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# Developing eminence in STEMM: An interview study with talent development and STEMM experts

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## Abstract

In the present day, we need outstanding scientists, engineers, mathematicians, and medical science researchers more than ever to solve the world's most pressing issues, such as climate change, water contamination, and cyber security. Naturally, we ask the question: What does it take to develop eminence in science, technology, engineering, mathematics, and medical science (STEMM)? To answer this question, we interviewed two relevant groups of experts: 14 talent development researchers and 14 STEMM experts. The interview questions were developed based on the theoretical framework of the Actiotope Model of Giftedness and the related educational and learning capital approach that differentiates five types of exogenous resources (educational capital) and five types of endogenous resources (learning capital) that feed into talent development toward eminence. The results show that all types of capital were regarded as important by the experts for developing eminence in STEMM. However, there were also differences. We describe the educational and learning capital that talent development researchers and STEMM experts considered to be important for talent development in STEMM, as well as the similarities and differences between the two groups.

KEYWORDS
expert interview, qualitative research, STEMM education, talent development

## INTRODUCTION

Throughout history, scientists, engineers, and mathematicians have made great contributions to human living and thriving. Some even changed the trajectory of human history. Think about Edward Jenner, who pioneered the concept and practice of vaccines in 1796; the Wright brothers, who invented the first successful motor-operated airplane in 1903; Alan Turing, who formalized the concepts of algorithm and computation in the 1940s; and Longping Yuan, who developed the first hybrid rice varieties in the 1970s and boosted food supply in high-risk famine areas ever since.

We need excellent scientists, engineers, mathematicians, and medical science researchers more than ever to solve the world's most pressing issues, such as pandemics, climate change, water contamination, and cyber security. What does it take to develop excellence and eminence in science, technology, engineering, mathematics, and medical science (STEMM)? To answer this question, we decided to turn to two groups of experts: talent researchers and STEMM experts. We selected the first group of experts, talent researchers, because they have devoted their careers to studying talent development and giftedness. Over the decades, researchers have been interested in exceptional individuals, such as Nobel Laureates, eminent scientists and artists, Olympic champions, chess grandmasters, famous inventors, and prodigies, and sought to understand how these individuals developed their talent and reached eminence.[1–11] In recent years, talent researchers developed theoretical models to conceptualize and explain the process of and key elements for talent development, such as Gagné's[12,13] Differentiated Model of Giftedness and Talent, Ziegler's[14] Actiotope Model of Giftedness (AMG), and Paik's[15,16] Productive Giftedness Model, to name a few. In the present study, we reached out to a group of established talent researchers to think specifically in the context of talent development in STEMM and reflect on important aspects for developing eminence in STEMM fields. The second group of professionals we turned to were STEMM experts. Although few of the STEMM experts possess systematic knowledge of talent development, they have developed a high level of expertise in STEMM and are far along on the talent journey. In other words, they have the lived experience of developing talent in STEMM fields.

The present study uses the AMG[14] as a theoretical framework. In particular, we based our study on the educational and learning capital approach that emerged from the AMG model,[17,18] in which exogenous resources (i.e., educational capital [EC]) and endogenous resources (i.e., learning capital [LC]) that potentially play a role in talent development are systematized. In the following, we give an overview of the AMG and the learning resources it proposes.

## Theoretical framework

Unlike traditional models of giftedness and talent, the AMG does not focus on human traits but on actions. The development toward eminence is interpreted as a gradual expansion of the individual's action repertoire, in which an individual is capable of increasingly complex actions in a talent domain. According to the AMG, an individual is said to be talented if a learning pathway has been identified for them that bridges the gap between their current action repertoire in a talent domain and a performance–excellent action repertoire. This gap can be substantial and often requires immensely long learning periods to bridge. However, in the AMG, for determining talent, not only individual aspects (such as intelligence, motivation, or learning behaviors) that play a role in learning are considered, but a comprehensive life environment analysis must be carried out to assess an individual's developmental opportunities toward eminence. In particular, environmental factors, such as the quality of learning opportunities, the effectiveness of teaching methods, and the competence of teachers, are considered. Thus, the traditional individual-centered view of giftedness or talent that focuses solely on individual traits is expanded by the AMG with a more comprehensive view of the entire system of the individual and their environment.

The AMG postulates that the probability of an individual achieving eminence in a talent domain relies on the learning resources the individual possesses and obtains along the way.[19] Learning resources can be identified either within the individual (called endogenous learning resources) or in the environment (called exogenous learning resources). Some examples of endogenous learning resources are goals, competencies, and attentional resources of the individual. Exogenous learning resources, on the other hand, include resources in the environment that support talent development, such as social contacts, didactic opportunities, and facilitating infrastructures. Ziegler and Baker[17] termed endogenous learning resources as "learning capital" and exogenous learning resources as "educational capital" and specified five types of capital in each category. Next, we provide a brief review of each type of capital and its importance for talent development.

## Learning capital

Learning capital refers to all learning resources that are located within the talented individual that can be used for their learning and development in a domain.[17] There are five types of LC: organismic, actional, telic, attentional, and episodic.

### Organismic LC

Organismic LC refers to the physiological and constitutional resources of a person, for example, a healthy body for conducting research activities, a good body size for playing basketball, and physical attractiveness for being an actress.[17] A healthy physical condition is important not only for physical activities but also for mental and cognitive activities.[20,21] Physical fitness has been found to be positively correlated with a range of cognitive performance and academic achievement.[22–27]

### Actional LC

Actional LC refers to "the action repertoire of a person—the totality of actions they are capable of performing… including cognitive activities" (p. 30).[17] In other words, an individual must be able to carry out certain actions in order to learn successfully. For many domains, this requires the individual to possess fundamental and advanced domain knowledge and essential skills.[28,29] Furthermore, ancillary knowledge and skills, such as effective learning strategies, are also crucial.[30,31]

### Telic LC

Telic LC refers to "the totality of a person's anticipated goal states that offer possibilities for satisfying their needs" (p. 30),[17] such as one's passion in a domain, functional goal setting, and learning goal orientation. Having short-term, learning-oriented goals positively impacts students' learning behaviors and academic achievement.[32–34] An interview study of six outstanding scientists revealed that setting clear, realistic, yet ambitious goals was important for their daily work and long-term pursuit of eminence.[35]

### Attentional LC

Attentional LC refers to "the quantitative and qualitative attentional resources that a person can apply to learning" (p. 31),[17] such as the amount of time available for learning and volitional strategies to focus one's attention on learning. Talent researchers[5,6,36,37] suggested that it takes a minimum of 10 years, or an equivalent of 10,000 h, of deliberate practice in a domain for an individual to reach an expert level. The 10-year (or 10,000-h) rule stresses not only the quantity of time spent on learning and practice but also the quality of learning effort and practice, as a practice must be carried out deliberately.[38] Thus, deliberate practice refers to a type of focused and effortful practice that is aimed at incremental improvement, and there is ample evidence illustrating that this type of practice improves learning.[36,39–41]

### Episodic LC

Episodic LC refers to "action patterns available to individuals based on their goals and the situation in which they act" (p. 317).[18] Episodic LC can be understood as conditional knowledge—knowing when and under which conditions to apply what kind of declarative and procedural knowledge. While actional LC refers to all the possible actions that an individual can theoretically execute, episodic LC refers to the ability to choose the right actions in a given context for reaching a specific goal. In other words, episodic LC connects actions, goals, and the environment. Thus, episodic LC may be accumulated over time as one experiences meaningful, goal-oriented learning. Episodic LC is an important type of learning resource for talent development. Vialle[42] found that whether students could choose the right actions for reaching a specific goal in a given situation (i.e., episodic LC) influenced their achievement. In addition, psychosocial and emotional skills belong to the episodic LC and play an important role in talent development.[43,44]

## Educational capital

Educational capital refers to all learning resources located in an individual's environment that support learning and development in a talent domain.[17] There are five types of EC: economic, infrastructural, cultural, social, and didactic.

