM education with the applications of engagement, capacity and continuity and team-based learning theories. Recruitment events for interns and scholars were held online and attracted participants via emails and interviews by CUNY faculty. Students were mentored by STEM education professors remotely each semester at City Tech and BMCC.

2.2.- Instrument used and their validation.

The external project evaluation data focused on measuring student impact and behavior changes as a result of E-NEST activities. The project evaluator worked with CUNY staff to evaluate the outcomes and impacts of the project and the effectiveness of the tiered scholarship model applied by City Tech and BMCC. Noyce explorers and scholars participated in 2021 summer workshops with team-based learning (TBL) activities where the following research tools were utilized by the program evaluator: remote focus group interviews, one-to-one student interviews and anonymous surveys to collectively assess E-NEST remote learning. Figure 2 describes the logic model of the project evaluation plan.

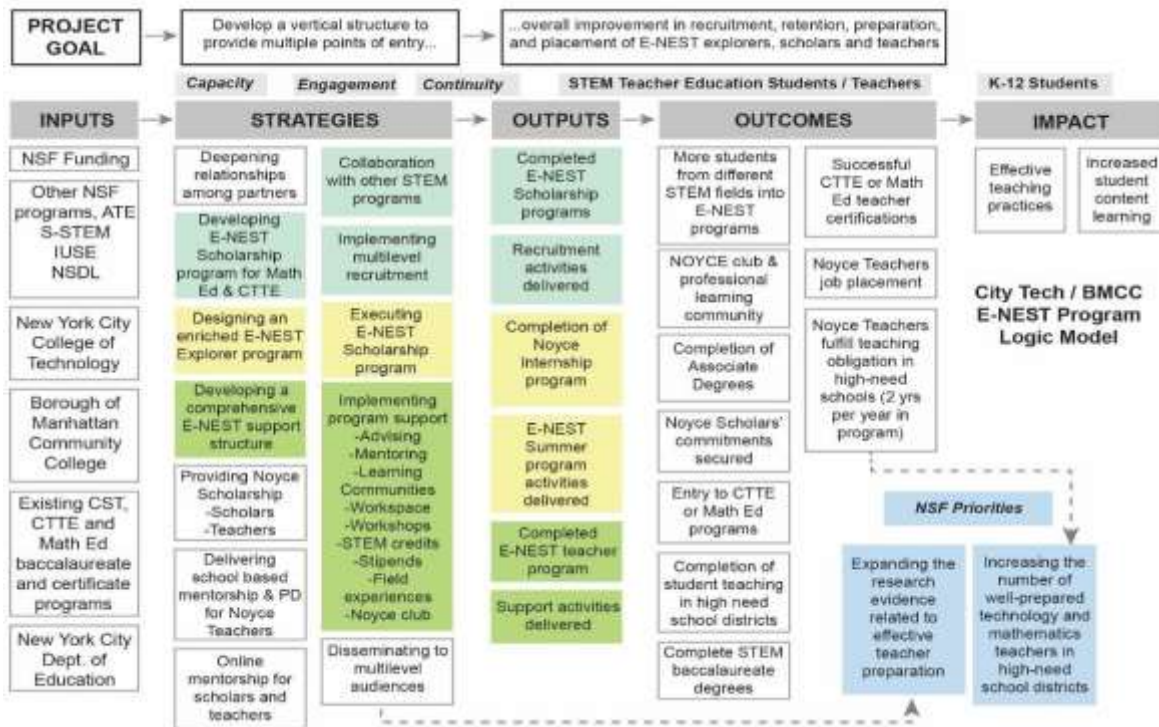


Figure 2. Logic Model of Project Evaluation Plan

The logic model developed illustrates the relationships among targeted strategies, outputs, outcomes and ultimate impact for both the E-NEST program and their K-12 students (Figure 2) (Christie & Alkin, 2003). Figure 2 above explains the timeline of the City Tech/BMCC E-Nest Program Logic Model including project goal details. TBL activities were integrated into the strategies' columns of this plan. Team-based learning is active and collaborative learning where students apply conceptual knowledge to solve problems. TBL in field experiences, Noyce clubs and learning communities along with mentoring experiences helped enrich the Explorer and Scholarship programs. The external evaluation was guided by five broad questions, each of which cuts across both the three tiers (Explorer, Scholar and Teacher) and foundations of project delivery (capacity, engagement and continuity and team-based learning): 1. To what extent, and with what quality, does the project team implement the strategies and develop outputs proposed for the project? 2. To what extent are diverse STEM students recruited to the teacher education program? 3. How effectively are those students prepared to be STEM teachers, considering student teaching, degree completion and teacher certification? 4. To what extent are students retained through educator preparation and induction processes? 5. To what extent do program graduates demonstrate effectiveness in terms of both teaching practices and impact on K-12 student learning?

The application of Evaluation Question 1 (Greene, 2007; Greene & Caracelli, 1997), considers data from (a) review of selected documents, (b) interviews of key project staff and (c) program records (e.g., recruiting activities, enrollment and program participation). In addition, summer workshop delivery quality was assessed using an adaptation of an existing City Tech Program/Workshop Satisfaction Survey. Questions 2-4 were answered using data from program internal records and a participant Scholar-Teacher survey. The latter instrument included demographic items on its first implementation and will be repeated as a survey in the later years of the project to track Noyce teachers as they complete their teaching obligation in New York City schools. Analyses for all questions were primarily descriptive, with inferential tests anticipated only for comparisons under Question 5. Annual evaluation reports focused on providing ongoing formative evaluation to help the project team monitor and improve project activities.

