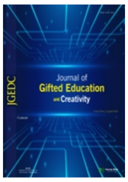

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Research Article

Young gifted students' STEM learning experiences: A bioecological systems view

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Abstract

Using Bronfenbrenner's bioecological systems theory, this concurrent mixed-methods study investigated the learning experiences of gifted students in a STEM enrichment program. Survey data were collected from students (n=530). Participants rated the enrichment program as highly supportive of STEM learning interests with appropriate challenges. The MANOVA results indicated no significant difference existed in students' perceptions of their courses. Analyses of parent surveys (n=196) and semi-structured teacher interviews (n=3) revealed that inviting learning environments, intellectual and socioemotional stimulation, responsive curricula and instruction, interest, and motivation in STEM prominently influenced students' learning experiences. The study concludes with implications for gifted education in STEM.

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Introduction

STEM education is at the forefront of current educational practices (English, 2016). STEM education integration is appropriate in early childhood education (Tippett & Milford, 2017), as children's early competencies are the cornerstone to developing proficiency in STEM (Mantzicopoulos et al., 2019). To plant STEM seeds, Common Core State Standards in Mathematics (CCSSM, 2010) and Next Generation Science Standards (NGSS, 2011) call for high-quality, early exposure to STEM. Introducing STEM during early childhood not only prepares young children with higher-order thinking skills for future success (Dubosarsky et al., 2018), but simultaneously debunks STEM stereotypes (Brophy et al., 2008) and closes early achievement and readiness gaps among students in STEM (Clasessens et al., 2009). To gain

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perspectives from several stakeholders in early childhood, this study invited input from students, parents, and teachers; multiple perspectives shaped this study to examine gifted students' learning experiences in a STEM enrichment program.

Literature Review

Theoretical Framework

The nature of talent development lies in the interactions of a developing person's multilevel and multidimensional environmental structures. Bronfenbrenner's (1994, 1995, 1999; Bronfenbrenner & Ceci, 1994) bioecological systems theory illuminated the contextual influences on a developing person's experiences and evolving attitudes. Bronfenbrenner posited that children and a series of environmental systems were mutually influential or progressively interacted with and accommodated each other. The enduring forms of interactions are called the *proximal process,* which produces complex and reciprocal effects on the developing person. The power of proximal process differential effects depending on the magnitude of joint function between the environmental contexts and characteristics of the developing person. To further deconstruct the definition and influence of environment, Bronfenbrenner divided an individual's environment into six ecological systems: developing person, microsystems, mesosystems, exosystems, macrosystems, and chronosystems.

In this study, the *developing person* at the center of bioecological systems theory refers to children with giftedness in STEM. Gifted children' personalities, aptitudes, and intensities of gifted children shape how they experience learning (Breedlove, 2021). Structures in *microsystems* include family, school, and community environments, and children's relationships with microsystems produce bi-directional influence. For example, playing with like-minded peers is suitable for gifted children's cognitive and socioemotional development (Riley & White, 2016). *Mesosystems* comprise the interactions of different microsystems; for instance, parental engagement in schools promotes the quality of programming and services to fulfill children's educational needs (Goodall & Montgomery, 2014; Matthews & Jolly, 2018).

Exosystems affect children's lives through extended families, neighborhoods/communities, school boards, and social media. For example, mass media's persistent depiction of intellectually gifted students as problematic or unpopular (e.g., mad geniuses, nerds, people who lack social skills) may lead to stigmatization of gifted students who consequently hide their giftedness to conform to social norms (Bergold et al., 2020). *Macrosystems* encompass the social and cultural values which indirectly influence children's beliefs and perceptions. For example, children whose indigenous knowledge is inconsistent with Western norms may undergo painful cognitive and psychosocial conflicts, which may lead to severe cultural disputes within their families (Chowdhury, 2016). *Chronosystems* refer to significant changes over an individual's life course, such as physiological changes, family loss, or economic crisis. For instance, the recent elimination of gifted education programs for children in New York and Seattle (Elsen-Rooney, 2020; Furfarro & Bazzaz, 2019) may deprive economically disadvantaged gifted children from accessible and advanced learning opportunities.

Ecological systems theory provides a holistic picture of the dynamic nature of children's development and offers insight into early childhood education. The talent development of gifted children in STEM requires the confluences of environmental catalysts from deliberate practices in and outside of schools.

STEM Education for Young Students

At the center of bioecological systems, young children are capable of learning advanced STEM at a developmentally informed level. Young children are born with innate talents in STEM, such as iterative thinking (Moore et al., 2018) and the natural tendency to observe (Eshach & Fried, 2005). In addition, young children instinctively think like scientists and engineers (Brophy et al., 2008; Tippett & Milford, 2017); they have natural intellectual dispositions, including a tendency to make sense of surroundings through analyzing, hypothesizing, and predicting (Katz, 2010), curiosity, creativity, and interest in STEM (Banko et al., 2013).

In microsystems of children, high-quality early childhood STEM education is critical. Early exposure to STEM can facilitate young children's understanding of the structure of the world (French, 2004) and develop scientific and engineering thinking (Eshach & Fried, 2005). Integrated STEM education provides students with independent and intuitive thinking abilities through engineering design and thinking (Bryan et al., 2016). For example, Tippett and Milford (2017) studied 14 pre-kindergarteners' learning experiences in STEM activities using a design-based approach. They found that students understood developmentally appropriate and relevant STEM concepts through discussion, and students were enthusiastic about learning STEM and sharing ideas. In addition, Wan et al. (2020) found that early childhood STEM education with programming robots, traditional engineering design, digital games, and integrated approaches significantly affected young children's knowledge, skills, and positive attitudes toward STEM.

As two other essential components in the microsystem, teachers and parents are pivotal gatekeepers for early STEM education. Teachers' confidence in teaching STEM, STEM knowledge mastery, pedagogy for child development, and STEM instruction influenced their eagerness and readiness to involve students in rich STEM learning (McClure et al., 2017). Nevertheless, challenges of teaching STEM in early childhood education persist. Wan et al. (2020) summarized the challenges in *exosystems*, which included limited time and resources, difficulty in catering to students' diverse needs, variable readiness in STEM, and insufficient professional development support. Moreover, parents' beliefs that STEM is for older children and boys, and their lack of confidence in supporting STEM learning also limits young children's STEM learning opportunities (Jackson & King, 2016). Therefore, the affordance of out-of-school enrichment programs provide alternative venues for young students to engage in high-quality STEM learning.