### Economic EC

Economic EC refers to "every kind of wealth, possession, money, or valuables that can be invested in the initiation and maintenance of educational and learning processes" (p. 27).[17] Economic EC impacts learning and talent development in many ways. For example, families' socioeconomic status (SES) was shown to predict children's language acquisition,[45,46] motivation to learn,[47,48] and academic success.[49–51] On average, children from low-SES families demonstrate slower vocabulary growth, achieve lower in standardized tests, and are more likely to exhibit negative attitudes toward learning. Wu and Chen[52] studied 31 Taiwanese physics and chemistry Olympians and noted that the majority were from high SES families. Furthermore, countries with more economic EC, such as the United States, United Kingdom, Germany, and France, produced more Nobel Prize Laureates in physics, chemistry, and medicine from 1901 to 2022.[53–55]

### Infrastructural EC

Infrastructural EC refers to "materially implemented possibilities for action that permit learning and education to take place" (p. 28),[17] such as books, educational toys, learning software, and experiment apparatus. Access to material learning resources and institutes is critical for talent development. For example, the number of books in a household predicts children's school achievement.[56] Having a computer at home positively influences grades in mathematics and sciences.[57] Furthermore, access to elite educational institutions is advantageous to developing eminence. For example, students attending selective STEM high schools gain more authentic research opportunities and experience in high school.[58] A relatively large number of Nobel Prize Laureates in physics, chemistry, and medicine from 1994 to 2014 worked at UC Berkeley, Columbia University, and the Massachusetts Institute of Technology (MIT), according to an analysis of biographical information on Nobel Laureates.[59]

### Cultural EC

Cultural EC refers to "value systems, thinking patterns, models, and the like, which can facilitate or hinder the attainment of learning and educational goals" (p. 27).[17] Values, attitudes, and beliefs about learning in general and about a specific domain modeled by parents and peers influence students' learning and achievement.[60–63] Moreover, cultural EC can influence learning and achievement on a societal level. For instance, East Asian countries that embrace Confucius's philosophies of education often place a very high value on learning and education and are willing to invest much in education,[64,65] which leads to higher achievement levels in their students, compared to students from other cultures.[66,67] On the other hand, cultural values and attitudes can be sources of negative cultural EC. One such example is the long-standing gender stereotype that female students are not as talented in STEMM as male students.[68–70] These sorts of gender stereotypes demotivate women from pursuing eminence in STEMM and contribute to the persistent gender gap in STEMM.[71–73]

### Social EC

Social EC refers to "all persons and social institutions that can directly or indirectly contribute to the success of learning and educational processes" (p. 28),[17] such as committed teachers, caring parents, supporting spouses, and mentors. Talent development research reveals that many eminent individuals had strong social support during their time of studies. For example, talented individuals often credited their parents, spouse, and friends for their emotional and tangible support throughout the long and strenuous journey to rising to the top.[74–76] Furthermore, eminent scientists often reported having at least one mentor during their formative years and attributed their success to the invaluable influence of their mentor(s).[1,11,77]

### Didactic EC

Didactic EC refers to "the assembled know-how involved in the design and improvement of educational and learning processes" (p. 29),[17] which can include parental skills, school curricula, instructional support, and training programs, to name a few. No individual could ever become an expert in a talent domain without excellent instructions from teachers, coaches, mentors, or special training programs. Bloom[78] compared several instructional methods (e.g., group learning, group learning with feedback, and one-on-one instruction) and found that students receiving one-on-one instruction achieved about two standard deviations above the students in a typical classroom group learning condition. One-on-one instruction in the form of mentoring or coaching is especially effective for talent development, particularly during the stage when the talented individual is acquiring advanced domain knowledge or honing their skills.[1,77]

## The present study

The purpose of the present study is two-fold. First, we want to explore key individual and environmental factors for developing eminence in STEMM fields. To this end, we conducted interviews with talent development researchers and STEMM experts. Second, we want to compare the responses of talent development researchers with those of STEMM experts to see how their views are similar or different. We summarize the inquiry of the present study in two research questions:

1. What learning resources do experts regard as most important for developing eminence in STEMM fields?
2. How do talent development researchers and STEMM experts concur or differ in their views about developing eminence in STEMM fields?

# METHODS

The present study was descriptive in nature, entailing systematic inquiry into experts' views on developing eminence in STEMM fields via semistructured interviews. The interviews were conducted with two groups of experts: (a) talent development experts, including professors and researchers in the field of talent development and giftedness research, and (b) STEMM experts, including professors and senior researchers in biology, engineering, mathematics, medicine, and physics. In the remaining sections, we will use the shortened term "TD experts" for talent development experts for parsimony.

## Sampling and participants

Convenience and snowball sampling techniques were utilized for recruiting the participants. Specifically, TD experts were recruited via the authors attending three professional conferences. The first group of experts were keynote speakers of an invite-only expert meeting on talent development and giftedness—the Nuremberg Talent Summit in October 2018. All of the 14 invited keynote speakers, who were internationally known experts in talent development and gifted research, were contacted via a standardized invitation email and invited to participate in the study. Ten of the 14 speakers agreed to participate. The second group of experts were keynote speakers at the 2019 International Research Association for Talent Development and Excellence (IRATDE) Biennial Conference in Taipei. Five TD researchers, who were keynote speakers at the conference, were invited to participate in the study, and three of them agreed to participate. Finally, one more TD expert was invited via the 2019 Worldwide Best Practices for Giftedness Conference, and the expert agreed to participate. In total, 14 TD experts agreed to participate. Of the 14 TD expert-participants, nine were female and five were male. The experts were from five continents: eight from North America, two from Asia (one resides and works in North America), two from Europe, one from Australia, and one from South America. All had earned a Ph.D. in educational psychology or related fields and worked in the field for an average of 32 years, ranging from 18 to 45 years. Their scholarly output ranged from 60 to 252 publications, with an average of 142 publications. Twelve of them were full professors, one was an associate professor, and one was a director of a center focused on gifted education.

STEMM experts were recruited via personal and professional connections. First, six professors in various STEMM fields were contacted directly from the authors' personal connections, and all of them agreed to participate. Furthermore, one of the six professors helped the authors to contact four more STEMM professors and senior researchers who agreed to participate. Additionally, the authors invited a physics professor who was a keynote speaker at the 2019 IRATDE Biennial Conference in Taipei, and the professor agreed to participate in the study. Finally, colleagues of the authors helped to recruit three more STEMM experts via their own professional connections. In total, 14 STEMM experts agreed to participate. Of the 14 STEMM experts, four were female and 10 were male. The experts were from four continents: six from Europe, four from North America (one resides and works in Europe), three from Asia (one resides and works in North America), and one from South America (resides and works in North America). Among the STEMM experts, all had earned a Ph.D. and had postdoctoral experiences. Specifically, seven were full professors: four in physics, one in mathematics, one in medicine, and one in biotechnology. Three were senior researchers in prestigious physical labs, three were associate professors in biological system engineering, and one was an assistant professor in plant biology. Their experience in the respective STEMM field ranged from 12 to 40 years, with an average of 25 years. Their scholarly output ranged from 25 to 567 publications, with an average of 166 publications.

## Data collection

A semistructured interview protocol was developed using the framework of the AMG and the educational and learning capital approach.

The interview protocol consists of four parts. The first part collects participants' demographic information, educational background, and professional experiences. The second part starts with an open question about the most important factors for becoming eminent in a STEMM field and is followed by asking more specifically about (a) individual and (b) environmental factors. The third part focuses on the different developmental stages of talent development in STEMM, and the final part asks about challenges and obstacles to become eminent in a STEMM field and how to overcome them. For the scope of this paper, we mainly focused on the answers to the individual and environmental factors for becoming eminent in STEMM.

Participants were interviewed individually by the first author from February 2019 to May 2020. Of the 28 interviews, 20 were conducted via Zoom, and eight were conducted in-person. The interview ranged from 33 to 103 min, with an average of 52 min. All interviews were recorded and transcribed.

## Data analysis

A hybrid coding method of inductive and deductive coding was employed. The present study sought to explore experts' views on factors contributing to developing eminence in STEMM. Therefore, inductive coding was chosen for the first cycle of coding. However, the decisions of grouping codes into categories and themes were guided by the educational and learning capital approach of the AMG framework,[14] which was deductive in nature.

Specifically, interview transcripts were coded and analyzed following three steps: (1) open coding, (2) axial coding, and (3) selective coding.[79,80] During open coding, the first author read each transcript and coded statements relevant to developing eminence in a STEMM field. Next, for axial coding, the first author reread the coded segments, revised codes, and grouped related codes into categories. This resulted in 341 coded segments and 234 unique codes. During this step, the second author also read the coded segments and codes and marked any questionable codes. The second author marked 44 coded segments (12.9%), and the two authors discussed these coded segments and agreed on the final codes. Additionally, the second author assessed the grouping of codes into categories and agreed on the categories and grouping. Finally, during selective coding, the two authors organized categories into themes and subthemes. In this step, the authors reviewed the codes and were able to categorize them into LC and EC based on the AMG framework.[14] Primary factors within each type of capital were labeled as subthemes.

We were also interested in whether TD researchers and STEMM experts differ in their opinions about the important aspects of developing eminence in STEMM. Therefore, we compared the themes, subthemes, and codes of the two groups and reported the comparative findings in each theme.

# RESULTS

We started the interview with the open question: What is really important if a person wants to become eminent in a STEMM field? All of the experts were able to come up with a list of factors right away. Among the 28 (14 TD and 14 STEMM) experts, 24 (12 TD and 12 STEMM) mentioned individual factors, and 22 (11 TD and 11 STEMM) mentioned environmental factors. Eighteen (nine TD and nine STEMM) of the 28 experts mentioned factors both within the individual and in the environment on their own. Following the open question, we prompted the experts by asking whether they could think of any other factors within the individual or in the environment. As a result, three (two TD and one STEMM) experts came up with individual factors only after the prompt, and six (three TD and three STEMM) experts came up with environmental factors only after the prompt. Using the framework of the AMG and the educational and learning capital approach, we categorized the factors mentioned by the experts into the respective type of LC and EC. LC refers to all learning resources that are located within the individual that can be used for talent development in a domain. EC refers to all learning resources located in an individual's environment that support talent development in a domain. Table 1 provides an overview of the number of experts from each group who mentioned LC and EC without prompt or only after being prompted.

