Research Trends and Priorities in K-12 STEM (Science, Technology, Engineering, & Mathematics) Outreach

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Abstract – K-12 STEM education is enjoying full attention in both national policy discussions and funding opportunities. This attention for K-12 education area has been increased due to the significance and benefits related to the implementation of K-12 STEM education. A great concern has arisen on the insufficient number and preparation of K-12 STEM teachers and low academic achievement of K-12 students toward STEM subjects in the U.S. K-12 STEM researchers and practitioners have suggested that informal STEM learning opportunities are as important as formal K-12 STEM learning. The goal of this study was to investigate contemporary research trends and priorities of STEM education, especially for informal settings. Our team followed three stages: (1) Preparation, (2) Analysis, and (3) Presentation. At the preparation stage, this study reviewed relevant prior studies investigating K-12 STEM education in informal settings and established a sound foundation on identifying STEM education research and practices. The analysis sought to obtain data such as project goals (objectives), concentrated disciplines, outreach institutes, research subjects (grade, gender, race, etc.), and their expected outcomes for all the abstracts of NSF (National Science Foundation) funded projects. Targets for these analyses were limited to searchable prior research papers (Advancing Informal STEM Learning (AISL) under the NSF DRL division: Research on learning in formal and informal setting). At the presentation stage, this study communicated the key research trends and priorities in K-12 STEM outreach research and practice. This study can provide an outline for designing K-12 STEM outreach related research and projects.

Keywords: STEM Education, informal setting, K-12, Outreach

INTRODUCTION

The professional communities of science, technology, engineering, and mathematics education in the United States are all supportive of the integrative efforts among STEM disciplines [1, 2]. National and global educational communities have prepared for their innovative research and implementation associated with STEM (Science, Technology, Engineering, and Mathematics) education.

Integrative STEM education indicates instructional efforts related to the teaching and learning of STEM content and process in the context of technological/engineering problems [3]. Specifically, the integrative STEM graduate program at the Virginia Polytechnic Institute and State University has developed the following brief definition based on their research and experience [4].

> "Integrative STEM education is defined as the application of technological/engineering design based pedagogical approaches to intentionally teach content and practices of science and mathematics education concurrently with content and practices of technology/engineering education. Integrative STEM education is

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equally applicable at the natural intersections of learning within the continuum of content areas, educational environment, and academic levels" [4]

This definition presents three key components of STEM education: (1) integrative efforts, (2) intention (purposefulness), and (3) students' design approach. Purposefulness has been recognized as important to the effective implementation of integrative STEM education. Also, many researchers have emphasized that the technological/engineering design is an effective strategic methodology and/or pedagogy for STEM education [3, 4]. Lastly, these integrative efforts can be extended into other school subjects or circumstances.

A clear characteristic presented in this approach is to pay attention to the students' benefits. The integrative STEM education can improve students' motivation toward STEM subjects: interest toward learning STEM subjects, perceived value, and perceived competencies [5]. These motivational benefits can positively affect students' decision regarding the STEM related career and their performance in STEM related subjects [6].

Our educational communities in the U.S. have expressed their concerns regarding an insufficient number of students, teachers, and practitioners in the areas of science, technology, engineering, and mathematics [7]. Also, the insufficient preparation toward the implementation of STEM education has been one of the most significant problems. In addition to STEM concerns based on claims of insufficient preparation, additional important concerns arise when considering the adequate dissemination and diversity issues within STEM areas. Due to the increased awareness toward STEM education, many K-12 educators and researchers have implemented STEM education in K-12 classrooms. While attention and support are needed within the formal education system, research has emerged to suggest that informal STEM learning opportunities are important. The goal of this study was to investigate contemporary research trends and priorities of STEM education, especially for informal settings.

METHOD: PREPARATION

To accomplish the goal of this study, this study followed three stages: (1) Preparation, (2) Analysis, and (3) Presentation. At the preparation stage, this study reviewed relevant prior studies investigating K-12 STEM education in informal settings and established a sound foundation for this study.