Influences of STEM Enrichment Programs

Several studies (e.g., Allen et al., 2019) have already examined the effects of university-based out of school STEM enrichment programs for K-12 students. These programs were characterized by a collaborative learning environment, STEM identity development, open-ended tasks, play (Mun & Hertzog, 2018), academically challenging course work, social support from peers (Olszewski-Kubilius & Lee, 2004), and appropriate learning challenges (Tay et al., 2018).

The influences of these programs were primarily measured from academic achievement and socio-emotional development perspectives (Kim, 2016). Chittum et al. (2017) found that K-7 students who participated in rural afterschool STEM programs reported that their motivational beliefs in science (e.g., perceptions of attainment, interest, utility values) sustained over time, which also were significantly different from non-participants. Zahidi et al. (2021) examined a science camp where comprehensive STEM modules were embedded with creative and experimental activities; results revealed statistically and significantly enhanced STEM knowledge among preschoolers. Researchers also found an increase in academic achievement after attending STEM enrichment programs (Golle et al., 2018; Yu et al., 2020).

Problem of Study

Recent studies on the effect of enrichment programs have focused on programs for upper grades (Gr.3-12), using pre-post and quasi-experimental designs (e.g., Cappelli et al., 2019; Gubbels et al., 2014; Sastre-Riba, 2013; Shi et al., 2013). For example, Cappelli et al. (2019) found a statistically significant increase in confidence and positive attitudes toward STEM for students in grades 7-12, but fewer significant changes for students in grades 3-6 after analyzing 15 university-based K-12 summer STEM programs. Related studies using mixed-method approaches only focused on the single perspective of students in upper grades (e.g., Mun & Hertzog, 2018; Wu et al., 2019), and few studies have incorporated parents' perspectives into program evaluation (e.g., Tay et al., 2018; Zahidi et al., 2021). However, a systematic understanding of how STEM enrichment programs contribute to young children's learning remains underexplored. Therefore, the effects of STEM enrichment programs for young children need to be further examined to provide deeper insight into students' STEM learning experience. To address the gap, this study investigated prekindergarten to grade 2 students' STEM learning experiences from the perspectives of students, parents, and teachers using a partially mixed concurrent equal status design study (Leech & Onwuegbuzie, 2009). The following research questions guided this study:

- To what degree do young students find their STEM classes interesting and challenging?
- What differences, if any, exist among students' perceptions of their STEM learning experiences across different classes?
- How do parents perceive the influence of STEM classes on their children?
- How do teachers describe providing quality STEM learning experiences for students?

Method

We used a partially mixed concurrent equal status design based on the nature of level of data mixing, time orientation, and emphasis of approaches in this study (Leech & Onwuegbuzie, 2009). The quantitative and qualitative data were analyzed separately until mixing and integrating the results to compare and draw inferences. Both the quantitative and qualitative phases of data collection and analysis occurred at the same time. Equal emphasis was given with respect to addressing the research questions, because the purpose of this study is triangulation. Such design is particularly appropriate in studies of program evaluation (Creswell & Clark, 2017).

Participants

Setting

Super Summer is a university-based enrichment program growing out of a research-intensive university in the Midwest United States where children with gifts in kindergarten(K) through grade 4 attend interdisciplinary courses in STEM, art, and social studies. They are involved with advanced content and open-ended projects that require higher-order thinking skills. All Super Summer program courses are designed to be at least two grade levels above students' current school grade to challenge academically, creatively, and artistically talented youth. The program is a one-week, full-day program with small class sizes ranging from 9 to 13 students.

The Super Summer program provides enrichment curricula to teachers. There are two sets of curricula that rotate every two years, though teachers sometimes modify the curricula based on the needs of students in each class. This study will focus only on STEM-based courses. The descriptions of selected courses are presented in Table 1.

Table 1. STEM courses information

Grade	Course	Course description	Disciplines covered
K	Terrestrial Science Explorers	This course introduces students to what scientists do and the main branches of science.	Physics, biology, chemistry, earth science
	Extraterrestrial Science Explores	This course takes the students on a journey into outer space, exploring astronomy in depth.	Physics, biology, chemistry, earth science, space science.
	Discovery through Experimentation	This course introduces diverse concepts and principles including natural energy, weather, plants/animals, and physics as they take an imaginary journey around the world.	Earth science, physics, biology, math
	Discovery through Engineering	This course uncovers the secrets of bubbles through experimenting with many different materials that can be used to make bubble wands.	Chemistry, physics, math, technology
Gr.1-2	Nature's Puzzle	This course helps students acquire knowledge of geography, biology, and chemistry, and encourages them to use inquiry skills to observe, gather evidence, analyze data, and make inferences about nature.	Topography, biology, chemistry, ecology

Respondents Information

The 2020 Super Summer program was canceled due to COVID-19. Thus, this study focused on the learning experiences of children with giftedness in STEM from 2014 to 2019. Five hundred and forty-two kindergarten to grade 2 students participated in the five STEM courses from 2014 to 2019, with 44% female students and 56% male students. The racial distribution was as: 53% of White, 30% of Asian, 6% of Asian American, 5% of Multi-racial, 2% of Hispanic, 2% of African American, and 2% of other. Five hundred and thirty surveys with valid and complete data comprised the final sample, which represented a student response rate of 98%. One hundred and ninety-six surveys from parents' survey data were collected, with a response rate of about 37%. Three out of nineteen Super Summer teachers participated into the interview. Table 2 includes the demographic information of the three teachers.

Table 2. Demographics of teachers

Pseudonym	Race	Gender	Years of Teaching	Class taught	Obtained Degree
Sarah	White	Female	4	Discovery through Experimentation & Engineering	Bachelor in elementary education
Alice	Asian	Female	6	Nature's Puzzle	Master in gifted education
Mary	White	Female	15	Terrestrial & Extraterrestrial Science Explorers	Master in gifted education

Note. Years of Teaching = years of teaching students with gifts and talents in this program.

