DOI: 10.1111/nyas.15108

REVIEW

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES

Attracting and developing STEMM talent toward excellence and innovation

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Funding information
German Federal Ministry of Education and Research, Grant/Award Numbers: 16DWMQP02A, 16DWMQP02B

Abstract

This article provides an overview of science, technology, engineering, mathematics, and medical sciences (STEMM) talent development from first exposure to a STEMM domain to achieving eminence and innovation. To this end, a resource-oriented model of STEMM talent development is proposed as a framework. It includes a three-stage phase model based on Bloom (1985), with the main focus on interest development in the first stage, skill acquisition toward expertise and excellence in the second stage, and style formation toward eminence and innovation in the final stage. A literature review shows that from an educational perspective, each phase is mainly characterized by the focus that Bloom postulated. However, it is important that all three stages (i.e., interest development, skill acquisition, and style formation) occur in a stage-typical manner. To explain how these primary objectives of STEMM development can be supported through STEMM talent education, Ziegler and Stoeger's (2011) educational and learning capital framework is used in the proposed resource-based model. A literature review shows that consistent provisioning of the resources specified in the model is necessary for individuals to complete a learning pathway to STEMM eminence and innovation.

KEYWORDS
educational capital, innovation, learning capital, learning resources, STEMM, talent development

INTRODUCTION

A society's ability to innovate depends on how well it attracts talent to science, technology, engineering, mathematics, and medical sciences (STEMM) fields and enables talented individuals to achieve excellence and innovation in these fields. For this reason, understanding how best to develop talent in STEMM is of great societal importance. STEMM talent development can be studied from two complementary perspectives. From a pure science perspective, interest is focused on the descriptive and explanatory aspects of STEMM talent development, whether or not it is successful. Prototypical disciplines are expertise research as well as learning and developmental psychology. From an applied perspective, interest is focused on how STEMM talent development can be practically supported, in other words, how the likelihood of someone developing their STEMM talent can be increased. Prototypical disciplines include STEMM education, STEMM didactics, and applied STEMM talent research. While both perspectives use partially overlapping models and methods, they also use divergent models and methods. This paper proposes an integrative perspective based on a resource-oriented approach that bridges the gap between basic and applied research on STEMM talent development.

Researchers have proposed various theories about talent development toward excellence and innovation.[1,2] Particularly promising approaches emphasize the evolution of talent, that is, talent is viewed

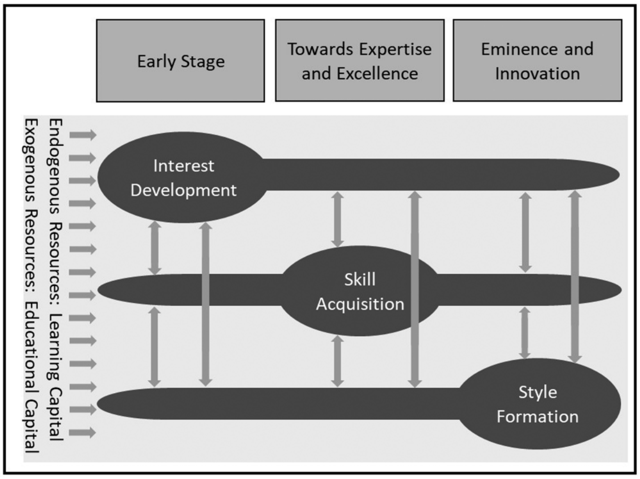

FIGURE 1 A resource-oriented stage model of STEMM talent development. Abbreviation: STEMM: science, technology, engineering, math, and medical sciences.

not as a phenomenon within a person but as an evolving entity driven by systemic interactions between individual and environmental aspects.[3,4] These approaches also help to understand why some individuals excel and others do not. One representative of such a developmental approach was Benjamin Bloom, who differentiated three stages of talent development based on interviews with outstanding individuals from different domains.[5] Stage 1 is about *interest development*. It refers to the early years of talent development, during which young talents fall in love with an idea or subject and become keenly interested in a subject or domain. Stage 2 is about *skill acquisition*. It refers to the middle years of talent development, during which talented individuals need to systematically expand and deepen their knowledge in the field and hone technical skills to a level of mastery. Stage 3 is about *style formation*. It refers to the later years of talent development, when individuals who have typically dedicated their lives to a field or domain transcend technical mastery, form a unique style, and explore original and significant problems. At this stage, talented individuals may challenge the status quo, bring revolutionary changes to their field, and create innovations.