Of the total 341 coded segments, about 54% of the segments were related to LC and 46% were related to EC. Furthermore, all 10 types of LC and EC were identified by the experts for talent development in STEMM. In the following sections, we report findings for each type of LC and EC. For each type of capital, we report the general findings and compare the opinions of TD experts and STEMM experts.

## Learning capital

Experts talked about a range of individual factors that they deemed important for developing eminence in STEMM fields. Of the 184 coded segments that were related to LC, 107 were mentioned by TD experts, and 77 were mentioned by STEMM experts. We categorized the factors into the respective type of LC: telic, actional, attentional, episodic, and organismic capital. Table 2 provides an overview of the number of experts from each group who mentioned the five types of LC without prompt or only after being prompted.

### Telic LC

Telic LC refers to "the totality of a person's anticipated goal states that offer possibilities for satisfying their needs" (p. 30).[17] Following the definition, we coded all statements about motivation in general and its different aspects (e.g., interest, drive, goal orientation, and persistence) as telic LC, as they are related to goals and goal-directed behaviors. The telic LC was the most frequently mentioned LC. Overall, 15 (seven TD and eight STEMM) experts talked about factors in the telic LC among the most important for becoming eminent in STEMM, and eight (six TD and two STEMM) more experts added factors in the telic LC to the list after the general prompt (i.e., are there any other individual or environmental factors?). Specifically, experts talked about four aspects of motivation: passion, enjoyment, goals, and perseverance. TD experts used these known

**TABLE 1** Total number of experts who mentioned LC and EC for STEMM talent development

| | TD experts | | | STEMM experts | | |
|---|---|---|---|---|---|---|
| | LC | EC | Both | LC | EC | Both |
| Without prompt | 12 | 11 | 8 | 12 | 11 | 9 |
| Only when prompted | 2 | 3 | 4 | 1 | 3 | 2 |

Abbreviations: EC, educational capital; LC, learning capital; STEMM, science, technology, engineering, mathematics, and medical science; TD, talent development.

**TABLE 2** Number of experts who mentioned LC for STEMM talent development

| | TD experts | | STEMM experts | | Total | |
|---|---|---|---|---|---|---|
| | Without prompt | Added after prompted | Without prompt | Added after prompted | Without prompt | Added after prompted |
| Telic LC | 7 | 6 | 8 | 2 | 15 | 12 |
| Actional LC | 10 | 2 | 3 | 4 | 13 | 6 |
| Attentional LC | 5 | 7 | 6 | 2 | 11 | 9 |
| Episodic LC | 1 | 5 | 4 | 2 | 5 | 7 |
| Organismic LC | 1 | 0 | 0 | 0 | 1 | 0 |

Abbreviations: LC, learning capital; STEMM, science, technology, engineering, mathematics, and medical science; TD, talent development.

psychological constructs. STEMM experts, on the other hand, often described similar concepts without using these technical terms.

Several TD experts deemed passion to be the most important thing for reaching eminence in any domain, including STEMM areas. They shared from their research of eminent people that these individuals have extreme and lasting passion for what they do, and they cannot get enough. One TD expert added that it is not just passion for the domain but also a love for learning that was often found in people who later became eminent. The STEMM experts echoed this point using their own examples. One physics professor described his passion for physics very early on, "[I] started out knowing I'll be a physicist since I was born. … When I was five, I asked my mom whether light is a wave or a particle… It didn't come from my family… It's just there." This passion not only led him to explore physics using all the resources he had as a child, but it also sustained him through many years of hard work and helped him bounce back from setbacks. Another engineering professor talked about her passion and the crucial role it played in her journey, "I *loved* my project in grad school… if I didn't believe [my project] would make a difference, if I didn't love it, I wouldn't have survived it." She contrasted her experience with a friend, who was also in graduate school at about the same time. Unlike her, the friend was not passionate about the project but simply finished it as a necessary task for graduation. Later, the friend left the field and started a career in a totally different area.

Additionally, STEMM experts stressed the importance of following one's passion despite difficulties and challenges. They knew that it was not always easy to follow one's passion, as obstacles such as a series of experimental failures, difficulties in finding an academic position, and financial instability can sometimes cause talented individuals to doubt their pursuit of excellence. Still, several STEMM experts encouraged young scholars to follow their passion, as one physics professor said:

> What I always tell [my students] is that if you really love what you do, you should simply do that. And this is independent of your financial conditions and other things… if you let your passion lead you in [the] main direction, the rest will follow.

Experts also talked about another source of motivation. A TD expert called it the "enjoyment and need to solve problems" and observed that eminent people in STEMM were often inquisitive about design issues, thinking about impossible things, and motivated to figure out how to make the impossible possible. Another TD expert shared a similar view, "You have to be fascinated with design issues. I personally feel STEMM fields are fundamentally built on the idea that you can design something new and that you can invent something." As for the type of problems to solve, a TD expert noticed that eminent scientists were those who chose to tackle the world's most pressing problems and designed solutions for the common good, rather than just focusing on gains for themselves.

Indeed, several of our STEMM experts shared stories of being curious and enamored of the process of problem-solving. One engineering professor told us that ever since she was a child, she was always involved in problem-solving. "My parents said that [I] never got in trouble for doing bad things, but I got in trouble for being curious." And one such example was her desire to know what would happen if she poked holes in her waterbed. She eventually did poke a hole in her waterbed to find out what would happen. A math professor reflected on the type of problems worth solving in terms of making contributions in STEMM fields:

> [T]he schooling system is such that you will often have to solve problems which have already been solved by other people, where a known solution exists. But I think in order to bring science forward, you really need to have the stamina to work on problems, which may not have a solution… It's important to be willing and to be able to pursue these hard problems.

Finally, TD experts underlined the importance of having both short-term and long-term goals as sources of motivation. Specifically, they suggested that long-term goals, such as becoming the best in a STEMM field, could help individuals keep their eyes on the prize and sustain them through challenging times, whereas short-term goals could direct individuals in day-to-day work to eventually achieve their long-term goals. However, one TD expert warned against specializing too early despite the importance of having goals. STEMM experts rarely used the term "goals," but several described an internal drive that pushed them forward. For example, a plant biologist shared:

> [My home country] has so many natural resources, but so few advanced in science. My desire is to use these opportunities [abroad] I have to create knowledge that can be used for my country. That's why I'm working with crops, rice, [and] maize that are normally seen in tropical areas.

However, when several STEMM experts were asked specifically whether having a long-term goal was important for eventually becoming eminent in a field, they disagreed. Instead, they argued that having a prefixed long-term goal might hinder an individual from exploring. Rather, they suggested young students to explore more and find their passion.

Another term often mentioned with motivation by TD experts was perseverance. STEMM experts elaborated more on this concept. One professor described it as "being willing to fail a lot and keep going and not get so hung up on it." Another professor described it as "just sticking with something and being stubborn and wanting to complete it" and told her students that perseverance is the most critical element for success.

## Actional LC

Actional LC refers to the totality of actions an individual is capable of performing. Following the definition, we coded statements about cognitive abilities and domain knowledge as actional LC. The actional LC was the second most frequently mentioned LC. Overall, 13 (10 TD and three STEMM) experts talked about factors in the actional LC among the most important for becoming eminent in STEMM, and six (two TD and four STEMM) more experts added factors in the actional LC to the list after the general prompt (i.e., are there any other individual or environmental factors?). The experts' statements relating to cognitive abilities mainly referred to either basic elements of intelligence or thinking skills. TD experts postulated that basic elements of intelligence, such as working memory (especially visuospatial sketchpad), attention, and speed of processing, are key for reaching eminence in STEMM domains. One TD expert gave an example:

> Show me a theoretical physicist with an IQ of 90. Is it impossible that somebody could become a theoretical physicist with an IQ of 90? It's not. Nothing's impossible. Is it likely though? No, it's exceedingly unlikely given what we know from the available evidence.

Another TD expert added to this point by citing research showing that even in the top-ability group, "intellectual ability differences are important for explaining success in STEMM, [as measured] by tenure, patents, or publications." Concerning STEMM experts, mathematics and physics experts emphasized the importance of math abilities and "a math mind." STEMM experts from the other STEMM areas did not emphasize that. When asked in a follow-up question, several of these experts frowned upon the emphasis on these basic elements of intelligence for developing eminence. Instead, they suggested that intelligence should be defined more broadly to include a range of cognitive and noncognitive skills that could be developed over time.

Furthermore, TD experts provided a list of thinking abilities that they deemed essential, such as logical thinking, critical thinking, flexible thinking, abstract thinking, and creative thinking. STEMM experts echoed their views and provided concrete examples. For example, several STEMM experts considered creative thinking as an indispensable element for reaching eminence, as a math professor remarked, "There's a lot of people going to STEMM, and they think in the box. But if we're talking reaching eminence, they have to be an out-of-the-box thinker."