Data Collection

Student Survey

On the last day of the Super Summer program, all students completed a paper and pencil evaluation form. The student evaluation form contained eight items to evaluate students' learning experiences across dimensions of interest and challenge. An example item is, "*In this class, we did many interesting activities*", "*I worked hard in this class.*" Survey item responses offered five different emojis to represent how well each statement reflected a student's perception; emojis represented *Yes, Probably, I do not know, Probably not,* and *No*. With explicit explanations for each emoji provided by Super Summer staff, students were given 20 minutes to complete the survey independently without the presence of teachers. Staff members were reminded to not direct students' decisions, and identifiable student information was not collected.

Parent Survey

Parent feedback was also collected as part of the Super Summer program evaluations at the end of every program year. All parents were encouraged to complete the parent survey (see appendix) voluntarily, and no identifiable parent information was collected. Since this study was interested in parents' perceptions of their students' learning experiences in STEM courses, only the data from items 1-11 and four open-ended questions (i.e. items 18-21) were analyzed in this study.

Teacher Interviews

To investigate teachers' perceptions of students' learning experiences, a participant recruitment email was sent to all teachers of Super Summer program from 2016 to 2019. Three Super Summer teachers who responded to the email participated into the semi-structured individual interviews which were conducted via Zoom and lasted between 30-45 minutes. The interview questions addressed teachers' perceptions about students' interests and motivations, as well as solicited advice for supporting students' learning in STEM.

Data Analyses

Quantitative Analysis

First, we performed an exploratory factor analysis (EFA) using SPSS Statistics 26 to identify factors that underlie students' perceived learning experiences (e.g., *Interest* and *Challenge*) with student survey data from non-STEM Super Summer courses during 2014 and 2019 (n = 524). Following EFA, confirmatory factor analysis (CFA) was conducted using AMOS 21 to verify the hypothesized factor model with student survey data from STEM courses in the same years (n = 530). The CFA model was estimated using full information maximum likelihood. To evaluate the fit of all models in this study, multiple goodness of fit indices was used, including model χ^2 test, Tucker-Lewis index (TLI; Hu & Bentler, 1999), comparative fit index (CFI; Hu & Bentler, 1999)[4], root mean square error of approximation (RMSEA; Marsh et

[4] TLI and CFI compare the target model to the fit of an independent model, of which values greater than .90 indicate good model fit (Hu & Bentler, 1999).

al., 2004)[5], and Bayesian information criterion (BIC; Schwarz, 1978)[6]. Next, the one-way multivariate analysis of variance (MANOVA) was conducted using SPSS Statistics 26 to determine any differences among students' perceptions of five independent STEM classes.

Qualitative Analysis

We uploaded all the qualitative data from the teacher interviews and parents' open-ended survey questions to Nvivo 12. Following Saldaña's (2015) process of data coding of we began our qualitative analysis.

For the first cycle of analysis, Author 1 coded independently and employed elemental and effective methods, which included an open coding process. Using the elemental method, initial coding helped the coders reflect upon the content and grasp the nuances of the data (Saldaña, 2015). Using the effective method, emotion and value codes which captured participants' feelings, values, and beliefs provided deep insights into participants' interpersonal and intrapersonal experiences (Saldaña, 2015). Integrating the initial codes, emotion codes, and value codes to the existing literature on STEM education, first-cycle open codes were developed to describe participants' discrete experiences.

In the second coding cycle, we used code landscaping to map the networks of codes and synthesize and clarify thoughts. Dey (2003) contended that diagrams disentangle the threads of our analysis. Then, open coding and axial coding were applied to categorize the codes; similar codes produced through the first and second coding cycles were clustered. From there, Author 1 and Author 4 examined all open codes to generate tentative categories and subcategories, emphasizing responses to the research questions. Since axial coding extends the analytic work from open coding to produce clear and concise insights, we compared the open codes to form axial codes by reducing redundancies (Boeije, 2009).

Lastly, after the second coding cycle, axial codes were reviewed to yield final selective codes. The first and second cycle codes were weaved into sentences with different variations. All authors worked together to examine the conceptual coherence in each narrative of potential selective codes and compare the differences within each code. Final selective codes were generated when consensus among authors was reached.

Ensuring Trustworthiness

Positionality

Author 1 was staff member in the Super Summer programs. This author had five years of experience in working with young gifted students, but neither author participated in data collection. Author 1 was a program coordinator from 2020 to 2021, but she did not work with any of the study participants between 2014 and 2019. Collectively the authors' experiences with students, parents, and teachers in the Super Summer programs enriched their understanding of students' learning experience in STEM-based classes.

Addressing Coding Bias

Before data analysis, Author 1 read through the interview transcriptions and wrote analytical memos to describe initial personal reflections about how she related to the participants and phenomena. The analytical memos served to sympathize and empathize (Saldaña, 2015) with the participants' descriptions. Additional strategies were also employed, such as records of the data analysis process, rationales of decisions and choices regarding selecting codes, reflexive journals, a clear audit trail, and member checking.

Results

Quantitative Results

EFA and CFA Results

To explore the factor structure of the student survey, data from the non-STEM kindergarten to grade 2 Super Summer courses were analyzed first. All eight survey items were subjected to an EFA with oblique rotation as the extraction

[5] RMSEA tells how well the model fits the populations' covariance matrix. Values of less than .05 are considered excellent, whereas values ranging between .05 and .08 indicate good model fit (Marsh et al., 2004).

