From STEM to STEAM: A Conceptual and Theoretical Analysis of Multidisciplinary Learning in School Education

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Abstract

The swift change of modern societies under the influence of scientific development, technological progress, and complicated problems in the world has made it necessary to reconsider the traditional school education. In reaction, STEM education became a reform based strategy to enhance analytical thinking, scientific literacy and technological competence. Nevertheless, the technical pre-eminence of STEM has been more and more challenged as lacking in creativity, human values and comprehensive development of the learner. This issue has resulted in the conceptual development of STEM into STEAM by incorporating the arts. The current chapter provides a qualitative and theoretical discussion of the current shift of STEM to STEAM in the school settings focusing on its application as a multidisciplinary learning model. Using constructivist, experiential learning, multiple intelligences and progressive learning theories, the chapter focuses on the ways in which STEAM creates integrative knowledge construction, creativity and meaningful learning. It also discusses STEAM education as a reaction to the modern curriculum changes, especially in reference to the goal of multidisciplinary and holistic vision of the National Education Policy

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Publisher: Anu Books, DOI: https://doi.org/10.31995/Book.AB355-F26.Ch.12
Book: Innovative Researches in India: Trinity of NEP 2020, IKS & Technology
Plagiarism Report: 05%

2020. There are pedagogical implications, the transformative role of teachers, and the conceptual challenges that are highlighted in the discussion in implementation of STEAM in schools. The chapter ends by concluding that STEAM education is an important pedagogical shift that can foster holistic growth, creative problem-solving, and competencies essential in the face of the future in school learners.

Keywords: *STEAM Education, STEM Education, Multidisciplinary Learning, School Education, NEP 2020*

1. Introduction

Modern school education is experiencing a great shift owing to the advancing scientific ideas, technological revolution in addition to the changing needs of the knowledge based global community. Pedagogical methods that are traditional, subject-dependent and rote-based are more often than not considered as insufficient to equip the learners with the ability to handle complex problem situations in the real world which involve creativity, adjustability and inter-disciplinary thinking. In this regard, the idea of Science, Technology, Engineering, and Mathematics (STEM) education became a reform-based program that should enhance problem-solving and scientific reasoning skills and technological competency in school students (Bybee, 2013). Step-technological education has been instrumental in thinking critically and creating new things, but its technical nature has been criticized as a failure to focus on the human aspect, creativity, and social-cultural aspects of learning.

The increasing realization that innovation is not purely a technical activity has seen the conceptualization of STEM to be extended to STEAM, incorporating the Arts. STEAM education recognizes the need to consider creativity, design thinking, aesthetics, and ethical reasoning as the key elements of meaningful learning and innovation. The scholars make a case that the presence of arts benefits students in terms of their interaction, creativity, and capacity to link abstract scientific information to lived human experiences (Henriksen, 2017). This movement represents a wider teaching philosophy that attaches importance to the overall development of the learner as opposed to academic specialization.

Pedagogically, the shift of the acronym STEM into STEAM can be seen as the shift to multidisciplinary learning, where knowledge

is built through the meaningful combination of different disciplines as opposed to being taught individually. Learning through a multidisciplinary approach helps the student to address real-life issues that are not disciplinary and hence leading to a greater level of understanding and transferable skills. It has been presumed that these integrative modalities conducive to higher order thinking, teamwork, and innovation, the 21 st century competencies (Perignat and Katz-Buonincontro, 2019). Both in school education and in general, STEAM-based learning environments provide opportunities to follow inquiry, experiment, reflect and express creativity, thus aligning the learning processes with natural cognitive and developmental patterns of children.

The theoretical backgrounds of constructivism and experiential learning also enhance the conceptual context of STEAM learning. Constructivist theory points out that learners are actively engaged in building knowledge as they interact within an environmental context whereas the experiential school of thought puts an emphasis on reflection about real experiences in building meaning. STEAM pedagogy and its focus on project-based learning, design challenges, and collaborative inquiry are aligned well with these theoretical views (Kolb, 2015). Combining science with artistic processes, STEAM education helps to provide a wide range of ways of knowing and learning, thus catering to the interests and intelligences of different learners.

