The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #41519

The Roles of Curriculum Designers and After School STEM Teachers as Environmental Features for High School Students' STEM Career Access (Fundamental)

Allison Antink-Meyer, Illinois State University

Allison Antink-Meyer is a pre-college science and engineering educator at Illinois State University.

Jeritt Williams, Illinois State University

Jeritt Williams is an assistant professor of Engineering Technology at Illinois State University, where he teaches applied industrial automation and robotics.

Dr. Matthew Aldeman, Illinois State University

Matthew Aldeman is an Associate Professor of Technology at Illinois State University, where he teaches in the Sustainable & Renewable Energy and Engineering Technology undergraduate programs.

Dr. Jin Ho Jo, Illinois State University

Dr. Jin Ho Jo is a Professor of Technology at Illinois State University, teaching in the Sustainable and Renewable Energy program. Dr. Jo also leads the Sustainable Energy Consortium at the university. Dr. Jo is an honors graduate of Purdue University, where he earned a B.S. in Building Construction Management. He earned his M.S. in Urban Planning from Columbia University, where he investigated critical environmental justice issues in New York City. His 2010 Ph.D. from Arizona State University was the nation's first in sustainability. His research, which has been widely published, focuses on renewable energy systems and sustainable building strategies to reduce the negative impacts of urbanization.

Promoting High School Students' Interest and Career Access to Robotics, Automation, and Design Around Sustainability: Affordances and Limitations in Teachers and Curriculum Developers Roles (Fundamental)

To promote interest and future choices around STEM careers, afterschool and other informal education programs have become key access points for students who may face greater challenges in entering STEM career pathways. Individual, environmental (including social), and behavioral factors each interact in ways that can promote interest and access to STEM learning and career opportunities or can limit such opportunities. Teachers, programs, and curriculum are all contextual factors that are important. Using Ecological Systems Theory, this study explored the environmental structures that influenced STEM teachers and undergraduate STEM majors' access to STEM and compared those influences to the environmental structures they perceived related to high school students access to STEM. A potential barrier between the curriculum as it is developed, and whom it is developed by, and the teachers who are responsible for implementing it came into focus in this study. Areas of conflict between the values of curriculum developers and implementers can have consequences for learners and their STEM access.

Background

The values of curriculum designers and those of teachers are each influenced at the personal and collective levels by a diversity of experiences, pressures, and priorities. Teachers' viewpoints and orientations toward science curriculum design have been shown to shift toward more emphasis on cognitive processes and humanistic curricula as their classroom experience grows [4]. Curriculum dissonance, or the lack of alignment between the intentions of developers and the implementation by teachers, is not only observed, but actually preferred among teachers in technology education settings [3]. This dissonance between what was intended and what is actualized can relate to a variety of factors. Notable among them are prioritizing students' interests and navigating curriculum when the content of the curriculum falls outside teachers' backgrounds and experiences [3].

This study explored the perspectives of teachers and curriculum developers involved in an afterschool program for high school students focused on Robotics, Automation, and Design for Sustainability (SUPERCHARGE). The purpose of the NSF funded afterschool program was to support student access to STEM career pathways for those of marginalized groups in three high schools in different neighborhoods in a large urban school district in the U.S. This study took place during the first year of the project where curriculum was being developed by faculty with the support of undergraduate STEM majors, referred to in the project and hereafter as designers. The designers' perspectives, as examples of students who had chosen a STEM career pathway, was of interest. They had gained access to STEM as a field of study and the researchers were interested in whether their own pathways would be reflected in the activities they were designing. The other stakeholder group involved in the planning year was a group of teachers who would become the afterschool facilitators of the STEM program. Those individuals valued STEM and students' access to it. As a group that provided input and feedback on the activities that were being developed, the researchers were interested in how their experiences and perspectives may or may not be reflected in the afterschool curriculum.