Other commonly mentioned aspects referring to actional LC were domain knowledge and domain-specific skills. Several TD experts mentioned mastery of domain knowledge and skills and argued that one must first accumulate domain-specific knowledge and become an expert in the field before one can break new ground. Furthermore, both TD and STEMM experts acknowledged the necessity of the breadth of knowledge, especially in the current era of multidisciplinary and interdisciplinary research. They proposed that those who became eminent sometimes broke new ground by bringing ideas from multiple disciplines. They also mentioned that to be able to do that, an individual first needs to know and keep up with new development in other relevant fields.

In addition to domain-specific knowledge, TD experts mentioned skills unique to STEMM fields, such as abilities to explain phenomena, quantitative skills, visual-spatial reasoning, abilities to work with their hands when assembling and disassembling experimental parts, and problem-solving skills. Moreover, both groups of experts regarded supportive research skills, such as scientific writing, conference presentation, and grant writing, to be important for reaching eminence in STEMM fields. One STEMM professor considered writing to be "the most important soft skill" and wished that writing was more emphasized during her school time, as she regretted not paying more attention to writing compared to her STEMM courses.

## Attentional LC

Attentional LC refers to "the quantitative and qualitative attentional resources that a person can apply to learning" (p. 31).[17] Following the definition, we coded statements about the quantity and quality of attentional resources for learning as attentional LC, such as the amount of time available for learning and strategies to focus one's attention on learning. The attentional LC was the third most frequently mentioned LC. Overall, 11 (five TD and six STEMM) experts talked about factors in the attentional LC among the most important for becoming eminent in STEMM, and nine (seven TD and two STEMM) more experts added factors in the attentional LC to the list after the general prompt. We categorized the codes within this LC into three subthemes: working hard for a long time, having a single-minded focus, and valuing time.

Both groups of experts agreed that developing eminence takes time and hard work. TD experts often used the term "deliberate practice" to emphasize that practice must be focused and deliberate for improving and progressing. TD experts considered deliberate practice necessary not only for perfecting domain-specific skills but also for becoming more creative. One TD expert reflected on her own studies interviewing eminent scientists and shared that all the eminent scientists worked at being creative. "It was not natural. I mean, I think it becomes more automatic over time perhaps, but it was a deliberate process." STEMM experts also believed in the value of hard work and the investment of time. One STEMM expert said:

> You have to work a lot. You have to be willing to put a lot of effort into the field. If you're just talented and you're not hardworking and really pursuing the things that you want to achieve, I mean, okay, then you will fail.

TD experts advocated for a single-minded focus, sometimes referred to as "singleness of purpose" in order to direct one's attention to learning in the talent domain. They explained that talented individuals often showed potential and developed interests in multiple areas. However, to go deep into a field and accumulate knowledge and expertise, at some point, talented individuals had to make a choice and focus on one domain. This view was supported by STEMM experts. One biology professor shared his own story: As a child and adolescent, he was very interested in both soccer and science. As he developed, he realized that he had to make a conscious decision to focus on science and fully devote his time and energy to pursuing science, rather than trying to split his time between soccer practices and science learning. However, several STEMM experts remained to have hobbies, such as sports, music, or arts, despite their single-minded focus in their respective domains. They told us that sometimes, ideas from these hobby areas inspired their research work.

A few TD experts also talked about a quality that they observed in eminent people—valuing time. One TD expert elaborated on this point:

> They learn the value of time early on. I think a characteristic trait of highly successful individuals is that they value time. They know that time is precious. Everything they do, it's like it centers around time. But they use it so constructively. They have productive habits.

Consequently, for talented individuals who want to eventually achieve eminence in a STEMM domain, TD experts suggested examining how they use time in and outside of school. Talented individuals should also "maximize as much as possible the amount of time spent in their zone of proximal development," one TD expert suggested, "as it helps foster and facilitate that accumulation of knowledge, then expertise, and then the ability to make those large contributions." None of the STEMM experts talked about this aspect of attentional LC.

## Episodic LC

Episodic LC refers to "action patterns available to individuals based on their goals and the situation in which they act" (p. 317).[18] It is about being able to apply knowledge and skills in appropriate situations toward a specific goal. Because episodic LC often links actional and telic LC together with the environment, it can be difficult to parse out. In our analysis, we coded experts' statements about metacognition, socioemotional skills, and other situation-appropriate actions (e.g., one's ability to unstick and find creative strategies when one encounters a challenge) as episodic LC. Overall, five (one TD and four STEMM) experts talked about factors referring to episodic LC as the most important for becoming eminent in STEMM, and seven (five TD and two STEMM) more experts added factors in the episodic LC to the list after the general prompt. We categorized the codes within this LC into four subthemes: metacognition, socioemotional skills, adaptive perseverance, and finding a niche.

TD experts commented on a few ways in which metacognition could play a role in talent development. First, they mentioned that talented individuals must become aware of their own ability in the talent domain at some point. STEMM experts confirmed this point. For instance, a couple of physics professors talked about noticing that they were better in physics than their teacher in high school, which made them consider their potential for excelling in physics. Second, TD experts emphasized the importance of talented individuals recognizing abilities and skills they still need to develop. For example, one TD expert remarked, "I do think it takes a smart person to figure out what they need to develop in order to become successful. I think that's kind of a metacognitive thing, and I don't think everybody has that." Similarly, several STEMM experts showed metacognitive reflection when thinking about their own development and identified areas for improvement. They were aware of their surroundings and the importance of learning from others' experiences. One STEMM expert provided the following example, "I saw a colleague struggling with a project because he wasn't familiar with biological informatics, … so I took the opportunity to learn informatics, and it turned out to be very useful for my current work." Third, TD experts referred to the importance for talented individuals to monitor and regulate their own learning, such as being able to complete tasks that they may not want to do but need to do. Similarly, STEMM experts talked about their experiences of regulating learning and completing necessary tasks in order to succeed, such as perfecting academic writing as it is important for publishing and grant application.

We categorized socioemotional skills into the episodic LC because they are almost always context-specific, thus exhibiting one's conditional knowledge. The most prevalent socioemotional skills mentioned by both groups of experts were communication and collaboration skills, as STEMM professionals need to work with others more and more nowadays. Furthermore, interpersonal skills, healthy self-promotion, and networking abilities were deemed important by both groups of experts for reaching eminence, as these skills can boost one's visibility in a field. One TD expert alluded that eminent people have excellent interpersonal skills:

> I think it's somebody who has some charisma to some extent. It's not just said that somebody who's pretty much an introvert but very bright, does a lot of good work, and gets noticed. But I think a lot of people I see around the university who are always getting awards, are pretty charismatic people. They know everybody, and they are well-connected. They shine not just for their research, but in terms of their relationship with other people.

STEMM experts also agreed that no matter how talented a person is, their ideas have to be seen in the field in order to be appreciated. Moreover, people-management skills were mentioned by a few STEMM experts as they learned to lead their labs and groups.

In addition to the perseverance categorized as a type of telic LC, both groups of experts talked about it from the perspective of episodic LC, that is, "knowing when to persist and when to quit." One TD expert was concerned about an overemphasis on perseverance in the culture, but not enough on the discernment of when to persevere and when to quit. This kind of conditional knowledge is an example of episodic LC. An engineering professor stated, "You have to know when it's time to give up versus when to keep trying hard. Is the failure a true failure? Or is it just need to be tweaked a little bit and then it could work?" Another physics professor pointed out that perseverance referred to never giving up on the end goal, but it would be smart to consider changing the approach to the goal if the previous approach failed. In other words, being willing to try over and over but adapting the approaches may be more effective than simply repeating the effort mindlessly.

Finally, both groups of experts emphasized the importance of finding one's niche and making a unique contribution to becoming eminent in a STEMM field. TD experts suggested that it starts with learning to ask important questions, choosing the right topic, and being willing to try out "crazy" ideas. One STEMM expert shared a story of an eminent scientist in her field:

> Sometimes good ideas mean you have to have stupid ideas. If it's obvious, then other people probably thought of it. And so sometimes you have to do things that people go, "What? Why are you doing that?" Making carbon nanotubes into a sensor. Michael Strano did that, and it was kind of a fluke like, "Hey, let's try this," and "Oh, my gosh. It works." He started a whole new field.

## Organismic LC

Organismic LC refers to the physiological and constitutional resources of a person. This type of LC was not brought up by the experts very often. Only one TD expert spoke about the importance of psychological robustness, which was counted as organismic LC. None of the STEMM experts talked about factors referring to organismic LC. Even after the general prompt, no other TD experts or STEMM experts came up with factors belonging to this LC.

Table 3 summarizes the subthemes for each LC mentioned by TD and STEMM experts.