3.- Results and Discussion.

The approach to data collection focused on formative assessments to measure student responses to the impact of project management and ECC and TBL theoretical applications along with early teaching experiences. The qualitative and quantitative data attained will be used to measure and modify the E-NEST three-tiered structure

during the program's period. The data collection procedures involving checklists and rating scales created reliable and valid information for these assessments. Findings from the evaluation will be tailored in part to contribute to the body of research evidence relating to teacher preparation, with the intention of increasing collective understandings of the factors that influence excellence in STEM teaching.

In this section, project evaluation data and online focus group interviews and online survey results were provided for the Noyce programs in the most recent years including the Explorers summer program. This was centered on the work conducted by CUNY faculty which has empirically connected certain "high impact practices" to evidence of student success and engagement. Explorers summer program participants were drawn from City Tech and BMCC STEM students in freshman and sophomore years and Noyce scholars. Summer 2021 workshop topics were: *Implement Online Hands-on Embedded System Project at Virtual Classroom, Classroom Case Studies, Data Literacy & Problem Solving, Mathematical Growth Mindsets & Games, Introduction to Teaching, Computational Thinking, Logical and Mathematical Underpinnings of Computers and An Exploration of Cryptography and its Applications.*

The data for E-NEST was collected from a sample of approximately 100 Noyce explorers and scholars who conveyed constructive feedback on the overall efficiency of the infrastructure of project management and implementation of the E-NEST program including the integration of ECC and TBL. The following qualitative data of student responses are from extracts of interviews:

- They did a great job of making the class interactive and engaging.
- I really liked the effectiveness of online teaching and learning. I found it to be interesting and well suited for me and the other students.
- The online teaching and learning provides a good understanding with downloadable resources that make it easy to have the information at hand to study. Also, the use of software provides good examples and tools which students can use to learn by practice.
- I personally feel like online teaching and learning is way more effective than in-person, provided the student does their part of work as well. Online, it's easier to engage students and make sure they are following.
- As of now, we have more platforms to utilize the information and apply it in order for students to understand it better as well as for professors to improve their online teaching skills.

Noyce explorers and scholars agreed that the remote E-NEST project management overall was constructive. Student responses included:

- I find that the remote E-NEST project management was well done and suited for me as a student and for the students as well.
- It was very effective. The remote work was very good and consistent with the content.
- It was very helpful and interesting.
- As it is now easier for students to attend workshops and be part of the project, they can still be part of activities that are pure benefits to student's careers.
- It was organized well and fun to take.