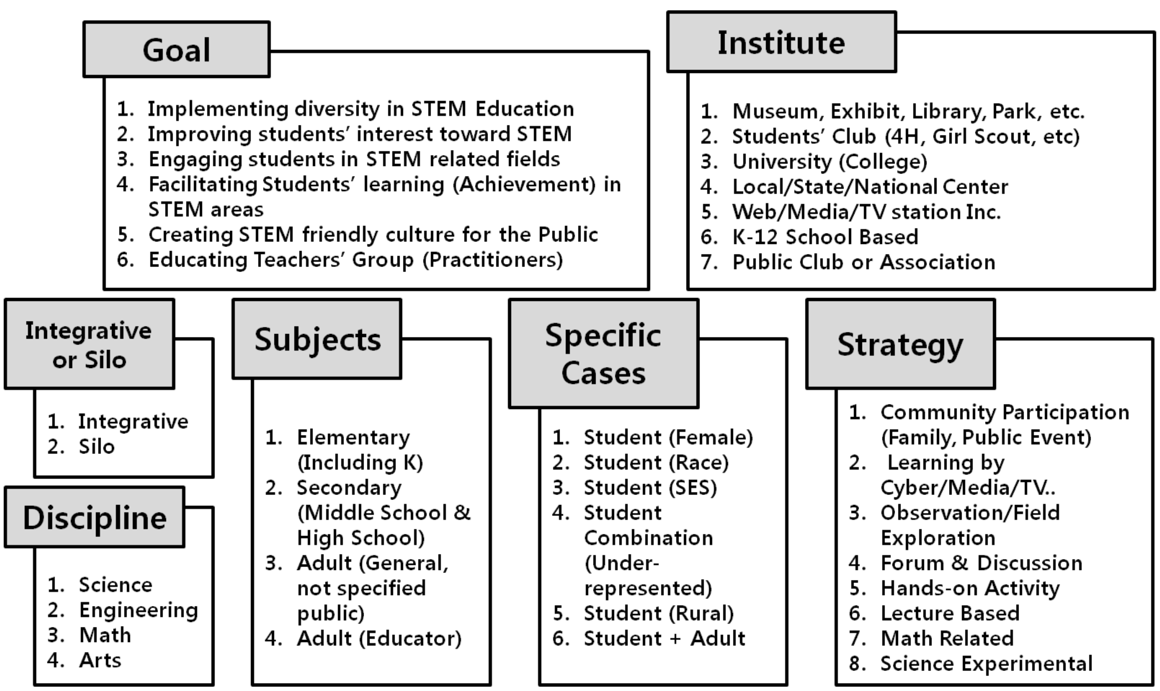

Figure 1. Categories and Sub-categories for Coding Process

Informal STEM learning can be described as any learning opportunities outside of the formal STEM classrooms [5]. NSF (National Science Foundation) has funded these informal STEM learning opportunities and related research in the AISL (Advancing Informal STEM Learning) of the NSF DRL division. A research team downloaded and analyzed all the abstracts of the AISL in NSF funded projects. During the analysis stage, each of team members analyzed the first thirty abstracts of the AISL and brainstormed the ideas regarding the categories and sub-categories as a preliminary analysis. The five categories (goal/purpose, institute, integrative or silo, targeted subjects/participants, and implemented strategies) and subsequent categories were drawn from this preliminary analysis. Finally, following categories and sub-categories were confirmed by four team members as presented in Figure 1. Based on these categories, individual member reviewed all the abstracts and checked a relevant sub-category for each category. After each rater analyzed the abstracts separately, our team checked their inter-rater reliability. The initial codes between raters were matched about 95.4%. The research team had a meeting to make a consented code for the abstracts not matched each other and finalized the analysis stage. Frequency and percentage for each sub-category were calculated and presented in the following section.