Bloom's stages remain an important guide in pedagogical practice, but they oversimplify reality. The microdynamics of skill acquisition encompass many plateaus, dips, and leaps.[6] Moreover, interest development (and, in a broader sense, motivation processes), skill acquisition (and, in a broader sense, learning and instruction processes), and style formation (and, in a broader sense, creative and innovation processes) are not self-contained sequential stages. Indeed, talent development toward excellence and innovation is a complex cyclical process, in which motivational processes, learning and instructional processes, and creative and innovation processes are repeatedly at work to varying degrees and in different manifestations. The following will elaborate on this and describe which educational agents, support measures, and resources are essential for attracting and developing talent toward excellence and innovation in STEMM. Our model is depicted in Figure 1. It illustrates that the three stages of STEMM talent development focus on different aspects of talent support: interest development, skill acquisition, and style formation. However, these aspects are nevertheless crucial and mutually dependent in each stage. They are the primary objectives of STEMM talent support at each stage. For these to be accomplished, endogenous and exogenous learning resources are required. These learning resources constantly surround and fuel STEMM talent development, and the process comes to a standstill if they are unavailable. We will first outline the stages and their objectives before focusing on the needed resources.

STAGES OF TALENT DEVELOPMENT IN STEMM AND RELEVANT SUPPORT MEASURES AND PEDAGOGICAL AGENTS

Early stages of talent development

An entry point for talent development in STEMM is often falling in love with a topic, idea, or discipline. This can happen at any age. In early talent development, playful approaches are particularly suitable for getting individuals excited about a talent domain.[7] In this phase, parents and teachers play a crucial role. They can act as role models and spark interest in these domains through their enthusiasm for STEMM,[5,8] as well as provide learning activities (e.g., experimentation and hands-on tasks) that pique learners' interest and curiosity.[7]

Over the course of K–12 education, play-based learning in STEMM increasingly gives way to learning arrangements focused on skill and competence acquisition.[9] Moreover, learners perceived as particularly motivated and talented often receive additional support.[10] For example, this can occur in a school context in elective courses outside of regular school hours or in specialized STEMM schools.[11] More often, however, it takes place outside of school, for example, in enrichment courses, special talent support programs, mentoring, or research internships.[12,13] Research participation and mentoring have proven beneficial in sparking individuals' interest in STEMM.[5,8,14] Such support measures, in turn, increase self-efficacy and outcome expectations in STEMM and long-term career aspirations for STEMM.[14,15]

However, not all groups of learners have comparable access to such learning opportunities,[16,17] which means not all talents receive appropriate support, and some are thus lost from the STEMM talent development pipeline at a very early stage. For example, students from families with higher levels of education and socioeconomic status (SES) predominate in school and out-of-school STEMM programs. At the same time, girls and learners with a migration background or from certain ethnic groups are significantly underrepresented. It is also important to note that interest in some STEMM fields (e.g., engineering) declines during adolescence (especially among girls),[18,19] which means that talented individuals already successfully participating in support measures may be lost for further talent development in STEMM unless appropriate measures are taken to stave off declining interest in STEMM. Parents and teachers remain influential during this period; however, peers take on an increasingly important role.[20] Accordingly, support measures and, in particular, formalized mentoring programs that involve both peer and high-status role models have particularly positive effects.[21,22]

Thus, during the early stages of talent development, motivational processes (e.g., the generation and maintenance of interest) and systematic learning processes (i.e., learning and instruction processes) play an essential role. The two areas are not separable from each other but are cyclically intertwined. For example, the motivation of learners is higher when the difficulty level of learning content is slightly above the current performance level,[23,24] when learning gains are systematically made visible,[25,26] or when learning strategies are applied more successfully.[27,28] At the same time, STEMM skills and competencies as well as antecedents for later talent development (e.g., learning strategies, self-regulation skills, and scientific writing) are more likely to be acquired and more effectively learned when STEMM content is experienced as valuable and exciting.[29]