Noyce explorers and scholars also responded positively to how team-based learning was an effective strategy in remote E-NEST learning. Student comments included:

- Team-based learning allows students to interact and work with each other.
- Team-based learning was effective where everyone helped each other out and the professor helped us out as well.
- The base work that is implemented in team-based learning is extremely useful.
- Team-based learning is very helpful in my opinion and it was also effective in E-NEST remote learning. Students cooperating with one another made understanding content easier.
- Listening to what other people think and perceive from the same situation can change the way we think and open horizons. In in-person classes, not everyone shares which is why I think everyone that is here is invested in their future and students will participate more remotely.

Figures 3 to 5 demonstrate key findings on the E-NEST online model specifically regarding the effectiveness of project management and engagement, capacity and continuity and team-based learning applications. Approximately 100 explorer and scholar students participated in the following survey responses using a rating scale. Figure 3 below illustrates that the majority of explorers and scholars strongly agreed (68.8%) and agreed (25%) that project management employed suitable online platforms to assist in teaching and learning. 6.3% neither agreed nor

disagreed. This constructive online platform enabled students to further enhance their studies in STEM education and increased overall student satisfaction.

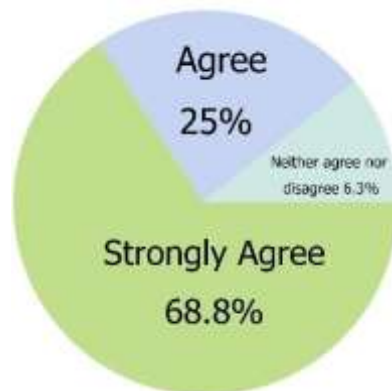


Figure 3. Project Management

Question- Project management developed online platforms that were suitable to assist in teaching and learning.

Figure 4 below illustrates that all students strongly agreed (87.5%) and agreed (12.5%) that they were given online opportunities, resources and guidance to support advancement in the Noyce program which is a principal feature of engagement, capacity and continuity. Remote activities including internships, mentorships with faculty and professional development workshops supplemented training for Noyce explorers and scholars.

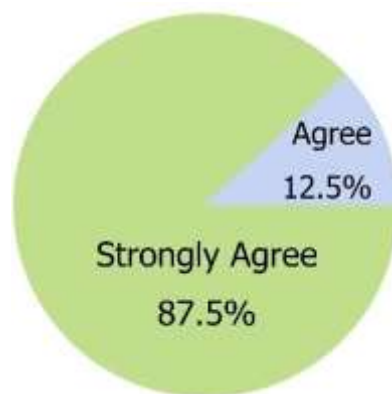


Figure 4. Engagement, Capacity and Continuity Strategy

Question- Students were given online opportunities, resources and guidance to support advancement in the Noyce program.

Figure 5 below displays that explorers and scholars strongly agreed (73.3%) and agreed (26.7%) that they were given the opportunity to practice using course concepts to solve problems remotely which is one major component of team-based learning. With team-based learning strategies, students progressed in the E-NEST curriculum and will become qualified STEM educators addressing the shortage of STEM teachers nationwide.

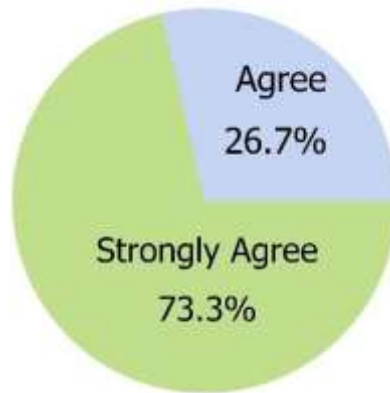


Figure 5. Team-Based Learning Strategy

Question- Students were given the opportunity to practice using course concepts to solve problems online.