FINDING: ANALYSIS

This section presents key outcomes (project goals/objectives, institute, concentrated discipline, research subjects/participants, and their implementation strategies) of this study.

Goals/Purposes of the STEM Outreach Activities

The goals/purposes for informal STEM education research and practices were categorized into six in Table 1. The implementation of a National Science Foundation Grant for Advancing Informal STEM Learning (AISL) has been targeted to implement diversity, improve students' motivational benefits, guiding students' careers in STEM fields, facilitate students' learning, create STEM literacy for the public, and educate K-12 practitioners.

Table 1. Goals/Purposes for Informal STEM Studies

	Goal Statement	Frequency	Percent
Valid (241)	Implement diversity in STEM education settings	16	6.6
	Improving students' interest toward STEM areas	21	8.7
	Engaging students in STEM related fields	18	7.5
	Facilitating students' learning (achievement) in STEM areas	37	15.4
	Creating STEM friendly culture for the Public	115	47.7
	Educating educators (K-12 teachers) group	34	14.1
	Total	241	100.0

The largest goal/purpose for implementation of a National Science Foundation Grant for Advancing Informal STEM Learning (AISL) is creating a STEM friendly culture for the public. This goal is presented in several ways (e.g. "for improving the public's STEM literacy", "for fostering widespread STEM literacy for general audiences", "a new approach to learning STEM concepts that may be helpful to families"). This accounted for 115 out of 241 projects (47.7%). The next largest goals/purposes are facilitating students' learning (achievement) in STEM area with 37 out of 241 funded projects (15.4%) and educating educators (K-12 teachers) group with 34 out of 241 funded projects (14.1%). Three are other goal/ purposes were identified. Improving students' interest toward STEM areas included 21 out of 241 funded projects (8.7%). Engaging students in STEM related fields included 18 out of 241 funded projects (7.5%). Implement diversity in STEM education settings included 16 out of 241 funded projects (6.6%).

Key Institute

By keeping in mind that the largest goal/purpose for implementation of a National Science Foundation Grant for Advancing Informal STEM Learning is creating a STEM friendly culture for the public, the top ranked key institutes are a perfect fit as presented in Table 2. With 70 out of the 241 of the funded projects (29%), museums, exhibits and displays, libraries and parks hold the top spot.

Table 2. Key Institute for Informal STEM Learning

	Key Institute	Frequency	Percent
Valid (241)	Museum, Exhibit & Display Inc., Library, Park	70	29.0
	Students' Club or Association	12	5.0
	University (Community College)	49	20.3
	Local/State/National Level Center or Institute	25	10.4
	Web Company/Media/TV Station Inc.	54	22.4
	K-12 Schools	15	6.2
	Public Clubs or Associations	16	6.6
	Total	241	100.0

The next two key institutes also match creating a STEM friendly culture for the public. Web companies, media, and TV stations account for 54 out of 241 funded projects (22.4%). Universities and community colleges represent 49 out of 241 funded projects (20.3%). The fourth and fifth ranked key institutes are local/state/national level centers or institutes with 25 out of 241 funded projects (10.4%) and public clubs or associations with 16 out of 241 funded projects (6.6%). The last 11.2% of the key institutes does not match the largest goal/purpose. They are K-12 schools with 15 out of 241 funded projects (6.2%) and students' clubs or associations with 12 out of 241 funded projects (5%).

Integrative or Silo

When reviewing the NSF funded informal STEM learning programs, the analysis indicates that out of 238 programs the instances of Integrative S.T.E.M. focus are only slightly more than those utilizing a Silo approach as presented in Table 3. Integrative S.T.E.M. has a relative frequency of 125 (52.5%) while the Silo approach yielded 113 (47.5%) of the programs that indicated a distinct difference.