[6] The Bayesian information criterion (BIC; Schwarz, 1978) selects a model based on the likelihood function. Among a finite set of models, the model with the lowest BIC is preferred.

method. The interitem correlation coefficients among all items ranged from .227 to .580, and all were significant at 0.001 level, indicating significant small to moderate positive correlations among items. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .863, above the recommended threshold of 0.5 (Williams et al., 2010). Bartlett's test of sphericity was significant ($\chi^2(28)$ =1050.486, p <.001) and verified substantial correlation among the data. Using Kaiser's criterion of eigenvalues greater than 1 (Field, 2009), the maximum likelihood factor analysis yielded a one-factor solution (explained 46.86% of the variance) and a two-factor solution (explained 55.42% of the variance). Table 3 contains the pattern matrix factor loadings of each item on each factor of the two-factor solution. Seven out of eight items revealed a factor loading greater than .40 cutoff on at least one factor. Results suggested that items 2, 5, 6 and 8 mainly loaded on factor 1, and items 3, 4, and 7 mainly loaded on factor 2. Factors 1 and 2 were moderately correlated, r=.619. Factor 1 seemed to measure students' interest in the classes (e.g., item 2, "In this class, we did many interesting activities"), while factor 2 seemed to measure how challenging the classes were for the students (e.g., item 4, "I worked hard in this class"). Although item 1 was loaded on both factors saliently at the cutoff score of .03, item 1 seemed consistent with the theoretical structure of factor 1. Thus, the two-factor model was preferred with factor 1 (items 1,2,5,6,8) and factor 2 (items 3,4,7).

CFA could indicate whether our choice of the two-factor model fits better with the data of STEM courses than the one-factor model. Descriptive statistics of all items for CFA are included in Table 4. The two-factor model was tested using maximum likelihood as the estimator. Factor loadings of the two-factor model are presented in Table 5. Results indicated support for a two-factor model with good data fit: $\chi^2(19)$ =72.996, p <.001, TLI=0.937, CFI=0.970, RMSEA = .073, BIC=179.635. The standardized correlation between the two factors was moderate (r =.75). Factor 1, *interest*[7], contained items 1, 2, 5, 6 and 8. Factor 2, *challenge*[8], included items 3, 4, and 7. The Cronbach's α for the *Interest* and *Challenge* subscales were .810 and .655, respectively, which indicated good and moderate internal consistency estimates for the sample data.

Table 3. EFA factor loading results

Item	Factor 1	Factor 2
Item 1	.310	.306
Item 2	**.680**	-.093
Item 3	-.089	**.605**
Item 4	.102	**.413**
Item 5	**.493**	.276
Item 6	**.766**	-.020
Item 7	.180	**.481**
Item 8	**.531**	.165

Note. Bold values indicate factor loadings >.40

Table 4. Item descriptive statistics for CFA

Item	M	SD	Skew	Kurtosis	Observed Range
Item 1	4.48	.98	-1.96	3.22	1-5
Item 2	4.63	.77	-2.44	6.39	1-5
Item 3	4.63	.80	-2.30	4.94	1-5
Item 4	4.62	.85	-2.56	6.40	1-5
Item 5	4.55	.92	-2.15	4.12	1-5
Item 6	4.54	.89	-2.03	3.55	1-5
Item 7	4.41	1.08	-1.85	2.51	1-5
Item 8	4.70	.81	-3.07	9.36	1-5

Note. n=530 for STEM courses. The ratings are on a scale from 1 to 5.

[7] According to Gentry and Owen (2001), interest is defined as "reflects positive feelings/preference for certain topics, subject areas, or activities" (p.4).
[8] Challenge is described as "engages the student and requires extra effort" (Gentry & Owen, 2001, p.4).

Table 5. Factor loadings of two-factor model

Factor	Item	Factor Loading
Interest	1. I want to learn more about the things taught in this class.	.59
	2. In this class, we did many interesting activities.	.69
	5. I like what I learned in this class.	.74
	6. My teacher made this class interesting.	.68
	8. I had fun in this class.	.70
Challenge	3. I was able to do the work in this class.	.64
	4. I worked hard in this class.	.60
	7. My teacher explained hard lessons so I could understand them.	.66

Note. n=530. All factor loadings were standardized and significant at $p < .001$.

Students Survey Results

Young students' perceptions of learning experiences in STEM-based classes are reported in Table 6. The mean *Interest* subscale scores for the five classes ranged from 4.53 (*SD* =.68) to 4.66 (*SD* =.61), which showed that students with giftedness in STEM found the STEM classes interesting. As for *Challenge* subscale, the mean scores ranged from 4.49 (*SD* =.71) to 4.62 (*SD* =.62), which suggested students were challenged in the classes. Overall, students expressed positive perceptions about their learning experiences in the STEM classes.

Table 6. Student perceptions of classroom quality by class

Course	N	Interest	Challenge
		M (SD)	*M (SD)*
Terrestrial Science Explorers	116	4.58 (.64)	4.62 (.62)
Extraterrestrial Science Explorers	104	4.66 (.61)	4.62 (.66)
Discovery through Experimentation	80	4.55 (.74)	4.51 (.80)
Discovery through Engineering	78	4.60 (.74)	4.53 (.77)
Nature's Puzzle	152	4.53 (.68)	4.49 (.71)

Note. The ratings are on a scale from 1 to 5.

One-way MANOVA was conducted to determine whether there were significant differences between *Interest* and *Challenge* among students' perceptions of five different STEM classes. The multivariate normality assumption was violated; moreover, univariate outliers were detected. However, the samples in each dependent × independent variable combination were more than 30, which indicated an adequate sample for multivariate analysis, then, the Multivariate Central Limit Theorem held. MANOVA is not very sensitive to violations of multivariate normality, provided there are not many outliers. The Box M of 18.795 indicated the homogeneity of covariance matrices across groups was assumed ($F(12, 1138131.86) = 1.552, p = .098$). Results showed no significant differences in students' perceptions of interest and challenge based on courses, $F(8, 1048) = .672, p = 0.716$; Wilk's $\Lambda = 0.99$, partial $\eta^2 = .005$.

Parent Survey Results

To triangulate students' perceptions of their learning experiences in STEM classes, parents' evaluation survey beliefs were also examined. Cronbach's α for the scale was estimated as 0.90 for these data, and the descriptive results are presented in Table 7. Parents' responses to all the items, except item 9, showed a mean score ranging from 3.98 (*SD* =0.82) to 4.82 (*SD* =0.39). This result demonstrated that from the parents' perspectives, children benefited from making new friends, knowledge enrichment, enhanced motivation for learning, and receiving timely help from teachers. Item 9 asked whether parents thought children were appropriately challenged in class. The mean of parents' response to item 9 varied from 3.56 (*SD* =1.09) to 4.06 (*SD* =0.92), which indicated that parents believed the STEM classes were not challenging enough for their children.