The project evaluation and data validates that the remote three-tiered infrastructure of project management and E-NEST program using the enhanced theories of team-based learning and engagement, capacity and continuity have effectively supported students and their academic achievement. The feedback presented in the focus group and survey responses based on a rating scale provide evidence that the online instruction of the Noyce program was highly appealing and motivating for learners. Students received ongoing feedback on remote assignments and group responses. Group assignments in the Noyce program improved online academic learning and team development. Students were able to increase knowledge and skills to advance in rigorous subject matter remotely through internships and professional development workshops. The use of online learning improves the quality of teaching and learning. Overall, the E-NEST project management team successfully adapted to remote learning content wholly online.

Table 1 and Table 2 below show the quantitative data results on 25 students' satisfaction in the Noyce scholarship program as a positive means of support and resources during their first year of teaching post-graduation from New York City College of Technology (CUNY). Out of 100 explorer and scholar responses and 25 teacher responses, the demography of respondents was estimated at 20% White, 25% Black or African American, 25% Hispanic or Latino, 20% Asian and 10% Other ethnicities. There was a total of approximately 35% male and 65% female respondents.

Table 1- Distribution of students' responses to post-Noyce scholarship questionnaire on early teaching experiences

Statement	Strongly Agree	Agree	Neutral	Disagree
1. I was well-prepared for the first year of teaching.	42.9%	28.6%	14.3%	14.2%
2. I was comfortable teaching in the classroom as a new teacher.	28.6%	42.9%	28.5%	0%
3. I applied team-based learning effectively in the classroom environment.	42.9%	42.9%	14.2%	0%
4. I engaged students in STEM education efficiently.	42.9%	42.9%	14.2%	0%
5. I developed effective strategies to teach multicultural students.	57.1%	28.6%	0%	14.3%

6. I integrated technology into the educational curriculum successfully.	42.9%	28.6%	14.3%	14.2%
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Table 2- Individual students' feedback to post-Noyce scholarship questionnaire on early teaching experiences

Statement	Noyce Scholarship Recipient Response
1. What types of additional support would you like to receive as a teacher?	- Teaching abroad opportunity - I'd like to receive extra support in technology. - Mentorship - Classroom management, non-teaching activities orientation - Using technology to teach in an effective way - Recently, I just need to finish my internship for the math education major.
2. What experiences did you learn from your first year of teaching?	- Classroom management - There is a major difference from teaching 9th graders and teaching 11th graders. The maturity and experience levels are so different and has a major impact on learning. - First year is hard. - I am not teaching for now. - I have not started my first year of teaching because I am still processing my college courses.
3. If there were any challenges, how did you adapt to make it a better experience?	- Always have new ideas to share with students. - The language barriers were challenging because there were students from various backgrounds. So grouping helped a lot in the math classroom. - Developed and refine classroom management strategies unique to each class; allowed students to work at their own pace, created opportunities to collaborate. Developed high expectations of my students and communicated clearly with them. - If there are any challenges, I will make modifications to move forward and progress.
4. What was the most rewarding experience you gained from participating in the Noyce Program?	- It made me clear with my goals as a Math teacher. - Internship. - I loved the support. - The workshops were very informative. - The opportunity to go into different classrooms to experience NYC classrooms in real time. This was most valuable to me when I went into the classroom in the first year. - I can listen to some professor's lesson and learn from their experience and get to know how to instruct a lesson that fit for all the students.

Table 1 displays that the majority of students strongly agreed and agreed that the Noyce STEM education project greatly benefitted them in their early teaching careers post-graduation from CUNY. This included satisfactory teacher preparation where students felt comfortable and were well-prepared in the classroom as new teachers. Students successfully motivated students in STEM education using culturally responsive teaching and modified engagement, capacity and continuity and team-based learning applications of theories remotely. As new teachers, they were able to constructively integrate technology into the educational curriculum and engage students in STEM education efficiently.