## Educational capital

In addition to individual factors, all the experts acknowledged the significant role of environmental factors, that is, a person's EC. One TD expert summarized it well:

> A person may have the make-up of a STEMM talent [that could] make a great contribution, but in their environment, there was no exposure. That person will never become a big figure in STEMM merely because of the [lack of] environmental exposure.

Of the 157 coded segments that were related to EC, 81 were mentioned by TD experts, and 76 were mentioned by STEMM experts. We categorized the statements about environmental factors into their respective types of EC: economic, infrastructural, cultural, social, and didactic capital. Table 4 provides an overview of the number of experts from each group who mentioned the five types of EC without prompt or only after being prompted.

## Economic EC

Economic EC refers to "every kind of wealth, possession, money, or valuables that can be invested in the initiation and maintenance of educational and learning processes" (p. 27).[17] Overall, only one STEMM

**TABLE 3** Subthemes of each type of LC by TD and STEMM experts

| | TD experts | STEMM experts |
|---|---|---|
| Telic LC | Passion<br>Enjoyment and need to solve problems<br>Goals (both ***long-term*** and short-term)<br>Perseverance | Passion<br>Enjoyment and need to solve problems<br>Goals (only short-term goals)<br>Perseverance |
| Actional LC | Basic elements of intelligence<br>Thinking abilities<br>Domain-specific knowledge and skills<br>Supportive research skills | Basic elements of intelligence (***especially math and physics***)<br>Thinking abilities<br>Domain-specific knowledge and skills<br>Supportive research skills |
| Attentional LC | Working hard for a long time<br>Single-minded focus<br>***Valuing time*** | Working hard for a long time<br>Single-minded focus |
| Episodic LC | Metacognition<br>Socioemotional skills<br>Adaptive perseverance<br>Finding one's niche | Metacognition<br>Socioemotional skills<br>Adaptive perseverance<br>Finding one's niche |
| Organismic LC | ***Psychological robustness*** | |

*Note*: Italicized and bolded subthemes indicate differences between TD and STEMM experts.
Abbreviations: LC, learning capital; STEMM, science, technology, engineering, mathematics, and medical science; TD, talent development.

**TABLE 4** Number of experts who mentioned EC for STEMM talent development

| | TD experts | | STEMM experts | | Total | |
|---|---|---|---|---|---|---|
| | Without prompt | Added after prompted | Without prompt | Added after prompted | Without prompt | Added after prompted |
| Economic EC | 0 | 2 | 1 | 1 | 1 | 3 |
| Infrastructural EC | 2 | 1 | 0 | 3 | 2 | 4 |
| Cultural EC | 9 | 3 | 8 | 3 | 17 | 6 |
| Social EC | 6 | 4 | 6 | 5 | 12 | 9 |
| Didactic EC | 6 | 5 | 2 | 3 | 8 | 8 |

Abbreviations: EC, educational capital; STEMM, science, technology, engineering, mathematics, and medical science; TD, talent development.

expert nominated economic EC to be the most important aspect after the opening question (i.e., What is important for becoming eminent in STEMM?), and one more STEMM expert and two TD experts mentioned aspects belonging to this EC after the general prompt (i.e., are there any other individual or environmental factors?). Two TD experts from different regions of the world gave similar examples illustrating how financial resources impact talent development. In their own respective country, there exist vast differences in financial resources from region to region. Children from less affluent regions often lack the means to pursue and sustain their learning, not to mention develop their talent. A physics professor also talked about the importance of economic EC for his talent development. He would not have attended university if he did not receive a scholarship from the university. Furthermore, in some STEMM domains, economic EC is essential for carrying out cutting-edge research. One professor working with nanomaterials commented:

> You have to have money. You have to be able to get grants and know how many students the grant can pay for to help you get your lab going or how much money they'll give you just to buy supplies… because without supplies, you can't get results. Without results, you can't get a grant. Without grants, you can't do anything.

## Infrastructural EC

Infrastructural EC refers to "materially implemented possibilities for action that permit learning and education to take place" (p. 28).[17] Two TD experts but no STEMM experts talked about factors in the infrastructural EC among the most important for becoming eminent in STEMM, and four (one TD and three STEMM) more experts added factors in the infrastructural EC to the list after the general prompt (i.e., are there any other individual or environmental factors?). We categorized the codes within this EC into two subthemes: access to atypical resources and institutional support.

TD experts argued that it would take an atypical level and quality of resources, rather than standard resources (e.g., access to books and universities), to facilitate the development of eminence in STEMM areas. One illustrated this point with the example of Bill Gates:

> Bill Gates talks about one of the advantages that he had was an environment where they happened to have a computer at his school, access to which was just unheard of back then because it would've been like the 70s. That was very rare [to] have access to computers and the internet, a little more ubiquitous now than it was 40 years ago.

However, this expert added that there can be "a lot of compensatory mechanisms" if one does not have access to those atypical infrastructural resources of the time, and "a surplus variety of other factors could help overcome."

STEMM experts, on the other hand, focused on the infrastructural support provided by their institutions, such as a university system or departmental setup that supports early career faculty members, provides travel funding for attending conferences, and makes it possible for them to organize professional events in their field.

## Cultural EC

Cultural EC refers to "value systems, thinking patterns, models, and the like, which can facilitate or hinder the attainment of learning and educational goals" (p. 27).[17] This EC was the most frequently mentioned educational capital. Overall, 17 (nine TD and eight STEMM) experts talked about factors in the cultural EC among the most important for becoming eminent in STEMM, and six (three TD and three STEMM) more experts added factors in this EC to the list after the general prompt (i.e., are there any other individual or environmental factors?). We categorized the codes within this EC into three subthemes, depending on the sources: family values and expectations, mentoring, and societal values.

TD experts talked about the influences of family values and expectations on one's talent development in STEMM in two respects. First, TD experts told us that some eminent people were initially introduced to their talent domain by their parents because the parents either worked in or valued the domain. Several STEMM experts' experience confirmed this point: They grew up in a family where their parents and older siblings valued education and STEMM, which gave impetus to their own talent development in STEMM. One of the STEMM experts told us that her parents always expected that she would go to university, even though neither of her parents had a university degree. Another engineering professor always knew that he would do something related to engineering because both his father and older brother are engineers. But not all STEMM experts had a close family member who worked in a STEMM area.

Second, several TD experts remarked that family also can instill work ethics in talented individuals, as parents and older siblings often modeled learning attitudes and work ethics for the talented individual. This was endorsed by one physics professor's story. He once thought he might have a disadvantage in studying physics because neither of his parents had a college degree or worked in physics, but later he realized that what his parents taught him was much more valuable, "My father was extremely persistent and strong in following his passion. So that was much more important training for me from my parents than getting the education because that, I could find elsewhere."

Another aspect mentioned in the context of cultural EC was mentoring, in the sense that great mentors can instill research attitudes of scientific pursuit in young budding scientists. One physics professor admired his Ph.D. advisor's "unbelievably high level of ethics" in doing science, which left an imprint on him: "When you actually do science, you can't cut corners. Sometimes we want something to happen, but you have to be brutally honest." Furthermore, both groups of experts defined good mentoring as a way to introduce young scientists to the domain culture, provide enough space for them to explore, and eventually help them identify topics where they can achieve more. STEMM experts stressed that the scientific model of mentoring is to help mold the next generation of scientists in terms of high scientific standards and ethics and help them find their own niche, rather than creating a cloned version of the mentor.

Experts also talked about cultural EC at a societal level. Several TD experts pointed out that some societal values may especially be a hindrance for women and minority groups to pursue STEMM eminence. One TD expert shared an example of such a negative societal value for talent development. In her country, smart girls are not viewed favorably in school. Consequently, many girls would rather act "dumb" in order to be accepted by their peers, although they are talented in STEMM. On the other hand, one female physics professor credited the societal values in her home country for her success because it was natural for females in her culture to have both an excellent career and a family. Therefore, she never felt the need to choose one or the other.

In a more complex way, societal values influenced eminence in STEMM fields through "天时地利人和"—a Chinese wisdom saying shared by a TD expert, which means to make any great contribution, three elements have to all be there: the right timing, the right place, and the right person. This point was echoed by a biosystem engineering professor, as she talked about getting into her domain at the right timing:

> It's one of those things that you can't really control. I have no say over when I was born and when I graduated. But for carbon nanotube sensors, I feel like I kind of came in towards the leading edge of that. That is what's helping me to be able to make the biggest changes. So that timing of when you can fall into that topic that you love. I loved carbon nanotube sensors.

In essence, the experts argued that society must be open to certain topics and value them, otherwise, eminent achievements are hardly possible.

## Social EC

Social EC refers to "all persons and social institutions that can directly or indirectly contribute to the success of learning and educational processes" (p. 28).[17] Following the definition, we categorized codes related to social and emotional support from key social agents, such as parents, teachers, and mentors, as well as a collective network of support into the social EC. This EC was the second most frequently mentioned educational capital. Overall, 12 (six TD and six STEMM) experts talked about factors in the social EC among the most important for becoming eminent in STEMM, and nine (four TD and five STEMM) more experts added factors in this EC to the list after the general prompt. We categorized the codes within this EC into two subthemes: support from social agents and a collective support network.