Creative and innovative processes also play a role in this early phase of talent development. However, different from later stages of talent development, creative and innovative processes are not about challenging the status quo of the field and creating socially relevant innovations,[30–32] but about unique and personally meaningful insights and interpretations as individuals learn new subject matter.[31,32] These could be new approaches to solving mathematics problems or discoveries in physics that are known but have not yet been covered in class. Such creative processes represent initial, creative interpretations that later may manifest into recognizable (and in some cases societally recognized) creations and innovations. These processes can be encouraged by parents, teachers, and mentors. Learning environments that encourage learners' curiosity and exploration, allow them to make their own decisions, and respect their opinions have proven particularly promising.[33] Creative and innovative processes are also closely related to motivational as well as learning and instructional processes.[31,32,34] For example, it has been shown that in the early phase of talent development, creative processes are mainly associated with intrinsic motivation (but see also the detrimental effect of extrinsic reinforcers),[34,35] that skills and knowledge are to some extent prerequisites for creative processes,[36,37] and that positive feedback from teachers predicts middle and secondary students' beliefs in their creativity.[38]

Talent development toward expertise and excellence

The early stage of talent development focuses on getting learners excited about a talent domain and maintaining their interest in the domain, teaching them basic skills and competencies, and enabling them to gain unique and personally meaningful insights and interpretations of the learning content. The focus in the next phase is primarily on acquiring expertise and developing performance excellence. This requires early systematic support and extensive learning processes, especially in competitive domains.[39,40] In most domains, about 10 years or 10,000 h of active, goal-oriented learning are necessary to achieve performance excellence.[39,40] The main reason for this large amount of time is the enormous amount of knowledge required to achieve excellence in most domains today. These extensive learning times do not include basic learning processes like those described above; instead, they involve approximately 10,000 h of *deliberate practice*.[41] Deliberate practice refers exclusively to highly organized, highly concentrated learning activities always aimed at improving one's performance. It is often perceived as aversive by learners, as it requires constant monitoring of one's learning process to achieve possible improvements, which requires a high level of attention. Studies show that this type of learning is significantly more conducive to performance than playful learning activities or work-based engagement with a domain focused on the error-free execution of what has been learned.[42,43] Learning processes that lead to excellence are highly complex and individualized, so they must be professionally planned and supported. For example, efficient, individually adapted learning goals must be set; learning activities designed for learning gains and tasks must be selected for a level of difficulty exactly one learning step above the current level of proficiency. Learners must also receive meaningful feedback that identifies strengths and weaknesses in the learning process, and sufficient and appropriate practice opportunities must be provided to address identified weaknesses and further develop strengths.[39–42]

Such learning processes can only be planned by highly competent individuals with an immense head start regarding experience and knowledge, both about the talent domain and planning and monitoring effective learning and motivational processes. For this reason, during this phase of talent development, learning processes are rarely accompanied by the same person or groups of people from start to finish. Instead, as the level of expertise increases, different individuals or groups of individuals become important.[5,44] In STEMM, these may initially be teachers or lecturers at universities, later supervisors at the graduate level, or content experts who have achieved excellence in the domain. Mentors also play a crucial role, for example, for dealing with the failures that often occur for the first time in this phase and for appropriately utilizing such failures for the benefit of the learning process.[45,46] Mentors also play an essential role in opening up new learning opportunities and professional networks or in helping mentees to acquire the values and insider knowledge of the domain.[5,46,47] In some cases, learners also receive support from multiple individuals with different foci. Especially in STEMM, support networks take on an increasingly important role in expertise acquisition.[44]

Not all individuals have equal access to support systems that enable them to achieve expertise and excellence in STEMM.[17] The reasons for this are varied and, along with appropriate intervention measures, form an essential area of research on talent development.[17,48–50] We will discuss some of these reasons in more detail below. However, it is impossible to completely plan and monitor such intensive learning processes without an adequate support system. Also, with increasing expertise, finding individuals who can plan and monitor the learning processes becomes increasingly challenging. Therefore, self-regulation processes are essential in talent development toward performance excellence. They refer to the ability to identify one's own strengths and weaknesses related to learning content and learning processes, to set appropriate learning goals, to plan and monitor one's own learning process, and to implement adaptations.[51,52] Self-regulation also plays a vital role in regulating one's own motivation and affect related to learning.[52,53] For this reason, self-regulation competencies should be taught early in talent development and further developed throughout expertise acquisition.[51,54,55]