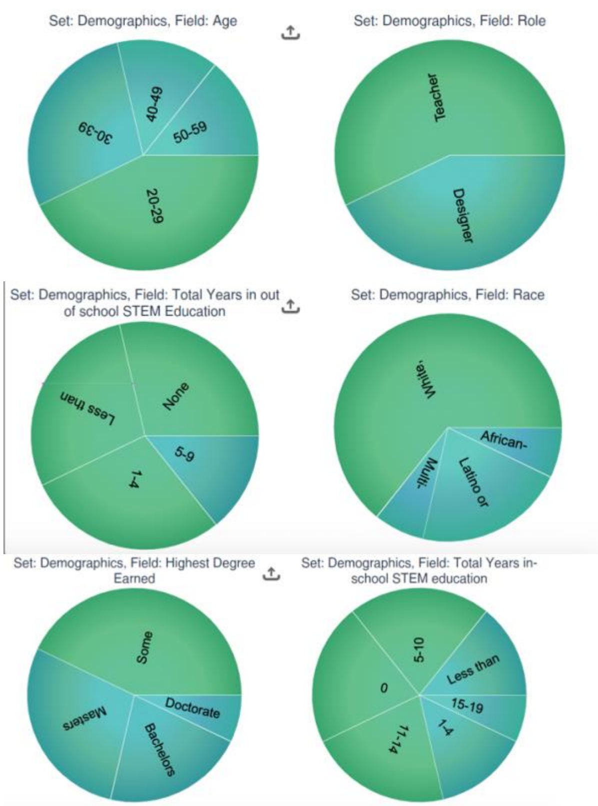
STEM career access is, in part, mediated by issues of equity that Blustein [1] categorize as structural, psychological, and relational barriers. Specific barriers include factors like institutional racism, and therefore a lack of role models for learners of marginalized racial, ethnic, and linguistic groups, and the unequal distribution of STEM resources. To promote interest and future choices around STEM careers, afterschool and other informal education programs have become key access points for students who may face greater challenges in entering STEM career pathways. Individual, environmental (including social), and behavioral factors each interact in ways that can promote interest and access to STEM learning and career opportunities or can limit such opportunities. Teachers, programs, and curriculum are all contextual factors that are important. Using Ecological Systems Theory (EST), this study explored the environmental structures that influenced STEM teachers and undergraduate STEM majors' access to STEM and compared those influences to the environmental structures they perceived related to high school students access to STEM.

EST was first introduced by Bronfenbrenner [2] to describe human development in ways that acknowledge the role that environments play. Individuals are influenced through their interactions with others, and those relationships and persons are also set within contextual factors that are consequential for development. Darling [5] described interrelationships as central to EST, specifically "individual development, contextual variability, and individual difference" (p. 206). EST was used as a theoretical lens for the current study because the purpose of the afterschool program that was the context of the investigation was developed to support high school students access to STEM career pathways. EST described five interrelated systems, these are the: (1) microsystem which consists of immediate environments and the relationships contained therein (e.g. family), (2) mesosystem which consists of the interactions between the microsystems (e.g. between parents and teachers), (3) exosystem, which describes the both informal and formal structures that interact and impose on the other systems and the individual including government policies, parents workplaces, (4) the macrosystem that consists of things like social norms, and the chronosystem which describes the influence of time. The purpose of this work was to explore the systems that the STEM teachers and designers each perceived in their own pathway to STEM access in order to examine whether it influenced how they perceived high school students' access.

Study Design

Study Participants. This study included two sets of stakeholders involved in SUPERCHARGE; STEM teachers who implemented the curriculum in the afterschool study and undergraduate STEM majors who were referred to as designers in the project. The designers worked with faculty to develop activities using micro:bit and environmental boards for high school students after school. During the study, the afterschool program had not yet begun, and the activities were being developed and finalized. Activities focused on air quality, designing remote control cars, exploring concepts related to urban heat islands and building efficiency, and the programming and build of a weather station. Eight STEM teachers participated in the study and were experienced educators who self-selected to lead SUPERCHARGE after school with one or two other co-teachers. One teacher was a languages educator and another taught environmental and life sciences. The remaining teachers were each computer science educators. Six designers also participated in the study. They were each STEM majors in either sustainable and renewable energy or engineering technology and were sophomores, juniors, or seniors in their programs. There was one exception; one student was a special education major with learning and teaching experiences related to STEM education. Figure 1 illustrates demographic information about the STEM teachers and designers as a group. All designers were in their 20s and some had some experiences working with students in out of school and in-school STEM settings. All teachers had five or more years of classroom teaching experience.