Table 2 demonstrates that students gained rewarding experiences from the Noyce STEM education project including the internships, professional development workshops and mentorships that were offered. These new teachers gained valuable lessons from their early teaching experiences and were able to adapt to any challenges that arose through modifying their teaching strategies. First year teacher support, professional learning workshops,

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4 teaching internships and lessons from faculty were some of the most fulfilling experiences from student participation
5 in the Noyce program. These varied activities equipped students to become qualified teachers who will continue to
6 learn and grow in STEM education. Other types of supplementary support students would like to receive as teachers
7 are teaching abroad opportunities, increased mentorships and additional support in technology and classroom
8 management.
9

10 The project evaluation and online survey and online focus group interview data examined the new remote
11 learning model where we created our own three-tiered infrastructure to productively manage the STEM education
12 project. Revisions on project managements, recruitment, mentorships and professional learning workshops were
13 implemented remotely at CUNY institutions, City Tech and BMCC. The results convey that faculty and students
14 effectively learned how to apply the main apps of Zoom, Google Meet, Microsoft teams and Blackboard Collaborate
15 Ultra proficiently in project team meetings and online learning.
16

17 Despite the advantages of E-NEST remote learning and project management, however, there were also some
18 recognized challenges during distance learning and project meetings. These challenges consisted of student
19 performance monitoring, internet connection stability and less engagement affecting student motivation. Students
20 were asked to turn their video on, but sometimes were not able to and this affected performance monitoring.
21 Unstable internet connections caused students and faculty to not be able to log onto sessions or miss portions of the
22 workshops and meetings. In the future, it might be appropriate to offer makeup sessions or additional meetings to
23 those students or faculty who were unable to log in for the full session or use the video function. While zoom
24 breakout room and chat functions allowed students to integrate one-on-one and in small group discussions, there still
25 was not as much engagement for students. With the COVID-19 pandemic, students might become less motivated
26 and have more difficulties in keeping their attention during the lessons, especially if the topic is complicated or
27 completely unfamiliar. In future sessions and workshops, it is considerable to offer the study content in different
28 learning forms to enable higher level thinking and communication, using various systems of symbols (Cakula,
29 2021). Also, another suggestion could be to allow students to choose the class format that best fits their individual
30 needs (Loftsson & Matthíasdóttir, 2021).
31

32 The overall findings from project evaluation and online survey and focus group interview data significantly
33 demonstrated that Noyce explorers and scholars highly approved of the E-NEST remote learning platforms and
34 project management. The digital platforms proved to be of high value for faculty and also for students who
35 successfully applied engagement, capacity and continuity and team-based learning theories remotely. These
36 technological tools were convenient for students and faculty and created a flexible work and learning environment
37 with savings in commute time and facility costs as well. Remote learning workshops, internships and project team
38 meetings were readily available and accessed an increased amount of students. The host designated co-hosts during
39 summer workshops in order for them to fully access all online functions. The breakout room and chat permitted
40 students to form small groups rather than just whole group instruction and be more engaged and pro-active in each
41 lesson. Recurring meeting reminders were emailed to all faculty and students with the online infrastructure. The
42 Noyce external evaluation was led by the project evaluator during the summer workshops by using both the breakout
43 room function and emailed survey links. This allowed students to assess the program by providing constructive
44 feedback and was a key advantage during the evaluation. Overall, the Noyce program adapted to remote learning
45 content effectively with the use of the enhanced three-tiered infrastructure and technological tools improved the
46 quality of remote teaching and learning and project management.
47

48 *Discussion and Comparison of E-NEST with Other STEM Education and Project Management Models*

49 With the E-NEST project management and STEM education curriculum shifting to remote learning, it was
50 essential to learn practical implications. Throughout the duration of the E-NEST project, in addition to the utilization
51 of online tools and techniques, faculty emphasized practicing project management proactively in lieu of reactively
52 when challenges had arisen (Delisle, Jugdev & Thomas, 2001). The data confirms that project faculty developed
53 effective online platforms for student learning. Productive leadership skills and flexibility permitted the E-NEST
54 team to assess and sustain a higher quality of education. The E-NEST's project management allowed students to
55 constructively learn in remote environments with best practices of classroom and time management consistent with
56 PMBOK and PCM guidelines (Crisan, Muresan & Ilies, 2010). The findings reveal that the project management
57 team applied ECC and TBL beneficially to increase student achievement and satisfaction.
58

The E-NEST curriculum adopted online tools to promote team-based learning where group work became more critical to support academic achievement throughout the duration of the pandemic period when class sessions were no longer held in-person. Significant training on technological tools for faculty was proven valuable for students to have augmented hands-on learning in group assignments. The project management team incorporated more technological tools to enrich the curriculum and proposes to continue to expand video usage with ECC and TBL theoretical applications. The modified E-NEST curriculum incorporated professional development conferences and meetings to fully support students and faculty. An emphasis on communication aided the project management team to establish this online technological STEM education project. It was imperative to communicate information clearly with multiple targets in mind (Buttimer et al., 2020).