The high extent of deliberate practice required for development toward expertise and excellence makes sense of study results showing that motivation and knowledge processes predict later performance equally well as high cognitive abilities.[40,56] Motivational processes are essential for both initiating and maintaining deliberate practice. For example, studies show that expectancy—value interventions that increase the expectancy of success (e.g., by teaching appropriate learning strategies and providing systematic feedback on performance gains) and the value of the learning content and domain (e.g., by discussing deep interest) motivate learners to engage in deliberate practice.[57,58] Motivation processes are also crucial for the maintenance and extent of deliberate practice. For example, studies show that the majority of learners stop deliberate practice prematurely and give up their commitment to seeking excellence.[59] Furthermore, studies indicate reciprocal relations between intrinsic motivation and deliberate practice.[60] Intrinsically motivated learners (i.e., those interested in the content and experiencing learning as valuable in and of itself) show more extensive deliberate practice; vice versa, deliberate practice leads to increased intrinsic motivation.[60]

Creativity and innovation processes are closely linked to acquiring expertise.[31,32,39,61] After years of formal schooling and acquiring expertise, talents in STEMM usually have achieved a professional-level status. They can work on problems, projects, and ideas that affect the field.[31,32] This form of creativity may include scientific publications, inventions that result in patents, or other novel contributions that advance the field. Innovative processes in this phase progress through several stages characterized by increasingly higher levels of creativity and innovation[62] but often remain within the framework of an existing paradigm. In contrast, contributions that challenge the field's status quo or bring revolutionary changes tend to be the exception in this phase.[31,32]

Eminence and innovation

At the highest level of talent development, eminence and innovation are the primary focus. Eminent achievements are achievements on the top level that meet the highest social standards, are socially recognized, and usually have historical significance for a field or beyond the field.[63] Individuals who have acquired expertise and excellence in STEMM through intensive learning processes over many years usually do not settle for merely perfecting well-known techniques and assimilating existing knowledge. Instead, they focus their efforts on rare and complex problems and aim to discover new knowledge and innovate.[41] Experts who aspire to eminence are, therefore, constantly involved in the quest for new innovative ideas and products to make a significant discovery or generate a central theoretical insight that will permanently change their domain of expertise.[42] Examples of outcomes at this stage of talent development include Nobel Prizes.

This level of talent development is reached only after many years of intensive engagement with a domain. There is evidence of a relationship between individuals' general productivity level and their probability of significantly contributing to the domain.[64–66] In STEMM, scientists usually make their first outstanding contributions in their 30s and their best in their 40s.[67–69] However, very few individuals succeed in reaching this highest level of talent development, and even those who do succeed in reaching eminence and innovation in their domain usually do so only once in their lifetime.

In order to achieve eminence and innovation in STEMM, various aspects on the side of the individual play a role, such as their expertise and performance excellence, outstanding motivation, psychosocial skills, and the ability not to be discouraged by setbacks or headwinds.[42,46,70,71] However, various external influences also have significance. For example, innovations must be accepted by a field's gatekeepers (e.g., reviewers, judges), and the domain must be willing to incorporate such innovations.[72] Accordingly, at this level of talent development, other individuals no longer primarily support learning and deliberate practice but act as sparring partners to discuss novel ideas. They also provide introductions to potential sponsors and relevant networks and help to inoculate against those who try to undermine creative and innovative work as well as help to overcome pushbacks against novel ideas.[73–75] In particular, mentors play a prominent role in this phase.[5,46]

It is worth noting that various equity gaps in STEMM also exist at this level of talent development. For example, white males from upper or middle socioeconomic classes are overrepresented. This is evident in terms of the awarding of Nobel Prizes in science, Fields Medals in mathematics, and the Charles Stark Draper Prize in engineering, among others.[17,76] Equity gaps at this level of talent development are, on the one hand, a consequence of unequal resources and opportunities at the preceding levels of talent development but are also characterized by specific resource and opportunity gaps on this level.[17] Changing the situation seems essential both from an individual and a societal perspective, particularly given that innovations today are primarily developed in teams, and diverse teams have particular potential for innovation.[77,78] However, it is not only for closing equity gaps that resources play a crucial role but also for talent development in general. In the following, we will explore this in more detail.