Both TD and STEMM experts shared their belief that social support plays a big role in talent development. One TD expert stated, "[For] environmental [aspects], … you need all three adults [parents, teacher, and mentor] to invest in you. But sometimes people don't have parents to invest in them. In those cases, a teacher or a mentor does come along." Indeed, several STEMM experts were first introduced to their talent domain by their parents and family members, as in the case of one engineering professor whose father and older brother were both engineers. In other cases, parents found ways for their children to experience STEMM, such as buying them STEMM toys and signing them up for STEMM summer camps. In addition to seeding interests early on, parents' emotional support throughout the journey was also pivotal. Several STEMM experts expressed gratitude to their parents for always believing in them and supporting them to chase their dream. When they were frustrated by obstacles and failures, their parents provided comfort and encouragement. Occasionally, STEMM experts mentioned social and emotional support from other family members, such as older siblings and later their spouses.

Another source of social support came from teachers, according to STEMM experts. When it comes to the social EC, it was less about teachers' instructional quality and more about them being kind, encouraging, and supportive. STEMM experts shared stories of a kind and encouraging math and science teachers in their schooling and thought that these nice teachers generated in them even more interest in science. Furthermore, a few STEMM experts recalled that their teachers recognized their exceptional abilities in them and directed them to the right field of study. A physics professor gave thanks to his physics teacher, who encouraged him to study physics at the university because the teacher could not answer all his questions. Unfortunately, a few experts also warned us that in some cases, teachers of talented students can become jealous and feel threatened by the students' talent. As a result, they might actually impede their students' talent development.

Compared to supportive parents and encouraging teachers, one TD expert regarded a good mentor as the most important learning resource in the environment, "If you find the right mentor, it will open doors for you. People can't do it by themselves because they don't know how to navigate this new world. They need somebody who has expertise and experience." Besides opening doors, other TD and STEMM experts also mentioned other types of support from mentors, such as providing career guidance, sharing contacts and insider knowledge, teaching psychosocial strategies to bounce back from a hard failure, and supporting mentees emotionally when they are plagued by self-doubt.

In addition to the social support from parents, teachers, and mentors, STEMM experts also described receiving valuable psychosocial and emotional support from a collective support network, or "a tribal connection," as labeled by a STEMM professor. A collective support network consists of a mixture of peers, colleagues, and mentors. It "creates a certain level of network connectivity, mentoring, and positive feedback from peers," said a biotech professor. Similarly, a math professor appreciated her collective support network as "somebody maybe points out to you, 'This is the conference to go to,' or 'this is the person you should meet for your work,' or 'did you read that paper?'" Other STEMM professors appreciated the emotional support from the network when they experienced a setback, such as a manuscript or a grant rejection. It was comforting for them to know that others in the network also experienced similar setbacks. Often, talking about these setbacks with their network members helped them reframe the setback and put things into perspective.

## Didactic EC

Didactic EC refers to "the assembled know-how involved in the design and improvement of educational and learning processes" (p. 29).[17] Following the definition, we categorized codes related to instruction and instructional support into the didactic EC. This EC was the third most frequently mentioned educational capital. Overall, eight (six TD and two STEMM) experts talked about factors in the didactic EC among the most important for becoming eminent in STEMM, and eight (five TD and three STEMM) more experts added factors in this EC to the list after the general prompt. We categorized the codes within this EC into two subthemes: appropriate challenges and sustained engagement and high-quality instruction.

First, TD experts stressed that talented individuals need appropriate challenges and continuous learning opportunities to be engaged and learn new things. "You can't develop your talent unless you're engaged. And you can't do that unless you have a sustained period of time where you are engaged," said one TD expert. She further noted that sustained engagement is "not just your simple sort of exposure or enrichment that happens every once a week… To move towards eminence, you need sustained engagement and learning new things." She and other TD experts gave examples of such learning opportunities in STEMM areas, including hands-on science opportunities, authentic

**TABLE 5** Subthemes of each type of EC by TD and STEMM experts

| | TD experts | STEMM experts |
|---|---|---|
| Economic EC | Financial resources for ***education*** | Financial resources for ***advanced research*** |
| Infrastructural EC | ***Access to atypical resources*** | ***Institutional support*** |
| Cultural EC | Family values and expectations<br>Mentoring<br>Societal values | Family values and expectations<br>Mentoring<br>Societal values |
| Social EC | Social support from family members and mentors | Social support from family members, ***teachers***, and mentors<br>***A collective support network*** |
| Didactic EC | Appropriate challenges and sustained engagement<br>High-quality instruction | Appropriate challenges and sustained engagement<br>High-quality instruction |

*Note*: Italicized and bolded subthemes indicate differences between TD and STEMM experts.
Abbreviations: EC, educational capital; STEMM, science, technology, engineering, mathematics, and medical science; TD, talent development.

research opportunities, and lab experience. One TD expert talked about another benefit of appropriate challenges especially at young ages, as these challenges could stretch talented individuals intellectually and develop resilience that would better prepare them for later challenges in life. Related to this point, STEMM experts indicated that sustained engagement often took place outside of the classroom, such as in science clubs, summer coding camps, and other types of extracurricular programs.

Second, several TD experts commented on the importance of having an excellent curriculum and high-quality instruction to lay a solid foundation for STEMM talent development, as the first formal STEMM instruction often came from math and science classes in school. However, some TD and STEMM experts expressed concerns that in many school systems across different countries, math and science taught in school are not the real math and science. They knew of many talented students in STEMM had to find a way to get through math and science in school in order to experience real STEMM in university and beyond. A physics professor described himself as “sleepwalking” in most of his physics classes in school and learned physics by himself reading physics books until he entered university. STEMM professors in more applied fields, such as engineering, did not express such concerns about math and science classes in school.

Experts talked about a more reliable source of high-quality instruction, which often came from mentors, especially when talented individuals became serious about excelling in their given field. At this stage, mentors provided technical support and helped talented individuals hone important skills, such as how to handle delicate experimental materials, how to write and publish in the field, and how to secure grants and run projects. According to our experts, mentors can be instrumental in shaping their mentee’s thinking by teaching them how to recognize and form interesting questions and how to approach and solve problems systematically yet creatively. One TD expert asked rhetorically, “How many Nobel Laureates ascribe some significant part of their success to a mentor? Probably most, if not all.”

Table 5 summarizes the subthemes for each EC mentioned by TD and STEMM experts.

## Combination of multiple types of capital

In addition to the factors that we categorized into the 10 types of capital, we also identified factors that at first glance seemed as if they could not be categorized as any capital, but on closer inspection were a combination of several types of capital. Interestingly, some of these factors are much discussed in talent development research, independent of the framework of LC and EC. We will discuss three factors that combine two or more types of capital: chance and luck, a wide range of experience, and centers of excellence.

### Chance and luck

Eight experts mentioned factors such as chance and luck as important for reaching eminence in STEMM. At first, chance and luck did not seem to belong to any type of capital. But upon closer examination of examples given by the experts, we concluded that they represented a combination of several types of EC (didactic, cultural, social, etc.). For instance, one physics professor started his Ph.D. with J. J. Sakurai, a pioneering and legendary theoretical particle physicist. Tragically, Sakurai passed away suddenly before he finished his Ph.D. Out of urgency, the professor, who was a timid Ph.D. student back then, went to another professor in the department, Professor John Dawson, although Dawson was in plasma physics. As a result, he became one of the few physicists who has expertise in both theoretical and plasma physics.

Although the professor described the unique experience of being mentored by two giants in physics as being “lucky,” we viewed it as a combination of didactic and cultural EC. The privilege of being taught by the best in the field is an aspect of didactic EC. However, the fact that he could simply walk down to find another eminent physicist in the department reflected the “richness” of the physics culture in his environment, thus, cultural EC.

Similarly, another professor described himself as being “extremely lucky” in that while he was finishing his Ph.D. in Munich, his then-supervisor connected him with an opportunity to study with a Nobel

Laureate in Zurich, which was a rare opportunity and proved to be a milestone on his talent development. This example also illustrated a combination of social and didactic EC. His supervisor in Munich was a type of social EC by connecting him with another prestigious mentor and opened doors for him. And studying under and working with two great mentors provided didactic EC for his talent development.

### A wide range of experience

More than three-quarters of the STEMM experts we interviewed had educational and working experiences in two or more countries. All of them mentioned their experience abroad on their own and deemed it valuable and enriching for their talent development. The experts talked about these experiences in terms of the benefits of several types of capital. First, experts reported that studying or working in another country stretched their own way of thinking and broadened their horizons in terms of research approaches and designs. This could be viewed as a form of didactic EC. Second, experts believed that these experiences widened their professional connections and established international networks, which could be considered cultural and social EC. Finally, several experts alluded to the experience of being in a less comfortable environment as an opportunity to develop their resilience, which could be regarded as a form of episodic LC.