In the Indian educational framework, the emphasis of multidisciplinary and holistic education expressed in the National Education Policy (NEP) 2020 adds to the topicality of STEAM education in school. NEP 2020 promotes the concept of incorporating arts, creativity, and learning as an experience in all curricular subjects, abandoning disciplinary silo thinking in favor of dynamic and learner-driven forms of education. Therefore, the transformation of STEM to STEAM is not only a change in the curriculum, but a philosophical and conceptual change in the way of school education.

It is on this background that this chapter makes a conceptual and theoretical examination of STEM to STEAM in schools. It aims to discuss the philosophical foundations, theoretical basis, and interdisciplinary quality of STEAM education with reference to its

ability to make the school learning more multiphased, purposeful, and future-oriented.

2. Conceptual Understanding of STEM Education

Science, Technology, Engineering, and Mathematics (STEM) education became a strategic educational solution to the increased need of scientific literacy, technological proficiency and innovation led economic growth. In theory, STEM education is not just a combination of four subjects but a model integrating approach to underline the interrelatedness of scientific inquiry, technological use, engineering design, and mathematical reasoning. The fundamental aim of STEM education in school level is to develop the capacity of learners to utilize disciplinary knowledge on real-life issues by way of analytical thinking, logical reasoning, and systematic problem solving.

In educational perspective, the concept of STEM education is based on the premise that significant learning takes place when learners are the participants of the learning process as opposed to the recipients of information. This model emphasizes an inquiry-based learning experience, experimenting and designing tasks, giving learners an opportunity to investigate phenomena, hypothesizing and building solutions. According to Bybee (2013), STEM education is perceived as a tool of developing scientific habits of mind, which comprise of curiosity, evidence-based reasoning, and innovation-driven thinking. These habits are believed to be necessary in equipping the students to be useful in a fast-changing technological community.

One of the salient features of STEM education is that it is interdisciplinary. As opposed to conventional subject-oriented teaching, STEM promotes the incorporation of ideas in different domains in order to solve real-world problems. As an example, scientific knowledge, mathematical modeling, and technology can be used to solve an engineering challenge at the same time. Kelley and Knowles (2016) stress that such an integrative approach facilitates the development of a deeper conceptual knowledge through allowing the learners to regard knowledge as integrated as opposed to separated. Concrete benefits of this interdisciplinary focus at the school level include imparting to students transferable skills, including critical thinking, teamwork, and flexibility.

Experiential and problem-based learning is another valuable conceptual characteristic of STEM education. The activities used in learning are usually based on real-life situations relevant to the learners hence making them more involved and memorable. Studies indicate that these learning environments facilitate the process of higher-order learning and make learners own up the learning process (Perignat and Katz-Buonincontro, 2019). Students can apply their theoretical knowledge and practice through real-life experimentation and design activities.

Nevertheless, as much as STEM education has played a major role in enhancing analytical and technical skills, researchers have expressed its inadequacy to look after creativity, ethical thinking and socio-cultural awareness. The highly technical emphasis has occasionally led to the fact that learning has been conceived in a very limited sense, where imagination, aesthetics and human oriented views are not given the necessary value. This theoretical shortcoming has encouraged teachers and scholars to reconsider the definition of STEM education, which eventually resulted in the development of STEAM as a more comprehensive and inclusive method of education.

3. Emergence of STEAM Education: Conceptual Shift

Although STEM education has been critical in enhancing analytical and technical skills among school students, there has been a growing academic debate that has pointed at its weaknesses in providing students with creative and imaginative capabilities and the human aspects of education. Contemporary societies are becoming more and more demanding of innovation to include not only scientific and technological skills, but also creativity in thinking, sensitivity in designs, moral judgment, and cultural sensitivity. This understanding has caused the conceptual development of STEM into STEAM by introducing Arts into the science and technology learning intentionally.