RESOURCES FOR TALENT DEVELOPMENT TOWARD EXCELLENCE AND INNOVATION IN STEMM

With varying weights on the three stages, interest development, skill acquisition, and style formation are the main objectives of STEMM talent support. The critical question in pursuing them is what to focus on and what factors must be considered. Due to the extensive learning processes and motivation required to develop talent toward excellence and innovation, research traditionally has largely focused on the individual.[79] However, nowadays, talent development toward excellence and innovation is increasingly seen as being located in the system of person and environment,[72] and resources at different system levels are considered crucial.[80–83] The research literature distinguishes endogenous resources (located within the individual) and exogenous resources (located in the individual's environment).

Endogenous resources/learning capital

The (subsystem) individual exclusively regulates endogenous resources. However, they can also be regulated exogenously through educational provision or feedback. Some endogenous resources that play an essential role in talent development have been discussed above. Ziegler and colleagues[84,85] systematized the endogenous resources needed for talent development toward excellence and innovation. They distinguished five types of endogenous resources, which they call learning capital: organismic, attentional, actional, telic, and episodic learning capital. The five types of learning capital are well suited for systematizing the learning and motivation processes described above and other relevant individual characteristics that are important for talent development (in STEMM). In the following, we will briefly introduce each type of learning capital.

Organismic learning capital comprises the physiological and constitutive resources of a person. These include, for example, sufficient sleep and physical fitness. The extent of existing organismic capital (e.g., sleep patterns and physical activities) shows correlations to performance already in the early phase of talent development[86] and gains further importance in the course of talent development due to increasingly extensive learning processes.[87] The same applies to *attentional learning capital*, which refers to the quantitative and qualitative attentional resources a person can direct toward learning. Individuals who later achieve excellence require attentional learning capital to systematically expand their action repertoires and dedicate sufficient time to engage with their talent domain. Numerous studies from expertise research[88] show the extent of attentional learning capital of individuals who have reached excellence or the degree to which their entire lives are focused on acquiring excellence. *Actional learning capital* refers to a person's action repertoire, that is, the total range of actions (including those of a cognitive nature, such as knowledge and skills) that they could, in principle, perform. The outcomes of excellent performers illustrate how comprehensive their actional learning capital is.[5,88] *Telic learning capital* encompasses a person's anticipated goal states that serve to satisfy needs. Telic learning capital thus encompasses various motivational processes that play a role in talent development. For example, in the early stages of talent development, telic learning capital contributes to individuals' decisions to engage in a talent domain (e.g., physics). Later, it plays a role in deliberate practice, where learners set challenging goals that are consistently above their current level of performance and not being discouraged by setbacks.[41,46] *Episodic learning capital* refers to the action patterns available to a person that are both goal-related and situation-related. In various domains, including the natural sciences, it has been shown that experts have a vast repertoire of standard solutions to typical problems,[88] that is, they have effective episodic knowledge that relates both to potential action contexts and to successful actions possible therein to achieve functional goals. This includes, for example, automated actions, available solution routines, or intuition.

Only if all of these endogenous resources are sufficient and aligned with each other is talent development toward excellence and innovation possible.[80,84,85] Providing sufficient exogenous resources at different system levels plays a unique role.

Exogenous resources/educational capital

Exogenous resources are also referred to as educational capital, which can (but need not) be used to enhance education and learning. Ziegler and colleagues[80,84,85] distinguish five types of educational capital: economic, cultural, social, infrastructural, and didactic educational capital. Biographical analyses and retrospective studies with eminent individuals have shown that during talent development toward excellence, all five types of educational capital must be provisioned in sufficient quantities at different system levels (e.g., family, educational system, country), and in an aligned manner for individuals to achieve excellence and innovation.[5,89,90] In the following, we will briefly introduce each type of educational capital.