Figure 1. Participant Demographic



Two research questions framed this study. These were:

1. What environmental structures influenced afterschool STEM teachers and undergraduate STEM majors (designers) access to STEM when they were learners, and how do those influences compare to the environmental structures they perceive influence their students' access to STEM?

2. How do the personal and student-focused environmental structures described by the teachers and undergraduate STEM majors compare to one another?

To address these questions a semi-structured interview and the PEAR CIS-E survey [6] was used to gather data. The survey captures demographic, STEM confidence and efficacy, and perceptions of student confidence and proficiency in STEM and 21st century skills and does not include any open-ended items. The interviews allowed for the individual perspectives of participants to be added to the data. The interview questions focused on their experiences as learners of STEM, interest, experiences, and also their perceptions of the access to STEM majors among students of color and multilingual learners. In addition, they were asked to reflect on how the after-school program could impact the high school students. Interviews were conducted via Zoom where they were recorded and transcribed in the video conferencing platform. The transcription was then reviewed using the audio recording by the first author to ensure accuracy. The unit of analysis in the transcript were participant utterances, which are defined here as discrete ideas conveyed by participants. An utterance ranged from one sentence or phrase to several minutes of description. The interviews were coded using EST [2] by the first two authors. Coding was conducted in Dedoose and two cycles of coding were first conducted independently before each author discussed and refined codes until 100% inter-rater reliability was achieved. Utterances were coded using one code only. If an additional code was relevant, that defined a new utterance.

The findings reflect the environmental structures that influenced STEM teachers' (henceforth *teachers*) and undergraduate STEM majors', who served as curriculum developers, (henceforth *designers)* access to STEM. Comparisons between the environmental structures they perceived related to high school students access to STEM and their own STEM influences were conducted using the coded transcripts and surveys. We also compared the influences each group reported to one another.

Findings

What environmental structures influenced afterschool STEM teachers and undergraduate STEM majors (designers) access to STEM when they were learners, and how do those influences compare to the environmental structures they perceive influence their students' access to STEM?

The environmental structures described by EST include schools and teachers, but also curriculum. In terms of access to STEM among the high school participants of SUPERCHARGE, the nature of the activities in the afterschool curriculum provide insight into the designers' perceptions of students' access to STEM. The authors were also interested in learning how the implementers of that curriculum, the STEM teachers, as well as the curriculum designers, experienced STEM as learners themselves. Table 1 illustrates how very easy (4) or very hard (1) the teachers and designers believed five specific STEM education practices would be for engaging students in SUPERCHARGE. That *ensuring activities are inclusive of students of all backgrounds* and was perceived as very easy to include in the curriculum by both teachers and designers on the survey. This aligned with the analysis of interviews with teachers more so than the designers, however. The teachers' perceptions of high school students' access to STEM most often related to students' micro and meso systems, and issues of access were central to their perceptions. For example, the following interview quote illustrates the microsystem code for both a teacher's *personal* microsystem as well as their perceptions of the *students'* microsystem.

> I feel like I had too many messages come at me that said that this is not the science world is not for me. I don't have a space in it. And I'm so excited to see a program that's gonna try and just create the space for anybody and that's just really cool (Teacher).

The survey indicates the designers' felt inclusion was relatively easy to provide, their focus was more on students' interests and other cognitive factors. For example,

> Seeing it [project activities] work in the real world and understanding those processes and enjoying putting it together because it's like building a puzzle. You know, it's just the main thing I'm interested in working with it. I think that it's bite sized chunks that are very usable and easily understandable, and at first, instead of challenging them, getting them interested is what we are creating (Designer).