STEAM education broadens the foundations of STEM in that the arts are seen as central to problem-solving and innovation as opposed to being peripheral/additional subjects. Creative processes of visualization, storytelling, design, and aesthetic reasoning are some of the creative processes that the arts contribute to the capacity of learners to conceptualize problems in multiple ways. Henriksen (2017) concludes that arts learning in STEM fosters imagination and innovation since it

encourages a learner to think divergently and think convergently. This integration is used in school education, which helps to make abstract scientific concepts more relatable and meaningful to the learners.

In theory, STEAM education signifies the move towards a more technicalized approach to learning, to a comprehensive educational paradigm, one that not only appreciates the cognitive aspect of the development but also the affective aspect of it. A mixture of artistic practices contributes to the development of emotionality, empathy, and cultural awareness, which humanizes scientific and technological learning to the extent of STEAM. This model is in line with the modern educational ideologies of holistic development of the child and learner-centered education. Researchers indicate that the STEAM learning environment provides a student with a chance to relate knowledge to their own experiences, social situations, and moral factors (Land, 2013).

The shift to STEAM as well indicates a more general shift towards the integrative and multidisciplinary learning. STEAM breaks down the inflexible academic lines through promotion to merge scientific investigation and the arts. As an example, the engineering design problems in STEAM classrooms can be considered to include artistic design principles, narrative construction, and aesthetic assessment, which enables students to tackle the problems more loosely and creatively. This kind of learning experience leads to better conceptual knowledge and ability of learners to transfer knowledge between contexts (Perignat and Katz-Buonincontro, 2019).

In school learning, STEAM education can provide a more varied structure that can embrace the diverse learning abilities, interests, and intelligences of learners. Through respecting artistic expression and applying scientific thought, STEAM develops fair learning environments that consider the use of various intelligence types and foster them. Therefore, the introduction of STEAM education represents the conceptual shift towards the multidisciplinary, creative, and human-focused learning and the basis to the more balanced and future-oriented education.

4. Theoretical Foundations of STEAM Education

The conceptual soundness of STEAM education is highly endorsed by the existing learning theories that drive active learning

and meaning-making through experiences and holistic development of learners. As opposed to conventional transmission-based methods of teaching, STEAM pedagogy relies on the constructivist and progressive teaching philosophy according to which learning is perceived as an interactive, dynamic and contextual process. All these theoretical frameworks confirm why arts should be integrated in school learning along with science and technology.

Constructivist Learning Theory offers the main theoretical foundation of STEAM learning. Constructivism is based on the writings of Piaget and Vygotsky, and constructivism is assumed to be a process where the learner engages in the construction of knowledge by interacting with the surrounding and social contexts. Inquiry-based, experimentation-based, and collaborative problem-solving exemplifies of STEAM learning environments allow students to learn by exploration and not by rote memorization. These conditions can foster more conceptual learning through the provision of students to relate new knowledge with the previous understanding and life experience (Fosnot, 2013). Constructivist learning is further boosted by the fact that the artistic processes help to promote the representation of symbols, visualization and creativity.

STEAM education is also rooted in critical theoretical basis of Experiential Learning Theory especially the learning cycle as introduced by Kolb. This theory suggests that learning is a cyclical process that makes use of concrete experience, reflective observation, abstract conceptualization, and active experimentation. STEAM pedagogy can be easily integrated with this cycle as it involves the students into practical projects, design tasks, and critical thinking. This is because these experiences can help the students combine theoretical learning with practical application, which will help them to create meaningful and durable learning results (Kolb and Kolb, 2017). The Theory of Multiple Intelligences by Gardner also enhances the theoretical justification of the STEAM education. This theory disputes the prevalence of linguistic and logical-mathematical intelligences in the conventional education by acknowledging varied forms of intelligences such as spatial, bodily-kinesthetic, musical, and interpersonal intelligences. Arts and creative practice, as implemented

in STEAM education, gives learners the chance to utilise more than one intelligibility, thus leading to diversity and customised learning experiences (Gardner, 2011). Also, progressivism and pragmatism have a role in the philosophical background of STEAM education. These schools of thought focus on learning through action, practical applicability and social usefulness of knowledge. The approach to solving real-life issues via interdisciplinary inquiry allows the STEAM education to reflect the pragmatic ideals and equip learners to handle intricate social and technology issues. Altogether, these theoretical premises make STEAM education a pedagogically decent and future-oriented model of multidisciplinary education in school schools.