Economic educational capital includes any kind of wealth, property, money, or valuables that can be used to initiate and sustain educational and learning processes. While economic educational capital has no direct influence on talent development, it can be used to stimulate and optimally support learning processes. In the early stages of talent development in STEMM, for example, economic education capital can be used by parents to get learners excited about STEMM, for example, by enabling them to participate in special STEMM opportunities (e.g., hands-on projects in summer programs). Studies show that children and adolescents from high SES families are more likely to take advantage of such opportunities,[91,92] which in turn has a positive impact on motivation (or telic learning capital) and achievement (actional and episodic learning capital).[93,94] However, economic educational capital also plays a vital role in the later stages of talent development. For example, individuals who have more economic educational capital are more likely to attend excellent schools and universities and invest in learning materials (e.g., books, software, labs) that support their talent development.[89,95] However, not only economic educational capital in the immediate social environment (i.e., family, educational institution) is essential, but also economic educational capital in the cultural context is necessary. For example, studies show that Nobel Prizes are awarded in heaps to researchers from countries with a high gross domestic product.[96–98] One reason is that in some research fields (e.g., particle physics), extremely high investments are needed to conduct research that can lead to innovations.[89,99]

Whether economic educational capital is used for talent development depends, among other things, on *cultural educational capital*, that is, the values, attitudes, thought patterns, and guiding principles that can favor or hinder the achievement of learning and education goals. Cultural educational capital plays a role in talent development at various system levels. For example, attitudes toward STEMM in the social context (e.g., those of parents or peers) influence whether individuals take advantage of STEMM opportunities[100,101] and whether they decide to engage in talent development toward excellence in STEMM, as well as whether they persevere in the intensive learning processes required for this purpose.[102–104] However, cultural capital in the cultural context (e.g., a society or country) is also crucial for achieving performance excellence and innovation. Numerous impressive examples of the impact of cultural educational capital on the success of national STEMM promotion strategies can be found. The appreciation of STEMM influences, for example, how much money is invested in STEMM education, which support programs that are available or whether people in a society or country perceive talent development in STEMM as valuable.[17] Gender and SES are identified in many countries as significant handicaps in attracting pupils and students to STEMM.[105] However, other cultural influences also play a major role. In South Korea, for example, although STEMM is valued, parents consider STEMM careers insecure and underfunded, so they prefer alternative careers for their children.[105] The difficulties of building cultural educational capital were dramatically demonstrated in South Africa, where STEMM was a "whites only" domain until the end of apartheid. Although extensive deracialization and restructuring of higher education was undertaken, the White (and Indian) system remained largely intact and continued to be a source of unequal educational outcomes in STEMM.[106]

Social educational capital includes all persons and social institutions that can directly or indirectly influence the success of learning and educational processes. Social educational capital can be distinguished according to whether it directly influences learning processes or generates favorable conditions for learning processes. The first category includes teachers, professors, colleagues, mentors, and scientific associations or science academies. The more extensive the social capital in this category and the greater the commitment and support competence are, the more likely individuals are to achieve excellence and innovation.[75,89] The second category includes individuals and institutions that provide access to learning situations (e.g., social relationships, network memberships, scholarship providers) or improve learning conditions (e.g., engaged parents, supportive spouses, childcare facilities). A distinctive example is the different availability of social educational capital for men and women in STEMM in many countries.[107] While women in heteronormative relationships often constitute positive social educational capital for their male partners by supporting their STEMM careers, men in such relationships often constitute negative social capital for their female partners because they require or implicitly expect them to provide greater amounts of care services required within partnerships and families (e.g., childcare, household chores). Ziegler and colleagues[108] showed that women's STEMM career trajectories depended on how much educational capital (especially social capital) was available and how they used it.

Infrastructural educational capital includes all materially implemented opportunities for action that allow learning and education. It affects the opportunity to achieve excellence and innovation in STEMM in two ways. First, the availability of infrastructural educational capital can generate interest. Typical examples are experimental kits in kindergartens or schools as well as universities or research institutions that provide access to courses or research databases. Second, infrastructural educational capital provides learning opportunities. An example is a study of 1.2 million inventors by Bell and colleagues.[109] They found that individuals whose families moved to a high-innovation area when they were young were more likely to become innovators. These exposure effects were technology-field specific. In other words, individuals who grew up in a neighborhood with a high innovation rate in a specific technology field were more likely to patent in this field.