and,

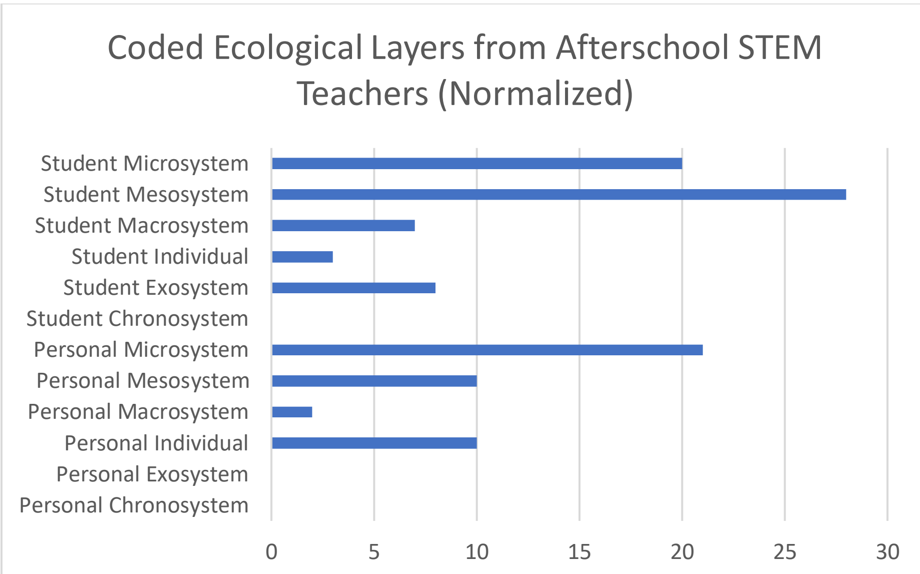
> I think fun projects, like races and you know different things that they're interested in will help them get interested in doing this for other applications (Designer).

Table 1
Teachers' and designers' perceptions of ease of using specific STEM engagement practices

Activity Engagement Practices	Role	Mean	Std. Deviation	Minimum	Maximum
Choosing activities that allow for hands-on exploration of STEM content	Designer	2.600	0.548	2.000	3.000
Choosing activities that allow for hands-on exploration of STEM content	Teacher	2.571	0.787	2.000	4.000
Leading activities that allow youth to engage cognitively with STEM content	Designer	2.200	1.095	1.000	4.000
Leading activities that allow youth to engage cognitively with STEM content	Teacher	2.571	0.787	2.000	4.000
Ensuring activities are inclusive of students of all backgrounds	Designer	3.000	1.225	1.000	4.000
Ensuring activities are inclusive of students of all backgrounds	Teacher	3.143	0.900	2.000	4.000
Delivering activities that build toward meaningful STEM learning goals	Designer	3.600	0.548	3.000	4.000
Delivering activities that build toward meaningful STEM learning goals	Teacher	2.571	0.787	2.000	4.000
Ensuring all students actively participate in STEM activities	Designer	3.200	0.837	2.000	4.000
Ensuring all students actively participate in STEM activities	Teacher	2.857	0.900	2.000	4.000

The ecological systems in EST were used as codes in the interview data and the environmental structures that are the most direct in terms of their influence on students include the teachers themselves. Teachers are access points to STEM that fall within those environmental layers. The teachers' personal micro- and mesosystems also featured prominently in their reflections where they described the role of specific classes, teachers and school environments on their interest and access to STEM (Figure 2). In Figure 2, the ecological systems were used to code the interview data. “Student” indicates their views about the high school students and “personal” indicates their views about their own experiences. The number on the bottom of figure 2 indicates the number of utterances coded as each EST structure.

Figure 2. Ecological systems codes for STEM teachers



As described in the next section related to research question 2, comparing teachers to the designers, teachers described areas of disconnect in terms of their access to STEM and its relationship to their personal backgrounds (i.e. gender, familial, racial). That they also perceived more ease in supporting activities inclusive of all students’ backgrounds may reflect that their personal pathways into STEM education. Other engagement practices were perceived as harder as reported on the survey, such as *choosing activities that allow for hands on exploration of STEM content*. Avery indicated on the survey that choosing hands on exploration activities of STEM content was hard. In her interview she discussed the tension between finding ways to engage them so they could develop self-efficacy and how she viewed herself as a model for them of a learner who persists.

> I think for my students it can be hard because some won’t try, they have to be engaged. It has to spark their interest, you know? I try to have it be hands on. They are seeing connections and leading the work. And I am learning alongside them. And I think that feels good to them. It feels good to me too. (STEM Teacher, Computer Science Educator, Interview)

This comment from Avery is also reflected in the survey data for the teachers shown in Table 2.

While Table 1 indicates that they find developing and implementing hands on activities more challenging, as a group, Table 2 indicates how important the work of engaging students as central in their STEM learning is to them.