5. STEAM Education as a Multidisciplinary Learning Approach

Multidisciplinary learning is an educational model whereby knowledge across several disciplines is convened to explore a similar theme or issue even though each of the disciplines maintains its epistemological core. This methodology can be used in school education so that it allows learners to have a more comprehensive view of the concepts, comparing them across disciplinary perspectives. The example of STEM education demonstrates the concept of multidisciplinary education since science, technology, engineering, mathematics, and arts are purposely combined to tackle real-world issues that cannot be sufficiently addressed through a one-subject lens.

In contrast to traditional subject-based learning, that tends to separate the knowledge into compartments, STEAM-based learning encourages the significant juxtaposition of disciplinary concepts. An example would be a classroom project that is based on sustainable architecture and would include scientific concepts of energy conservation, mathematics, engineering design cycles, technology, and aesthetic and culture issues. This type of integration promotes the learners to appreciate that knowledge is interrelated and cognitive flexibility is facilitated. Drake and Reid (2020) purpose that multidisciplinary learning classrooms aid in conceptual coherence and facilitation of learning transfer in other contexts.

The STEAM education is also very similar to the inquiry-based and problem-based learning models, which are also the core of multidisciplinary pedagogy. The instruments and ideas in various

disciplines encourage students to ask questions, explore issues, come up with solutions, and reflect on results. This is where we foster the skills of higher order thinking which include analysis, synthesis and evaluation. The studies indicate that STEAM-based multidisciplinary learning results in a higher level of creative and collaborative application of knowledge and readiness to handle more complicated problem solving scenarios in real life (Quigley and Herro, 2016).

Moreover, STEAM learning encourages the learning culture of collaboration at schools. Teamwork, communication, and shared decision-making are something that multidisciplinary projects usually demand, and it gives learners an opportunity to interact with varying views and methodologies. The benefits of such collaborative experiences are in addition to the subject understanding, the experiences facilitate social and emotional skills, such as empathy and respect. According to Perignat and Katz-Buonincontro (2019), multidisciplinary learning based on STEAM is both cognitively and personally effective because it balances the analytical rigor and creativity in an exploration.

In school education, STEAM as a multidisciplinary educational approach has a flexible structure that allows different interests and abilities of learners. Through the appreciation of both the arts and science, STEAM disrupts the hierarchical organization of subjects and fosters education equity. Therefore, STEAM education could be a paradigm of interdisciplinary learning that overcomes the barriers of disciplinary knowledge, creativity and applicability of that knowledge in real-world situations, adding value to more integrated and significant educational experiences of school learners.

6. Alignment of STEAM Education with NEP 2020

National Education Policy (NEP) 2020 is a major change in paradigm in Indian schooling in the sense that it focuses on holistic, multidisciplinary, learner-centered teaching and learning. The breakup of disciplinary silos and encouraging curricular integration to achieve creativity, critical thinking, and conceptual knowledge is among the cardinal points of NEP 2020. In this respect, STEAM education is very much correlated with the philosophical and pedagogical vision, which is described in the policy. NEP 2020 directly promotes

experiential learning, inquiry-based instruction and incorporation of arts, sports and vocational skills throughout the school education. The focus of the policy is on creativity and aesthetic sensibility as the key educational outcomes and the arts are regarded as part and parcel of cognitive and emotional development rather than co-curricular activity that is optional. STEAM education realizes this vision through integrating the process of arts into the scientific and technological education, thus contributing to the focus of the policy on the holistic development of learners (Government of India, 2020).