Didactic educational capital comprises the accumulated know-how for designing and improving educational and learning processes. In STEMM, average and top performance has increased enormously in recent decades. Today's high school students, for example, exhibit mathematics competencies that used to take outstanding mathematicians of earlier centuries decades to acquire. One reason for these improvements is the enormous increase in didactic educational capital. Improved teaching methods, superior curricula, pedagogically improved learning feedback, materials (e.g., learning software, books) that are optimally designed from the viewpoint of learning psychology enable ever-higher learning yields in ever-shorter periods. An essential contribution to this has undoubtedly been made by research branches (e.g., in psychology, pedagogy, and didactics) that deal with optimal learning and instruction processes and thus create more and more didactic educational capital.

CONCLUSION

STEMM talent development is a complex process that has stimulated much research in recent years and, as a result, is increasingly well understood. Moreover, building on these findings, the implications for STEMM support at the different stages of STEMM talent development and the factors that need to be considered are becoming increasingly apparent. It was, therefore, possible to develop a model along the lines of Cartwright[110]. Such a model is antirealistic and primarily serves to systematize scientific knowledge.[111] We have proposed a resource-oriented model of STEMM talent development (see Figure 1). Our model is intended to serve as a tool for both talent development researchers in STEMM and those involved in practical STEMM talent promotion. By helping them both structure and organize information and make it more accessible and understandable, we hope for cross-fertilization and synergies between research and practice. Our model defines, first, in the tradition of Bloom,[5] the main accomplishments of the three Bloomian phases of (STEMM) talent development: interest development, skill acquisition, and style formation. These milestones of STEMM talent development can also guide STEMM talent support. In contrast to the original model, however, it was shown that although these three concerns are weighted differently diachronically across the three phases, all three concerns constantly interact synchronously within each phase, albeit with differing weights in a given phase.

Furthermore, the model emphasizes the critical role of learning resources. Through its consideration of exogenous and endogenous resources, that is, educational and learning capital, it takes equal account of individual and environmental factors. Individuals are socialized into a talent domain and adopt the practices of the community, but at the same time, they also develop individuality by pursuing innovative goals at each stage of talent development. The availability of educational and learning resources is the fuel of STEMM talent development, and developing an individual style is the ultimate goal. Where many learning resources are concentrated, excellence clusters.[112–114] Ziegler and Stoeger[17] refer to *megatopes*, which are environments in which excellence and innovation are concentrated and are characterized by an outstanding degree of learning resources. Megatopes can be a model for practice in many respects. For example, the People's Republic of China has been extremely successful at the International Mathematical Olympiads. Its representatives have performed best at the last three Olympiads.[115] Like most countries, they train the members of their teams.[116] On a very concrete level, such megatopes are best-practice examples of how countries can improve their nomination systems, team training camps, the selection and training of coaching teams, and so on. More abstractly, they can also teach, for example, how social and infrastructural educational capital can be successfully orchestrated.[117]

Looking into the future, the framework of learning and educational capital can help to systematically design megatopes for the stages of STEMM talent development and STEMM talent education. When doing so, it is critical to keep the principle of continuity in mind.[118] Quality learning opportunities in STEMM must be available along the entire learning pathway in STEMM for interest development, skill acquisition, and style formation. If the chain breaks, so does the learning pathway. Unfortunately, this is increasingly true for vulnerable groups, who have historically been the victims of equity gaps in STEMM development.[17] However, wherever educational capital and learning capital are available in sufficient measure, there is STEMM talent.

AUTHOR CONTRIBUTIONS

H.S. and A.Z. conceptualized the manuscript. H.S. wrote the first draft of the manuscript. L.L. and A.Z. revised the manuscript. All authors read and approved the final manuscript.

ACKNOWLEDGMENTS

This research was conducted as part of the project MesH_MINT, funded by the German Federal Ministry of Education and Research (16DWMQP02A, 16DWMQP02B). The authors assume full responsibility for the contents.

Open access funding enabled and organized by Projekt DEAL.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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How to cite this article: Stoeger, H., Luo, L., & Ziegler, A. (2024). Attracting and developing STEMM talent toward excellence and innovation. *Ann NY Acad Sci.*, 1–10. https://doi.org/10.1111/nyas.15108