Table 7. Parents' responses to parent evaluation survey

Item	Terrestrial Science Explorers *M* (*SD*)	Extraterrestrial Science Explorers *M* (*SD*)	Discovery through Experimentation *M* (*SD*)	Discovery through Engineering *M* (*SD*)	Nature's Puzzle *M*(*SD*)
1.My child's teacher was available to help if he/she had a problem.	4.37 (0.73)	4.67 (0.47)	4.41 (0.84)	4.37 (0.96)	4.65 (0.62)
2.My child's teacher kept us informed of procedures and activities.	4.32 (1.06)	4.64 (0.75)	4.60 (0.80)	4.10 (1.18)	4.63 (0.60)
3. My child liked the teacher.	4.70 (0.51)	**4.82 (0.39)**	4.67 (0.62)	4.57 (0.86)	4.81 (0.53)
4.Making new friends was one of the best parts of this program for my child.	4.20 (0.81)	**3.98 (0.82)**	4.19 (0.83)	4.03 (1.03)	4.02 (1.00)
5.My child enjoyed his/her peers in this program.	4.27 (0.71)	4.48 (0.61)	4.56 (0.58)	4.43 (0.86)	4.52 (0.67)
6. My child was enthusiastic about his/her class.	4.56 (0.57)	4.74 (0.56)	4.59 (0.69)	4.47 (0.94)	4.67 (0.73)
7.My child would like to return.	4.69 (0.81)	4.72 (0.54)	4.70 (0.86)	4.57 (0.86)	4.67 (0.86)
8.My child learned a lot in the class.	4.68 (0.95)	4.32 (0.71)	4.52 (0.64)	4.47 (0.86)	4.62 (0.66)
9.The class my child attended was challenging for him/her.	3.80 (1.01)	**3.56 (1.09)**	3.67 (1.18)	3.77 (1.28)	**4.06 (0.92)**
10.My child was motivated to learn in his/her class.	4.33 (0.73)	4.50 (0.58)	4.48 (0.70)	4.43 (0.90)	4.63 (0.60)
11. I am satisfied with my child's accomplishments in this class.	4.39 (0.70)	4.52 (0.61)	4.41 (0.80)	4.37 (0.96)	4.69 (0.65)

Note. The ratings were on a scale from 1 to 5. n=196.

Qualitative Results

Qualitative results from the parent survey and teacher interviews are presented in Table 8, including frequency counts for each axial code.

Results of Open-ended Questions in Parents Survey

Parent (n=196) responded to four open-ended survey questions which asked about their perceptions of the short-term benefits, drawbacks, classes or topics they would like to see offered in the future, and the single most memorable moment their child(ren) experienced in the Super Summer program. The data analysis of open-ended questions yielded three major themes.

Theme 1: Inviting Learning Environment

Inviting learning environment referred to the STEM classroom learning environment where students with giftedness in STEM were invited into a learner-centered environment filled with enjoyable learning opportunities. In a psychologically safe learning environment, students had opportunities to engage in meaningful interactions with knowledgeable peers from diverse backgrounds. Students' individual needs were addressed, and they were engaged in joyful extended learning throughout the summer.

Table 8. Examples of open, axial, and selective codes and frequency

	Examples of open codes	Axial codes	Selective codes	**N.Res**	**N.Ref**
Parent survey (*n*=196)	Environment with well-behaved classmates; diverse environment with new students/teachers; interact with like-minded students.	Learner-centered environment	Inviting learning Environment	41	43
	Overall enjoyment; out of school enrichment.	Continuous and enjoyable learning opportunity in summer		23	24
	Exposure to accelerated advance concepts; do complex hands-on scientific experiments	Deep diving into advanced STEM activities	Intellectual stimulation	73	99
	Creative thinking; critical thinking.	Higher order thinking skills development		14	18
	Enjoy challenge; excitement for learning; interest in math and science; aspiration for science and math	Increased motivation and interest in science and math	Socioemotion al stimulation	33	54
	Confidence; respect; kindness; communication skill; collaboration skill; take up challenge.	Psychosocial skills development		31	50
Teacher intervie ws (*n*=3)	Various topics relating to real-life world; advanced content beyond schools; a series of hands-on experiments; integration of different disciplines' knowledge.	Well-structured learning content	Responsive curriculum and instruction	3	7
	Search more complicated activities; give students choices to do activities; expand on activities; plenty time to do tasks	Differentiated teaching		3	4
	Opportunity to make new friends; learn to cope with failures and perfectionism; socialize in activities.	Socioemotional teaching		3	5
	Come with broad knowledge in STEM; like to solve problems	Prior knowledge in STEM	Prior experience with STEM	3	5
	Strongly motivated; be curious in nature; have deep interest.	Prior motivation & interest in STEM		3	3

Note. No. of respondents = number of parents or teachers supporting the axial code; No. of references = number of references for the axial code **N.Res**: No. of respondents **N. Ref**: No. of references

Learner-Centered Environment. Forty-one parents with 43 references described the STEM-based course learning environments as engaging and inviting for their children to learn with like-minded and well-behaved peers in a culturally diverse environment. Parents observed that their children made new intellectual friends and enjoyed interactions with various children. Supporting comments included, "[My child is] enjoying every day going to the program meeting friends and teacher" (P12, June 2014). Parents also commented that their children deeply explored STEM knowledge with peers who shared similar interests and enjoyed learning. For example, parents commented, "She was delighted to learn in an environment with well-behaved classmates" (P2, June 2014) and "She enjoyed being in a part of the program where other children enjoyed learning as well" (P170, June 2019). Parents also indicated that teachers demonstrated individual interest in students and were responsive to their instructional needs. The parent of a child who had immigrated to the United States two months prior described that her child "seem[ed] to appreciate the 'open conversation' dynamic in the classroom," and she appreciated "great teaching-enthusiasm for the children's interest" (P172, June 2019).