### Centers of excellence

Another example of a combination of several types of capital is "centers of excellence," as labeled by several TD experts. A center of excellence refers to the hotbed of a talent domain, where the best resources and the best individuals in the domain reside. For example, the center of excellence for IT is Silicon Valley and for physics is CERN. TD experts described three benefits of being in the center of excellence. First, it would give access to already eminent people in the field because that is where the greatest reside. A physics professor recalled his experience studying and working in "the Mecca of high energy physics":

> This is what I forever treasure and appreciate to the environment of Stanford Linear Accelerator Center, which at the time was the Mecca of high-energy physics. And the founding fathers at that time were still active. They were still around me, and Nobel Prize laureates just walking around the corridor. We had lunch together and so on.

In the center of excellence, the talented individual is likely to be immersed in the most pioneering work in the field, where they can learn from eminent people about the right questions to ask, receive feedback on their research, and get a sneak peek of the newest development of the field. Therefore, being in the center of excellence can be considered a cultural and didactic EC.

Second, TD experts proposed that being in the center of excellence would provide access to like-minded and competent peers, which would promote not only ongoing intellectual sparring but also a sense of belonging. Several STEMM experts underlined that science is not a single-person show, where one just sits in their own office all day long and produces research. Instead, scientists need to talk about their ideas with colleagues informally and use their colleagues as their sounding board. STEMM experts asserted that these regular informal conversations are critical for talented individuals to progress in their research, which could be a form of didactic EC. Moreover, STEMM experts also hinted that being in the center of excellence could provide a sense of belonging to talented individuals, who sometimes may feel out of place in their schooling experience. One math professor gave an example:

> It's also important to give them the opportunity to meet other people that have similar interests and also talent at a comparable level… It's more about this, "Oh, this is really interesting, and there are other people that are interested in it. It's cool and I want to continue to stay in this community." I think this has a very strong effect, especially because in school, at least mathematics in school is quite dull. And usually, the classmates are not on the same level. So it's really important for them to know [that] other people who have talents feel the same.

Having like-minded and competent peers can also be motivating, as a STEMM expert remarked, "Work with people who also enjoy what they are doing, who are excited about science, it's contagious!" Thus, this aspect of being in the center of excellence could enhance both social and cultural EC.

Finally, STEMM experts proposed that being in the center of excellence may help the talented individual attract more resources, such as large grant funding, outstanding graduate students, and well-known collaborators. One engineering professor discussed this:

> The university you're at, it kind of ties into your reputation.… And part of it is in order to be good, you have to be good. You have to have that good reputation. And then you'll get the best people applying and joining your group.

Therefore, the center of excellence can also be associated with the infrastructural and economic EC. And all these resources associated with the center of excellence will likely catalyze the talented individual's pursuit of eminence.

## DISCUSSION

The present study was guided by the AMG[14] and its educational and learning capital approach.[17,18] The study had two aims. First, it investigated talent development experts' and STEMM experts' views on the most important factors for developing eminence in STEMM fields. Second, it examined whether the two groups of experts concurred or differed in their views regarding talent development in STEMM fields. To this end, we interviewed 14 TD researchers and 14 STEMM experts. The qualitative data provided evidence of all the 10 learning resources and insights into how they were utilized in the context of talent development in STEMM. Of the 341 coded segments, LC ($n$ = 184) was mentioned more often than EC ($n$ = 157). Overall, the views of the two groups of experts regarding the resources needed for talent development aligned. However, there were also some differences. In the following, we discuss the findings on the different types of capital and go into more detail about the similarities and differences between the perspectives of the two groups of experts.

## Learning capital

When asked what is important for developing eminence in STEMM, all but one of the 28 experts mentioned at least one type of LC, namely, resources for learning and talent development that are located within the individual.[17] Out of the 184 coded segments about LC, 107 were brought up by TD experts and 77 by STEMM experts. Their answers covered all five types of LC: organismic, actional, telic, attentional, and episodic.

The most frequently mentioned LC was telic LC, as many experts from both groups regarded motivation and motivation-related aspects to be essential for developing eminence in STEMM. The critical role of motivation in talent development has been well documented,[81] and the findings of our study supported it. In addition to statements about motivation in general, experts addressed the importance of passion for the domain, enjoyment of problem-solving, and setting goals. They also emphasized the critical role of perseverance in the long and arduous journey of talent development. Comparing the two groups of experts, both groups contended that extreme passion and love for the domain, as well as the enjoyment and need for solving problems, must be in place if an individual were to embark on the journey to pursue eminence in STEMM. However, regarding goals, the two groups of experts' opinions diverged to some degree. TD experts stressed the importance of having both long-term and short-term goals, whereas STEMM experts thought having short-term goals to stay on track was important but did not regard it necessary to have a fixed long-term goal, as it may restrict talented individuals from exploring all possibilities, especially at a young age. This is consistent with findings that some academic talent domains, such as engineering and medical sciences, do not require early specialization.[82,83] Indeed, in our study, professors in the fields of biosystem engineering and medicine advocated for a more free-to-explore approach, especially for talented youths.

The second most frequently mentioned LC was actional LC. Most TD experts ($n$ = 12) and half of the STEMM experts ($n$ = 7) stressed the importance of general cognitive abilities, as well as mastery of domain-specific knowledge and skills, which is consistent with previous research.[84,85] Concerning general cognitive abilities, both groups of experts talked about basic elements of intelligence and some thinking skills, such as logical thinking and creative thinking. However, within the STEMM domains, differences arose. It seemed that for STEMM domains that are more math-intensive, experts emphasized intelligence more, as experts of mathematics and physics emphasized the role of intelligence more than those in the fields of biology, medical science, and biosystem engineering. Regarding domain-specific knowledge and skills, both groups of experts talked about the importance of STEMM research skills (e.g., explaining a phenomenon and conducting experiments) and supportive research skills (e.g., presentation and grant writing). Several TD experts specifically talked about mastery of domain-specific knowledge, but surprisingly, none of the STEMM experts mentioned this.

The third most frequently mentioned LC was attentional LC, as 12 TD and eight STEMM experts acknowledged the role of attentional resources for developing eminence in STEMM fields. Experts mainly talked about three aspects related to the quantity and quality of attention. First, both groups of experts unanimously stated that it takes a lot of hard work for a long time to achieve eminence. Several TD experts used the term "deliberate practice," which refers to a type of focused and effortful practice with the purpose of improving incrementally.[36,38,40] Although STEMM experts did not use the term, they concurred by providing examples of deliberate practice. Second, both groups of experts advocated for single-minded focus, which referred to channeling one's attentional resources to one talent domain, instead of splitting attention and effort into several areas. Finally, a few TD researchers brought up the aspect of valuing time, as they reflected on the eminent people they had read about or interviewed before. They stated that eminent people knew the preciousness of time and were determined to use it wisely. Therefore, they suggested that those who aimed to become eminent in STEMM fields must also value time and use it constructively. None of the STEMM experts discussed this aspect.

Episodic LC refers to action patterns available to individuals based on their goals and the situation in which they act.[19] Six TD and six STEMM experts talked about this type of capital. Experts' statements regarding episodic LC were about metacognition, socioemotional skills, adaptive perseverance, and finding a niche. Comparing the two groups, TD and STEMM experts' views aligned well: TD experts commented on these aspects, and STEMM experts often provided examples in their own talent journey reflecting each aspect. The role of metacognition and socioemotional skills in talent development has been gaining more attention in talent research.[44,86] In addition, several TD and STEMM experts emphasized the importance of adaptive perseverance, which requires an individual to differentiate situations where they should persist and where they should give up. Finally, both groups of experts agreed that finding a niche and making unique contributions were essential for becoming eminent in a field, as indicated in Bloom's last stage of talent development[1] and supported by talent research.[43,87]

The least salient type of LC was organismic LC. Only one TD expert spoke about psychological robustness, which was counted as organismic LC. Even after the general prompt, none of the other TD experts or STEMM experts came up with any aspect related to organismic LC.

Interestingly, in a few cases, STEMM experts asked the interviewer for examples of individual factors. When enough sleep, regular exercise, and a healthy diet (these are organismic LC) were given as examples of individual factors, STEMM experts agreed that they are important for talent development in STEMM, although they did not come up with these aspects on their own.

## Educational capital

When asked what is important for developing eminence in STEMM, all of the 28 experts talked about at least one type of EC, namely, resources that are located within the individual's environment that can be used for learning and talent development.[17] Out of the 157 coded segments about EC, 81 were brought up by TD experts, and 76 by STEMM experts. Their answers covered all five types of EC: economic, infrastructural, cultural, social, and didactic.