Table 3 below compares the current E-NEST curriculum with the previous NEST curriculum (Shen et al., 2020). With the E-NEST project being administered remotely, there were several learning aspects that were modified to enhance student achievement. In the E-NEST curriculum, there was an increase of synchronous and asynchronous learning opportunities and recruitment, flexibility and accessibility for student learning, small group discussions via app functions and commute time and facility cost savings. Overall, the remote learning model proved to be successful and featured numerous advantages to the previous in-person STEM education curriculum.

Table 3- NEST and E-NEST Curriculum Learning Comparison

E-NEST (Remote Learning)	NEST (In-Person)
Increase of learning opportunities: Synchronous and asynchronous learning activities	Synchronous learning activities at scheduled times
Flexibility for students with self-paced learning	Structured environment with rigid learning
Internet connection stability challenges	Full access to consistent learning
Breakout room functions for small group discussions	In-person small group discussions
Expansion of student recruitment	Limited student recruitment due to facility size
Accessible for all students	Limitations for student participation
Restricted student performance monitoring	In-person assessments and exams
Savings in commute times and facility costs	Greater commute times and facility costs

Table 4 below compares in-person and online project management strategies. Online project management strategies helped widen opportunities for collaboration and communication. With E-NEST project management, the advantages consisted of increased project meetings, communication, collaboration and social engagement using a variety of modes, flexibility of scheduling and locations and expansion of creativity. Overall, project progress was greatly improved with project efficiency being maximized using technological tools.

Table 4- E-NEST and NEST Project Management Characteristics

E-NEST Project Management	NEST Project Management
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Variety of modes of communication: online apps, email, increased phone and messaging communications	Limited modes of communication: face-to-face and email with other limited communications
Flexibility of scheduling and locations	Time constraints and single location meetings
Videoconferencing permitted greater amounts of social engagement	Development of natural relationships
Increased collaboration using technological tools	Collaboration at mostly in-person meetings
Greater independent work and responsibility expanding creativity of team members	Direct supervision of team
Improvement in overall project progress due to various modes of communication, collaboration and increased number of project meetings	Less overall project progress with limited communications and collaboration with fewer project meetings

4.- Conclusions.

To address the global challenges of online learning during the COVID-19 pandemic (Ali, 2020), the enriched three-tiered remote learning model was implemented with two NSF-funded STEM education programs at CUNY. The E-NEST project applied teaching and project management strategies remotely based on the modifications of the theories of team-based learning (Ruder, Maier & Simkins, 2021) and engagement, capacity and continuity (Artis & Washington, 2021). The E-NEST STEM education project management model was also compared to (Delisle, Jugdev & Thomas, 2001) and (Crisan, Muresan & Ilies, 2010) along with the NEST curriculum (Shen et al., 2020). The implications of this study's findings from qualitative data illustrate that a successful remote learning and project management model was developed to teach STEM education.

The empirical results reported herein should be considered in the light of some limitations. This project needs to accumulate additional data in future project years to improve results. We still need some improvements in the current work to apply it to education systems on a larger scale. Hereafter, this new E-NEST remote learning infrastructure can be useful as a role model for many other online educational platforms and contribute to research in STEM education in higher education institutions internationally. In the forthcoming years, we plan to apply the three-tiered remote learning model to all 25 CUNY universities and will expand and build upon remote learning strategies to improve the new curriculum. We will re-assess project management strategies and make the necessary modifications. In addition, we will accumulate further program data and external program evaluations to build upon findings of our research. Ultimately, we will construct a more rigorous, all-inclusive STEM education distance learning model.

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