Continuous and Enjoyable Learning Opportunities. Twenty-three parents expressed that Super Summer program provided opportunities for their children to stay active and engage in summer. Parents also noted that they were glad to see children progress academically and use time productively throughout the summer. Comments such as "reinforcing a school-type environment" (P15, June 2014) and "stimulation during summer break" (P76, June 2018) demonstrated that parents perceived Super Summer STEM learning was valuable for sustaining children's academic engagement.

Theme 2: Intellectual Stimulation

Intellectual stimulation referred to the cognitive challenges and enrichment that students with giftedness in STEM received from the program. Students engaged in various STEM activities designed to solidify and deepen their scientific knowledge; these activities also honed students' hands-on skills. The advanced STEM activities encouraged students' creative and inquiry capacities, which enabled students to identify and solve problems creatively.

Deep Diving into Advanced STEM Activities. Seventy-three parents made 99 references that described how the Super Summer program provided opportunities for their children to engage in complex hands-on and minds-on scientific experiments. Comments included, "[The program provided] access to learning about the engineering design process, creating/building" (P93, June 2017). Parents were also glad to see children exposed to advanced STEM knowledge and noted that their children were able to "explore wide new knowledge" (P112, June 2017), "learn about various topics in science" (P159, June 2019), and have "exposure to subjects and details beyond her normal classroom" (P127, June 2017). Parents also reported that children started to understand science concepts beyond the regular classrooms, develop essential awareness of science segments, acquire fundamental scientific and engineering methods, and be less intimidated by science. Examples of parents' responses included, "she loved the exposure to new concepts versus her regular classroom" (P117, June 2017) and "[The program] let my child understand how fun science is" (P80, June 2017).

Higher-Order Thinking Skills Development. Fourteen parents reported that their children benefited from learning more advanced thinking skills, such as creative thinking in problem solving. One parent wrote that the classes provided his child with chances "to solve a problem creatively" (P111, June 2017), which was echoed by the comment, "expanded her imagination and creativities" (P94, June 2017). Also, the program's emphasis on scientific practices of inquiry and discovery improved students' abilities to think, as evidenced by a comment, "Her thought process has been improved" (P72, June 2017).

Theme 3: Socioemotional Stimulation

Socioemotional learning is a critical component to meet affective needs of students with giftedness in STEM. Students developed psychosocial skills, such as confidence and interpersonal and collaboration skills, which are important for talent development. In addition, students' motivation and interest in STEM increased.

Increased Motivation and Interest in STEM. Thirty-three parents indicated that their children's interests in science and math were elevated, as children enjoyed engaging in intellectual challenges, were excited about STEM activities, and ignited their aspiration for science and math learning. Illustrative comments from parents included "increased interest in experimenting and learning" (P85, June 2016), "being excited about new creations/activities, exploring different concepts, skills" (P141, June 2018), and "she has regained her excitement for learning" (P115, June 2017). With increased motivation and interest, students' behaviors toward learning also changed. One parent indicated, "She wanted to come to camp everyday instead of school" (P98, June 2017). One parent was surprised to see that her child always wanted to "be the first in the classroom in the morning" (P80, June 2017), explaining that this had never happened before.

Psychosocial Skills Development. Thirty-one parents commented that they observed social and emotional changes among their children, including boosts in their children's confidence. Representative comments included, "gained confidence through experiencing new, different routines and challenges" (P143, June 2018) and "Her confidence seems to improve and grow" (P172, June 2019). One parent appreciated that teachers helped his younger child realize his talents and encouraged him to be confident, particularly because her younger son felt overshadowed and intimidated by his elder brother's high abilities. Children enjoyed sharing their experiences with new friends and helping each other on classroom projects. Parents also reported that their children learned how to work collaboratively with peers through team activities. One exemplary comment stated, "[My child is] learning to be kind and helpful" (P84, June 2016). One parent commented that her child started to understand and apply the values promoted by the Super Summer program, such as "respect, teamwork, and kindness" (P124, June 2017). Another parent reported their child's enhanced curiosity, "I was happy that she started to be curious about things surrounding us, which we take for granted" (P139, June 2019). Children also developed empathy through solving real-world problems; a supporting quote stated, "She is concerned about the world and environment" (P118, June 2017). Moreover, six parents indicated that their children enthusiastically shared their camp experiences and the scientific knowledge they were learning in class. Seven parents also mentioned that their children began embracing challenges as a result of their experiences at camp.

Teacher Interview Results

Semi-structured interviews with former STEM teachers aimed to examine factors that contributed to students' learning experiences. In addition, the interviews aimed to provide a more comprehensive representation of students' learning by examining students' and parents' perceptions. The interviews yielded two significant themes, which are described in the following sections.

Theme 1: Responsive Curriculum and Instruction

As part of integrated STEM education, the curricula were designed to accommodate students' academic and socioemotional needs. The curricula consisted of several engaging and motivating contexts that resembled students' real-life experiences and provided platforms for real-world applications. Learning activities included rich opportunities for students to engage in engineering design and conduct scientific experiments which mimicked the work of engineers and scientists. Given that students entered the program with different interests and readiness, differentiated teaching was highly valued. Socioemotional teaching was also valued by teachers in the program.

Well-Structured Learning Content. Teachers commented that learning content was the driving force behind students' intrigue and motivation. They indicated that various STEM topics related to students' real life experiences ignited students' curiosity. Alice commented, "They are pleased they learn something that could be used in real-life situations" (individual interview, December 5, 2020). Students also had opportunities to learn about above-grade-level scientific concepts and conduct a series of hands-on and mind-on experiments. Mary described, "The hands-on is what is critical for keeping their attention and having a problem for them to solve and work on" (individual interview, December 10, 2020). Further, teachers explained that students were excited to experiment with materials that were not available at their schools.

Mary commented, "I think the idea of creating, having them share that worked well for that age group, as they all are very excited about what they did" (individual interview, December 10, 2020). The STEM classes heavily emphasized students' critical thinking and problem-solving skills, which provided students a psychologically safe environment to explore, express, and engage them in thinking like scientists and engineers. Moreover, the integration of interdisciplinary knowledge across STEM and arts engaged students. Sarah commented, "I think [the class] kind of pushed high ability students a little bit and created an atmosphere where they wanted to learn a little bit more. It is not like normal math and normal science, and it is specialized into something more fun" (individual interview, December 12, 2020).