Table 3. Integrative or Silo Approach toward Informal STEM Outreach

	Integrative or Silo	Frequency	Percent
Valid (238)	Integrative efforts for the implementation (STEM)	125	52.5
	Silo approach for the implementation (S/T/E/M)	113	47.5
	Total	238	100.0

In the programs where a concentrated discipline is identified, science heavily outpaces engineering, mathematics, and the arts. Out of 204 programs, 179 (87.7%) fell into the science category as presented in Table 4. It is notable that mathematics focused programs only accounted for 6 (2.9%) of the programs. This is only slightly higher than the arts at 4 or 2.0%. Engineering programs are more than twice that of those mathematically focused at 15 or 7.4%. However, it is appears that the trend in funding is for science focused programs.

Table 4. Concentrated Discipline for Informal STEM Outreach

	Concentrated Discipline	Frequency	Percent
Valid (204)	Science (Biology, Chemistry, Earth & Environment, etc.)	179	87.7
	Engineering	15	7.4
	Mathematics	6	2.9
	Arts	4	2.0
	Total	204	100.0

Targeted Subject

When reviewing the programs for targeted subjects, it is interesting to note that a large portion of the programs are geared for the general public with 81 out of 235 (34.5%) of the programs identified this way as Table 5. Approximately another 1/3 of the programs are targeted at students specifically with 86 (36.6%) of the data. Within this group, however, the programs tend to be focused more on secondary school students by a ratio of more than 2 to 1 with 61 secondary and 25 elementary focused. The final third of the programs tended to show focus on educators or educators and their students with 68 (28.9%) of the data. Within this group, the programs that focused on educators only represented 41 programs (17.4%).

Table 5. Targeted Subjects or Participants for Informal STEM Outreach

	Targeted Subject	Frequency	Percent
Valid (235)	Elementary School Students (K-5)	25	10.6
	Secondary School Students (Middle/High Schools)	61	26.0
	Adults (General Public)	81	34.5
	Adults (Educators)	41	17.4
	Combination (Students + Educators)	27	11.5
	Total	235	100.0

Of the NSF funded abstracts identifying target audiences or populations (N=235), less than half identified specific cases of the targeted subjects (N=105) as Table 6. Of the abstracts with specific case subjects, 41.0% indicated projects designed for students in combination with another population, *Students +Other populations* (N=43). Of the abstracts with specific case subjects, 39.0% indicated that the proposed project targets some combination of a particular gender, race, low socioeconomic group, or special needs individuals, *Combination (Gender, Race, SES, and Special Needs* (N=41). Projects that target only female students, *Female Students* (N=10), represent 9.5% of funded projects which indicated specific cases for the target population. If these ten projects are found in the *Elementary School Students (K-5)* or *Secondary School Students (Middle/High Schools)*, (N=25, N=61), projects targeting female K-12 students only represent 11.6% of K-12 projects. This may provide evidence that there is a lack in trends or priorities directed at addressing the underrepresentation of females in STEM careers.

Projects that target only students of underrepresented races, *Unrepresented Race Students* (N=6), represent 5.7% of funded projects which indicated specific cases for the target population. If these six projects are found in the *Elementary School Students (K-5)* or *Secondary School Students (Middle/High Schools)*, (N=25, N=61), projects targeting K-12 students who belong to races underrepresented in STEM only represent 6.98% of K-12 projects. This may provide evidence that there is a lack in trends or priorities directed at addressing the underrepresentation of particular races in STEM careers. Projects that target only individuals of rural areas, *Rural* (N=3), represent 2.9% of funded projects which indicated specific cases for the target population. Projects that target only people belonging to a low socioeconomic group, *Low SES* (N=2), represent 1.9% of funded projects which indicated specific cases for the target population. These findings indicate that 80.0% of NSF funded outreach projects integrate at least two specific cases of the audience that is proposed to benefit from the initiative rather than using a silo approach to determine the target population.