The most frequently mentioned EC was cultural EC, which refers to value systems, thinking patterns, and models from family, schools, work environments, and society. Twelve TD and 11 STEMM experts brought up at least one aspect of cultural EC. Their responses fell into the subthemes of family values and expectations, mentoring, and societal values. Comparing the two groups of experts, their views on all three aspects of cultural EC were similar. Concerning the influence of family, previous studies showed that parents' careers in a STEMM field could influence their children's later achievement in STEMM.[88] In addition, parents' work ethics and attitudes affected their children's values and attitudes.[89] Both aspects of family and parental influences were confirmed by the two groups of experts. Experts also contended that another way of gaining cultural EC is through mentoring. TD experts stated that mentors can introduce young scientists to the domain's culture and model research attitudes and ethics for them, as suggested in previous studies,[90,91] and STEMM experts shared stories of their mentors providing such cultural EC. Finally, both groups of experts acknowledged that societal values can positively or negatively influence talent development in STEMM. Several TD and STEMM experts warned that societal values in many cultures make it more difficult for women and minority groups to pursue STEMM eminence, although one female STEMM expert also provided a positive example of her culture's influence. Furthermore, both groups of experts suggested that STEMM eminence sometimes depends on the right timing and place, which means if a scientist happens to be working in a domain or on a topic that is valued by society, for the time being, they are more likely to obtain the necessary resources for success.

The second most frequently mentioned EC was social EC, which refers to support from other people or social institutions that influence learning. Ten TD and 11 STEMM experts talked about at least one aspect of social EC. Specifically, they mentioned social and emotional support from key social agents (e.g., parents, teachers, and mentors) and a collective support network. Comparing the two groups, TD experts stressed that parents could affect their children's talent development by encouraging their interest development and providing emotional support, as found in previous talent research.[58,89] Indeed, several TD experts credited their parents' support in these ways for their success in STEMM areas. Moreover, both groups highlighted the indispensable role that great mentors play in developing eminence in STEMM from the aspect of social support. Specifically, experts mentioned that great mentors open doors, provide career guidance, share contacts and insider knowledge, and offer emotional support when mentees encounter failures and obstacles. These kinds of mentor support were consistent with previously documented mentor support.[44,90,91] In addition, STEMM experts but no TD experts mentioned two more types of social EC. The first one was encouraging teachers. Although TD researchers also acknowledged the important role teachers might play, they mostly talked about teachers in terms of didactic EC (i.e., the instruction they provide). STEMM experts, on the other hand, reflected on having teachers who were kind and encouraging, which increased their desire to invest in their respective STEMM domain. The second type of social support uniquely mentioned by STEMM experts was a collective support network consisting of a mixture of peers, colleagues, and mentors. STEMM experts contended that it was important for them to have such a network of support because people in their network were often going through the same struggles and learning how to conquer them, so they could cheer each other on. Other times, more senior researchers in this network could offer emotional support and tangible help as they have already gone through the process before.

The third most frequently mentioned EC was didactic EC, which refers to the assembled know-how involved in the design and improvement of educational and learning processes. Eleven TD researchers and five STEMM experts mentioned at least one aspect of didactic EC. The importance of two types of didactic EC was stressed by both groups of experts: a combination of appropriate challenges and sustained engagement, as well as high-quality instruction. Comparing the two groups of experts, first, both groups argued that the environment has to continuously provide appropriate challenges (e.g., authentic research opportunities and scientific competitions) for the talented individual so they can remain engaged and continue to develop. Regarding high-quality instruction, only TD experts emphasized this type of didactic EC. Perhaps STEMM experts were now beyond the stage of knowledge acquisition, therefore, thought less about the didactic resources, whereas TD experts reflected on the whole process of talent development, thus, highlighted the role of high-quality instruction. However, some TD and STEMM experts expressed concerns about mathematics and science taught in school, as the content and approach of these subjects often do not reflect mathematics and science at the university level and in the real world. Among the STEMM experts, especially mathematics and physics professors expressed such a concern, whereas experts from other STEMM domains did not. Because mathematics is a school subject that starts early on and goes on for many years, more math-intensive domains may be affected if the instruction quality is inferior.

The remaining two types of EC were less salient. Only three TD and three STEMM experts talked about infrastructural EC. Comparing the two groups, they focused on slightly different aspects of infrastructural EC. TD experts talked about infrastructural EC mainly in terms of having access to an atypical type of resources, whereas STEMM experts mainly focused on the institutional infrastructure that provided organizational support to help them progress in their tenure track and research advancement.

Finally, only two TD and two STEMM experts talked about economic EC. TD experts focused on the economic EC on a regional level, providing examples of fewer educational resources given to students from less affluent regions for their talent development. STEMM experts, on the other hand, focused on how economic EC impacted their own talent development, in terms of scholarships for attending university and grant money for conducting cutting-edge research.

### Factors combining multiple types of capital

We also identified a few factors that represent a combination of several types of capital. First, several experts talked about chance and luck in reaching eminence in STEMM fields. Initially, this did not seem to belong to any capital. Upon analyzing experts' examples, we viewed it as a combination of a few types of capital. Experts expressed luck in the sense of several seemingly unrelated or unexpected events that helped them along their journey. Often, these events represented a mixture of being in an enriching environment (cultural EC) with great mentors (social and didactic EC) and competent peers (social and didactic EC) and studying the right topic at the right time (cultural EC). Similarly, experts also talked about the importance of having a wide range of experience, which allowed them to learn about different cultures (cultural EC), meet more people (social EC), and learn how to do research from different research groups (didactic EC). Furthermore, a wide range of experience fosters the development of episodic LC. Finally, several experts talked about being in the center of excellence, which offers rich culture in the domain (cultural EC), opportunities to interact with the brightest minds in the domain (social and didactic EC), and other organizational advantages (infrastructural EC). It can also promote the talented individual's development of episodic LC. These examples supported the view of the AMG,[14] which posited a dynamic interaction between the individual and environment in the process of talent development.

### Limitations and directions for future research

The study used semistructured interviews to investigate 14 TD experts' and 14 STEMM experts' views on the most important factors for developing eminence in STEMM fields and compared the views of the two groups of experts. However, there are some limitations to the findings. First, it is important to acknowledge that not all STEMM areas were represented by the STEMM experts we interviewed. One notable limitation of the study is that perspectives from some STEMM domains, such as chemistry, computer science, and mechanical engineering, were missing. Moreover, some STEMM fields (e.g., physics) were more heavily represented than others. These limitations were due to the convenience and snowball sampling techniques. However, we contend that this investigation was an initial attempt that used an in-depth interview approach to systematically examine and compare the perspectives of these two groups of experts on talent development in STEMM. Future research should continue to explore the views of experts from other STEMM domains, such as chemistry and computer science, to understand talent development in these STEMM domains.

Furthermore, we noticed that even among the STEMM experts, there seemed to be domain-specific differences in their views. However, it is beyond the scope of this paper to systematically examine the differences among the STEMM domains. Future research should examine each STEMM domain and the similarities and differences of experts' views on talent development from different STEMM domains.

Finally, compared to the TD experts, there was more variation among the STEMM experts regarding their seniority in the field. This might be problematic because the experts' current career status (e.g., beginning of the tenure track vs. full professor for many years) could influence their perspectives on talent development. Future research should invite STEMM experts who are at the beginning, in the middle, and toward the end of their careers and compare whether there are differences among their views on talent development.

## CONCLUSIONS

This study systematically examined and compared talent development experts' and STEMM experts' views on developing eminence in STEMM fields. Guided by the AMG[14] and its educational and learning capital framework,[17,18] we interviewed TD and STEMM experts and analyzed the interview data. We were interested in (a) how each type of capital may manifest in the context of developing eminence in STEMM fields, and (b) if any additional themes beyond the current list of LC and EC may emerge from the interviews. All of the experts concurred that both individual and environmental aspects are important for developing eminence in STEMM, and all 10 types of capital were mentioned. We did not find any additional type of capital. Instead, several factors (e.g., chance and luck) represented a combination of several types of capital, which further supported the systemic approach of the Actiotope Model.[14] This study added to a small body of research that uses a qualitative approach to investigate the role of educational and learning capital for talent development.[92]

TD experts talked about more aspects related to LC than EC, whereas STEMM experts talked equally about the two aspects. The most often mentioned LC was telic capital (e.g., motivation and perseverance), actional capital (e.g., cognitive abilities), and attentional capital (i.e., working hard for a long time). The most often mentioned EC was cultural capital (e.g., cultural influences), social capital (e.g., social support), and didactic capital (i.e., opportunities for sustained engagement). TD experts' views aligned well with existing research on talent development.[85,89,93,94] The findings also show that TD and STEMM experts agreed for the most part and differed in a few places, such as the importance of long-term goals. Furthermore, STEMM experts included aspects that were not so much discussed in talent development research, such as a wide range of experience and a collective support network. Therefore, continued conversations between TD researchers and already established STEMM experts may provide more insight and clarity for talent development in STEMM fields.

## AUTHOR CONTRIBUTIONS

L.L. and H.S. designed the study, conceptualized the manuscript, and prepared the interview protocol. L.L. carried out the interviews and performed the initial coding of the data. H.S. conducted a reliability check of the coding. L.L. wrote the manuscript. H.S. revised the manuscript. Both authors read and approved the final manuscript.

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## COMPETING INTERESTS

The authors declare that they have no competing interests.

## PEER REVIEW

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