Differentiated Teaching. All teachers described differentiated teaching strategies that they used to accommodate individual students' needs. Two teachers noted that they had spent too much time on content that highly advanced students had already mastered; as a result, the teachers reported coming to class with a broad multilevelti-level intellectual activities to enhance flexibility and engagement. Using this autonomy-supportive approach, students were given choices to participate in the same activities at different complexity levels. Teachers also ensured plenty of time for students to refine their projects with appropriate scaffolding and timely feedback. In addition, all teachers mentioned that in a physically and psychologically safe environment, students had opportunities to think outside the box, speak their minds, and explore freely.

Socioemotional Teaching. Students' socioemotional learning was embedded in academic aspects of the curriculum, as most of the learning projects required collaboration where students could make new friends through teachers' flexible groupings. Mary described the value of student collaboration when she stated, "Talent is being fostered by those discussions that they are having and those interactions with like-minded peers" (individual interview, December 10, 2020). Teachers also worked with students on their interpersonal skills to encourage positive team actions (e.g., carefully listening to each other, showing mutual respect, assuming responsibility for a team), and modeled strategies to help students cope with failures.

Theme 2: Prior Experience with STEM

At-home early childhood experiences among children with giftedness in STEM were a key contributing factor of students' success. Early exposure to STEM prepared young students intellectually and psychologically for increased learning challenges, and parents' deliberate cultivation of learners' curiosity played a pivotal role.

Prior Knowledge in STEM. Teachers indicated that students entered their classrooms with broad knowledge in STEM, which enhanced their engagement. Some children's parents were scientists who had exposed their children to scientific content during at-home discussions. This finding helped explain why some parents commented that their children should be increasingly challenged in the Super Summer program. Sarah explained, "It is a fine line in the sense that the country has become so set on pushing students to rote learning. I feel like Super Summer is geared to exactly developing that critical thinking, that problem solving, working together, those kinds of things, which far outweighs the content" (individual interview, December 12, 2020).

Prior Motivation and Interest in STEM. Teachers observed that from day one of the program, most students were strongly motivated and interested in learning. Students' prior motivations and interests in STEM psychologically prepared them for more advanced and complicated learning activities, as well as enhanced their curiosity. Moreover, students exhibited excitement to solve problems. Mary shared her observations with students on the first day, "I felt like they were motivated to solve problems, they were motivated to find out more, they wanted to delve deeper into things, and they were asking those deeper questions. I felt like the motivation was intrinsic" (individual interview, December 10, 2020). Family was also crucial to developing students' interest in STEM. Alice explained, "what their interests are is associated with what their parents do. They look up to their parents" (individual interview, December 5, 2020). Mary commented about how families of Super Summer students had prepared them for the program, "At home, students have been given more opportunities to be curious, so they have developed that it is okay to be curious, there is not necessarily a right answer...I think part of the interest, it comes from family exposure, but I think part of it just comes from them wanting to figure out puzzles, and that is what science is" (individual interview, December 10, 2020).

Discussion and Implications

This study examines the learning experiences of young children with giftedness in STEM in an enrichment program in the Midwest United States. The findings suggest that young students generally perceive the STEM courses as interesting and challenging, and there were no significant differences among students' perceptions of the five different courses. These findings align with previous studies which focused on the upper grades (Ghaderizefreh & Hoover, 2018; Miller & Gentry, 2010; Tippett & Milford, 2017; Vennix et al., 2018; Yu et al., 2020). Bronfenbrenner's ecological systems theory provides an in-depth framework for understanding young students' STEM learning experiences in broader contexts (Crawford et al., 2020).

Developing Person

Among developing children's emotional state and dispositional tendencies are defining properties that enable proximal processes to occur. Similar to previous findings (e.g., Vennix et al., 2018), results from this study suggest that young students with giftedness in STEM are intrinsically motivated and enthusiastic in STEM learning (Banko et al., 2013).

When provided opportunities to understand the nature of science (Stylianidou et al., 2018) and learn real-life applications of STEM (Vennix et al., 2018), young students are more likely to maintain inquisitive attitudes and intellectual curiosity in their areas of interest. Dabney et al. (2012) found that students' early participation in out-of-school activities contributed to their career interests and pursuit of STEM subjects in college. These early experiences and motivations improve young students' school readiness, concept acquisition (Toran et al., 2020), academic performance, and cognitive and socioemotional development (Gubbels et al., 2014) in the future.

Microsystem

To be developmentally effective, children's interactions with multidimensional environments should increase in cognitive complexity rather than be based on repetition. Students' interactions with like-minded knowledgeable peers, responsive teachers, supportive families, and high-quality STEM enrichment programs in their microsystems play an immediate and significant role in influencing their learning experiences.

Results of this study indicate that inviting learning environments and appropriately leveled intellectual STEM stimulations provide enjoyable and challenging learning experiences for students. When young students are interested and challenged in class, they demonstrate engagement and commitment to advanced STEM learning, a finding verified in prior studies (e.g., Brubacher & Silinda, 2019; Jensen & Sjaastad, 2013; Jungert et al., 2020). In the Super Summer program, teachers involve young students in authentic project-based learning, through which students engage in self-directed learning and see themselves as capable. Meanwhile, students' interactions with course components (e.g., advanced content, complex tasks, teachers), are not unidimensional but reciprocal. That is, students gradually become more motivated to take up challenges, initiate advanced activities, and persist with increasing interest levels and self-confidence (Litzler et al., 2014).

Another significant finding is socioemotional enrichment, which psychologically and socially prepare young students with giftedness in STEM for advanced STEM learning. Wilkerson and Haden (2014) suggested that evaluations of programs with short durations (<60 hours) should focus on affective rather than academic outcomes to align with the scope and expected reach of program. Findings show that young students' gifts could be fostered in active interactions with peers who share similar interests and readiness for cognitive challenges. Furthermore, peer cooperation, communication, and support significantly influence young students' individual values and attitudes (Gubbels et al., 2014).