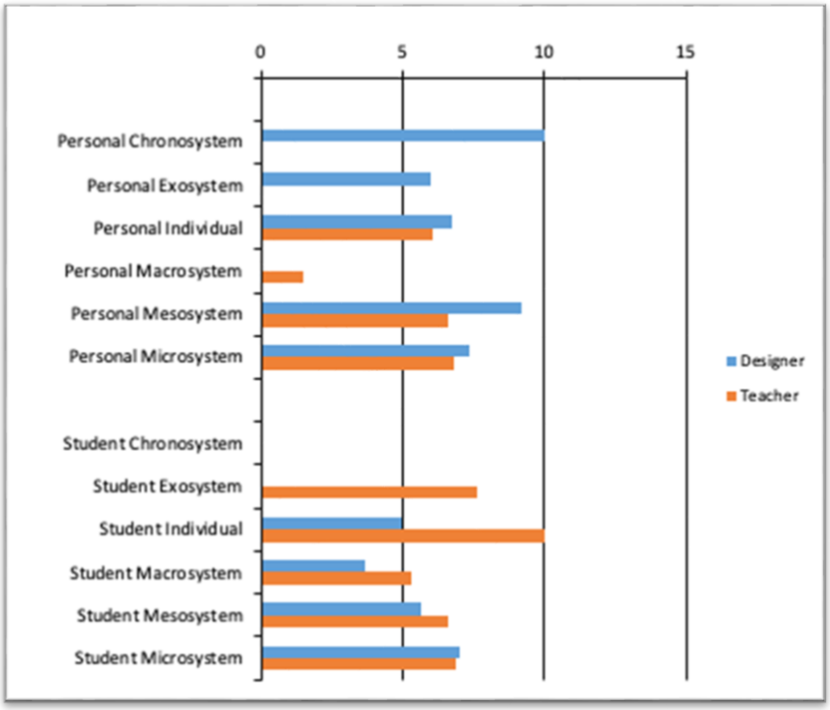
Table 2. Teacher Survey-Views about Students' STEM Development

Youth Development in STEM Practices		**Mode**	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**
Supporting students to share their ideas and opinions	Designer	3.176	3.200	0.837	2.000	4.000
Supporting students to share their ideas and opinions	Teacher	3.124	3.286	0.756	2.000	4.000
Helping students to connect STEM activities to the real world	Designer	1.080	2.000	1.414	1.000	4.000
Helping students to connect STEM activities to the real world	Teacher	3.000	3.143	0.690	2.000	4.000
Allowing students to make decisions that impact their STEM learning experience	Designer	2.824	2.800	0.837	2.000	4.000
Allowing students to make decisions that impact their STEM learning experience	Teacher	3.007	3.429	0.535	3.000	4.000

How do the personal and student-focused environmental structures described by the teachers and undergraduate STEM majors compare to one another?

The teachers and designers identified similar areas of importance in terms of the layers of the Ecological Systems and their influence on them personally as well as on the high school students. Though specific to their experiences and their roles as described in the previous sections, the relevance of the individual (cognitive and affective) perspectives, and the meso and micro systems were coded across both groups. Figure three illustrates the weight of codes among the designers and teachers. The number at the top of figure 3 indicates the number of utterances coded as each EST structure.

Figure 3
Code weight by role



Differences between the influences that teachers and designers identified were observed across both the personal environmental structures as well as the high school student focused influences. There were two environmental structures identified by the designers that were not identified as access factors by the STEM teachers (see Table 3). These were the personal chronosystem and the personal exosystem. The chronosystem is the outermost level of Ecological Systems Theory [2] and relates to the role that time and lifespan transitions play. For example, Eric reflected on the role of timing in his STEM career pathway.

> It was a little bit of a combination from like all angles and kind of like a real good timing. I was always a little bit more towards plants and stuff with zoology. I always liked animals, that was always something that I really held onto as an interest but then I saw sustainability and renewable energy being something really important in the next 20 to 30 years down the future and I wanted to be a part of that, I saw an opportunity.
> (Eric, Designer and Renewable and Sustainable Energy major)

Similarly, the role of the exosystem was only explicit in the interviews with the designers. The exosystem is the third layer nested within the chrono and macro systems in Ecological Systems Theory and this system is comprised of social structures that may not directly impact an individual but has a critical role in its interaction with the structures that do. Yori, for example, reflected on her energy use in her apartment in terms of the local energy companies and her growth in awareness of her role and power in understanding energy use in economic terms.