In addition, NEP 2020 encourages multidisciplinary learning as the way of equipping learners with complex challenges in real life. The nature of STEAM education is that it enables interplay between scientific thinking, technology, engineering design, mathematical reasoning, and artistic thinking. This convergence reflects the international views on the integration of curriculum, in which the ideas of multidisciplinary approaches are taken as the means of the conceptual coherence and interest of the learner (Drake & Reid, 2020). Project-based and design-based learning experiences provided through STEAM help NEP to achieve the objective of not only memorizing knowledge and studying it but also accessing it and gaining a deeper insight into the knowledge itself.

Another aspect that the policy brings to light is the need to develop 21 st century skills of problem-solving, collaboration, communication and adaptability. The competencies naturally develop in an environment based on STEAM because the model allows promoting teamwork, reflective thinking, and creative problem-solving. It has been found that integrated learning models promote cognitive and socio-emotional skills, which is in line with the vision of NEP 2020 of teaching as a way to produce responsible, creative, and socially responsible citizens (Perignat and Katz-Buonincontro, 2019).

Therefore, STEAM education may be considered a pragmatic and pedagogically effective model by which NEP 2020 transformative objectives in an educational institution can be achieved. STEAM can be viewed as an effective policy implementation and education reform strategy because it focuses on multidisciplinary integration, creativity, and experiential learning.

7. Role of Teachers in Implementing STEAM Education

The role of teachers in the successful realization of STEAM education in schools cannot be underestimated, because the success of learning in the multidisciplinary learning heavily relies on pedagogical vision, instructional design, and classroom practices. The shift of the conventional subject-centered instruction to the STEAM-based one necessitates the teachers to re-imagine their roles as transmitters of information by inquiry, creativity, and collaborative learning. This change is consistent with the educational philosophies centered on learning that are learner based and focused on active learning and construction of knowledge. The teacher in STEAM classes is a learning designer that designs meaningful learning experiences that mediatize various disciplines around real-world problems. Instead of learning topics separately, students are instructed by teachers on learning concepts through projects, design challenges and inquiry-based tasks to integrate scientific reasoning and artistic expression. These pedagogical practices require flexibility, creativity and thorough knowledge of interdisciplinary linkages. As stated by Quigley and Herro (2016), the teachers who practice the STEAM pedagogy should be ready to deal with the uncertainty and open-ended learning process because the results tend to be the emergent ones, not predetermined. Another important aspect of the work of teachers in STEAM education is collaboration. Multidisciplinary learning may require collaborative pedagogy in which the educators in various subject areas collaborate to plan and execute integrated learning experience. This group process does not only enhance curriculum planning, but also teaches the students how to think interdisciplinarily. It is indicated that collaborative teaching contributes to a higher level of pedagogical coherence and promotes the successful combination of arts and STEM subjects (Henriksen et al., 2020).

In STEAM learning institutions, teachers also have the role of creating inclusive and conducive learning environments that take into consideration the differences in abilities and intelligences among learners. Using the artistic processes of visual design, storytelling, performance, the teachers can attract students with different learning preferences and strengths. This inclusivity is in line with the

constructivism and multiple intelligences theories, which focus on meaningful and personalized learning processes (Gardner, 2011).

Furthermore, STEAM education implementation needs lifelong professional education and contemplation. Teachers need to continue professional growth as a way of improving their interdisciplinary content knowledge, pedagogical expertise, and belief in the innovative teaching techniques. Theoretically, teacher preparedness to STEAM does not depend on technical knowledge but expands to pedagogical flexibility, reflective practice, and innovation readiness. Therefore, educators are the key change agents on how to transform the theoretical potential of STEAM education into classroom work.