Table 6. Specific Cases of the Targeted Subjects or Participants

	Specific Cases of the Targeted Subject	Frequency	Percent
Valid (105)	Female Students	10	9.5
	Unrepresented Race Students	6	5.7
	Low SES	2	1.9
	Combination (Gender, Race, SES, and Special Needs)	41	39.0
	Rural	3	2.9
	Students + Other populations	43	41.0
	Total	105	100.0

Key Strategies for the Implementation

Projects receiving funding from NSF indicate strategies for implementation within the abstract. Abstracts were analyzed for key strategies as Table 7. Of the abstracts indicating strategies for implementation (N=238), 35.7% proposed the use of cyber technologies, media, television documentaries, and other spin-offs from the three aforementioned platforms, *Learning by Cyber, Media, TV documentary, etc.* (N=85). Strategies which indicate a hands-on activity or design-based challenge, *Hands-on (Design Based Challenge) Activities,* represent 21.0% (N=50) of funded projects. 14.7% (N=35) of funded projects utilize activities within communities, *Community Based Participation (Family day, Local event, etc.)*. Projects which offer observational opportunities through field trips and explorations represent 11.3 % (N= 27) of those receiving funding, *Experience by Observation, Field Trip, Exploration, etc.*

Abstracts describing dissemination of deliverables through conferences and forums represent 8.4% (N=20) of funded projects, *Conference, Forum, and Discussion*. 5.9% of projects focus on experimentation in science fields (N=5), *Science Experimental Focus*. Those projects implemented via activities which focus on areas of mathematics (N=6), *Math Related Activities Focus,* make up 2.5% of funded projects. Only one funded project indicated that lecturing was the key strategy for implementation, *Lectures.* Though many funded projects indicated additional strategies other than the key strategy identified through the coding methods of this study, these findings were based on the main strategy touted by the abstract narrative. These findings indicate that over half, 56.7%, of NSF funded projects utilized cyber technologies, media, television, or hands-on design based activities for the key implementation strategies.

Table 7. Key Strategies for Informal STEM Outreach

	Key Strategies for the Implementation	Frequency	Percent
Valid (238)	Community Based Participation (Family day, Local event, etc.)	35	14.7
	Learning by Cyber, Media, TV documentary, etc.	85	35.7
	Experience by Observation, Field Trip, Exploration, etc.	27	11.3
	Conference, Forum, and Discussion	20	8.4
	Hands-on (Design Based Challenge) Activities	50	21.0
	Lectures	1	.4
	Math Related Activities focus	6	2.5
	Science Experimental Focus	14	5.9
	Total	238	100.0

CONCLUSION AND RECOMMENDATION

The goal of this study was to investigate contemporary research trends and priorities of informal STEM learning. The findings of analyzing the NSF funded abstracts were presented regarding project goals/purposes, project institute, integrative or silo focus, concentrated discipline, target population and specific cases, and strategies for project implementation.

Informal STEM learning has been implemented to achieve diverse goals. The most predominant goal/purpose for implementation of a NSF informal STEM learning grant is creating a STEM friendly culture for the public. Also, these projects have paid attention to the benefits of STEM education (e.g. students' academic achievement, motivational gain, career awareness) as identical to the research findings and conclusion in the prior studies of contemporary STEM education.

Overall in the three categories of integrative or silo focus, a concentrated discipline, and targeted subjects, it appears that integrative STEM programs focusing on science for the general public would tend to fit the category of programs funded by NSF. It is a clear trend that contemporary informal STEM outreach communities are adopting more integrated and meaningful focus to their audience.

Specifically, NSF funded outreach projects integrate at least two specific cases of the audience (e.g. students and adult group, students with underrepresented race, gender, region, and economic status.) that is proposed to benefit from the initiative rather than using a silo approach to determine the target population. With a rapid innovation of emerging technologies, informal STEM learning has utilized these strategies of facilitating students to learn by cyber technologies, media, television, and documentaries. Keeping up with the contemporary technological innovation, they are actively accepting the hands-on or design strategies. Informal STEM outreach and research have accepted the "diversity" philosophy regarding their target population and also embraced more active strategies for implementing diverse and meaningful informal STEM learning.

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