> My energy usage depends on the weather. You'll have your air conditioning on, but if it's 70, and you open your windows…understanding that can help you. Energy conserve as a mode that's incentivized by [Energy Company Name] doesn't just have to be switched on when you sign up. I can conserve energy when I think about it. And logically, it makes sense like oh, it's only 70 like so my house will not get too hot or too cold. I just turn it off and then I don't have to pay. People forget that you save money when you conserve. And if you understand that you can do that often throughout the year, it does make an impact like, you know, I'm saving $1 today, but over the year, and I'm saving much more so my understanding of weather and energy usage and costs really matters. (Yori, Designer and Renewable and Sustainable Energy major)

Among the STEM teachers, the only system of environmental structures that was exclusively identified by that group was the macrosystem. This layer is cultural and includes political, social, and economic systems as cultural structures with profound influence of the environmental structures that affect every community, family and individual. The ways that culturally embedded norms are experienced can connect one experience to another. For example, two STEM teachers identified a culturally embedded experience of STEM in their own youth as important. While these teachers have different backgrounds and come from different communities the role of racial and gender norms around STEM influenced their access.

> Even those who are interested in [STEM] like when they get into those spaces. I feel like the spaces themselves, are, a bit intimidating. I'll speak for myself; I remember being the only Latina in my lab classes. Sometimes that in itself is pretty intimidating to continue. (Anna, Computer Science Teacher)

> There were certainly no women in STEM I had to look up to let alone Women of Color. I come from a Filipino family, and, like there are nurses everywhere but that's not a physics career and so from a personal perspective. That's why my interest is bringing that to the school.
> (Angela, Languages and STEM Teacher)

Both reflections relate to the microsystem as well. They are tied to environmental structures that directly influence an individual. But equitable access to STEM among minoritized racial and gender groups is not a local issue, it is a cultural one.

Conclusions

The perceptions of these two groups of stakeholders provide insight into the environmental affordances and contextual influences that might relate to behaviors among potential future STEM professionals [5]. Affordances imply supports and this study illustrates examples of affordances situated through the lens of EST, but also illuminates barriers both as they are perceived by these two groups of stakeholders but also as they may be created by these groups [1]. That the designers perceived more ease around the development of opportunities for inclusivity but less value of practices like helping students connect STEM to the real world suggest a potential barrier between the curriculum as it is developed and the teachers who are responsible for implementing it. The implications of the present study are a narrowed focus for future research. Curriculum dissonance, such as this implies, describes a conflict of values between the curriculum and the implementers which can have consequences for learners and STEM access. In many ways, however, the environmental affordances described in these findings acknowledge how important the role of the teacher and curriculum are in creating opportunities in STEM. Explorations of how dialogue between teachers and curriculum designers might influence the efficacy of STEM curriculum to promote opportunities in STEM is one means of furthering research as a result of these findings.

References

[1] D.L. Blustein, "A critical exploration of assumptions underlying STEM career development," *Journal of Career Development,* 49, 2, pp. 471-487, 2022.

[2] U. Bronfenbrenner, “Ecological systems theory,” in Encyclopedia of Psychology, Volume 3. A. E. Kazdin Ed., Washington, D.C., USA: Oxford University Press, 2000, pp. 129–133.

[3] R.A. Brown, "Curriculum consonance and dissonance in technology education classrooms," *Journal of Technology Education,* 20, 2, pp. 8-22, Spring, 2008.

[4] D. Cheung & P.H. Ng, “Science teachers' beliefs about curriculum design,” *Research in Science Education,* 30, pp. 357–375, 2000, doi.org/10.1007/BF02461556.

[5] N. Darling, “Ecological systems theory: The person in the center of the circles,” *Research in human development*, 4, 3-4, pp. 203-217, 2007.

[6] C. Sneider, & G.G. Noam, "The Common Instrument Suite: A means for assessing student attitudes in STEM classrooms and out-of-school environments." *Connected Science Learning,* 11, 2019. [Online]. Available: https://www.nsta.org/connected-science-learning/connected-science-learning-july-september-2019/common-instrument-suite.