Given that continuing stimulation through proximal process is beneficial for talent development, children's interactions with parents on a regular basis over extended periods of time exhibit significance. Findings also demonstrate that the intensity of parent-child interactions in STEM-related activities contributes to young students' early intrinsic motivation toward STEM (Jungert et al., 2020). This implies that apart from positively seeking STEM learning opportunities for their children, parents should also be providers of STEM-related experiences (Eccles et al., 1993).

Mesosystem

The mesosystem encompasses the dynamic interactions of the microsystem groups, which includes the inter-balance of teacher-parent, teacher-program, and parent-program interactions. According to our findings, building trustworthy cooperation among teachers, parents, and programs can enhance students' learning experiences and fulfill students' diverse educational needs (Chowkase, 2021; Goodall & Montgomery, 2014; Jolly & Matthews, 2018; Stylianidou et al., 2018). The Super Summer program's professional trainings help teachers develop their pedagogical and cultural competencies, support their effective interactions with students, and improve their design and implementation of creative and holistic teaching approaches (Stylianidou et al., 2018). The program also provides teachers with hands-on tools such as well-developed curricula, innovational teaching strategies, and other sources of educational materials. Collaborative and cooperative efforts among program coordinators, teachers, and parents produce appreciable quality in young students' STEM learning.

Exosystem and Macrosystem

The ecosystem and macrosystem consist of opportunity structures resulting from socioeconomic status, ethnicity, geographic location, and ideologies of culture. The proximal process exerts its greatest effects in more economically advantaged and stable environments, as well-educated families tend to ensure their children's access to various STEM enrichment learning opportunities outside of school. This aligns with previous studies in gifted education such as Grissom et al. (2019) who explained, "a student in the top SES quintile is more than six times more likely to receive gifted services than a student in the bottom quintile" (p. 1). Well-educated families have the capacity to respond to children's immediate physical and psychological needs, and parents' responsiveness to children's initiatives and consistency in parenting style promotes exploratory behaviors. In addition, a university-based community provides high-quality STEM learning resources, which increases young students' exposure to STEM and enriches their experiences in scientific explorations.

Limitations

This study has several limitations. First, the self-reported student survey completed by young students may lack insight into the complexity of their experiences and environmental factors of influence. However, studies have confirmed that young students can reliably and validly self-report their experiences when age-appropriate instruments are used (Varni et al., 2007). Although the student survey was short and succinct, from a measurement perspective, limitations of a ceiling effect and restriction of range occurred in this study when most students chose "strongly agree" or "agree". While it is possible that inaccuracies of measurement exist (Vogt, 2005), it is also possible that students enjoyed their enrichment courses which was reflected in the consistently high scores. The survey scale was also limited by only two constructs of interest and challenge. There are other constructs that influence students' perceptions of STEM learning in enrichment programs, such as motivation and learning autonomy, though they were not addressed in this study. Another concern is respondents' potential for social desirability bias, including students and parents, who tend to provide socially acceptable answers (Fisher et al., 2000). Furthermore, Super Summer program generally attracts academically and economically advantaged groups of students who perhaps have already received STEM enrichment at school and home. Further research should include how to recruit young students from culturally, economically, and linguistically diverse backgrounds. Finally, the results generated from this study's Super Summer enrichment program cannot be generalized to other enrichment programs, and transferability of its applicability to other sites, students, and institutions is left up to the reader.

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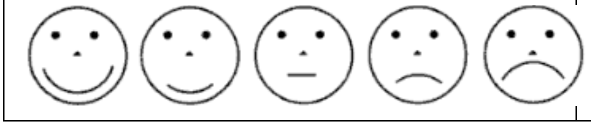
Appendix

Student Survey

Yes Probably I don't know Probably not No

Circle the face that best fits your answer:

	1. I want to learn more about the things taught in this class.
	2. In this class, we did many interesting activities.
	3. I was able to do the work in this class.
	4. I worked hard in this class.
	5. I like what I learned in this class.
	6. My teacher made this class interesting.
	7. My teacher explained hard lessons so I could understand them.
	8. I had fun in this class.

Parent Survey

Please rate how much you agree with each of the following items. Write the appropriate number in the space provided using the following scale:

1= Strongly Disagree **2**= Disagree **3**= Undecided **4**= Agree **5**= Strongly Agree

___ 1. My child's teacher was available to help if he/she had a problem.

___ 2. My child's teacher kept us informed of procedures and activities.

___ 3. My child liked the teacher.

___ 4. Making new friends was one of the best parts of this program for my child.

___ 5. My child enjoyed his/her peers in this program.

___ 6. My child was enthusiastic about his/her class.

___ 7. My child would like to return.

___ 8. My child learned a lot in the class.

_____9. The class my child attended was challenging for him/her.

___ 10. My child was motivated to learn in his/her class.

___ 11. I am satisfied with my child's accomplishments in this class.

___ 12. Information in the program brochure was clear.

___ 13. The acceptance packet was informative.

___ 14. Registration procedures were efficient.

___ 15. The online registration process was efficient (if applicable)

For the following two (2) questions, please circle your response.

16. Was your child in a gifted and talented program at his/her home school this past year? Yes No My kid's school does not have gifted programs

17. On average, how often does your child access the Internet from home?
No access Rarely Once a week Multiple Times a Week

Daily Multiple Times a Day

We appreciate your thoughtful answers to the following questions.

18. What has been the greatest short-term benefit to your child from your child's participation in this program?

19. What has been the greatest short-term drawback to your child from your child's participation in this program?

20. Are there other classes or topics you would like to see offered in future sessions of the program?

21. What was the single most memorable moment your child experienced in his/her class this session and explain why that experience was important to him/her.

Teacher Interview Protocol

1. When did you teach in our super summer program? How many times have you taught in Super Summer program? What courses have you taught?

2. What was the most memorable moment you experienced in your class? Why?

3. Do you think your class is challenging enough for some gifted and talented students?

4. Do you thinks students are motivated to learn? If so, in what ways?

5. Do you thinks students are interested to learn? If so, in what ways?

6. Do you think students in your class have enough opportunities to choose different tasks? Please give some examples.

7. From what aspects do you think Super Summer Program contribute to students' talent development in STEM?
8. From your perspective, what else could the Super Summer program do to improve their service for students' talent development in STEM?
9. Do you have anything important that you think we should know but wasn't covered in previous questions?