8. Challenges in the Transition from STEM to STEAM Education

Although the shifts towards STEAM education are evidenced by a solid theoretical and pedagogical justification, the process of the shift between STEM to STEAM in school education is also characterized by a number of conceptual, structural, and pedagogical issues. These problems are not only operational but deep-seated in the conventional education ways of thinking, curriculum models and evaluation methods that still favour disciplined compartmentalization and content-intensive learning. Among the main issues is a strict design of curriculum that focuses on subject-related learning outcomes and standardized content coverage. Conventional curriculums typically do not allow much freedom of structural interdisciplinarity and creative inquiry, and it is hard to meaningfully integrate artistic processes into STEM areas. Researchers state that without curricular flexibility, STEAM will be simply an attempt to superimpose the arts, which will be used as supplements to learning and not as a part of it (Land, 2013). This shallow kind of integration compromises the conceptual integrity of STEAM education.

Another important challenge in embarking on STEAM is teacher preparedness. Numerous educators have been oriented in discipline-based paradigms and might not be confident or knowledgeable in the use of arts to be integrated with scientific and technological teaching. Lack of interdisciplinary pedagogical training may lead to unwillingness to innovate or to use old methods of

teaching. According to Henriksen et al. (2020), the successful application of STEAM needs a change in the beliefs of the teachers regarding knowledge, learning, and assessment, which would have to be maintained throughout the professional growth and institutional learning.

The conceptual issues with STEAM education are also based on assessment practices. Traditional measurement plans can tend to focus on the memorization of facts, the use of procedures, which are inadequate in assessing creativity, teamwork and design thinking and reflective learning. Absence of alternative assessment frameworks in line with STEAM pedagogy can deter multidisciplinary approaches by the teachers. It has been proposed that integrating pedagogy and assessment is limited in its transformative power when there is a lack of alignment between the two (Perignat and Katz-Buonincontro, 2019). Also, institutional and cultural aspects determine the usage of STEAM education. The culture of the school that embraces high performance in examinations instead of exploratory learning may stop pedagogical development. Lack of resources, time and administrative pressures also make implementation even harder. Theoretically, these issues indicate the necessity of systemic change, as opposed to a particular instructional reform. In this way, although the STEAM education seems to be a powerful multidisciplinary paradigm, its effective transformation of STEM implies a new approach to curriculum design, teacher education, and assessment philosophies. These issues have to be tackled in order to achieve the potential of STEAM as a comprehensive and transformative method of school education.

9. Educational Implications of STEAM Education

There are far-reaching implications of this conceptual change towards STEM to STEAM education in school education especially curriculum design, pedagogy, learner development, and even the philosophy of education. Being a multidisciplinary model, STEAM defies traditional ideas of subject precedence, and demands a more holistic and learner-oriented process of schooling. STEAM education, in terms of curriculum, requires integrative and flexible curriculum frameworks that enable significant cross-disciplinary interactions. Instead of structuring the learning process around discrete subjects,

the curriculum must be structured around themes, real-world issues and inquiry-based projects that inherently tap into scientific, mathematical, technological, and artistic knowledge. The given approach facilitates conceptual integrity and allows learners to comprehend the applicability of knowledge outside of textbook contexts (Drake and Reid, 2020).

The aspects of STEAM education that promote the relevance of experiential, inquiry-based, and project-oriented approaches to learning include pedagogical implications. Teachers would be urged to play facilitative roles guiding the learners to exploration, design, reflections and expression of creativity through processes. Such instructional changes enhance a more interactive approach and the development of the higher-order thinking strategy, including analysis, synthesis, and evaluation. It has also been found out that integrated learning environments improve the ability of students to creatively solve problems and learn together (Quigley and Herro, 2016). When it comes to the learner development, STEAM education promotes the comprehensive development of learners, as it pays attention to the cognitive, emotional, social, and creative aspects of learning. STEAM allows different types of intelligences in the classroom by respecting both the artistic expression and scientific thinking, which ensures inclusivity in the classroom. The approach works in harmony, which is why creativity, empathy, adaptability, and ethical awareness are developed, qualities that are becoming more and more crucial in multifaceted and rapidly evolving communities (Perignat & Katz-Buonincontro, 2019). On a larger scale, the STEAM education brings consequences to the philosophy of education per se. It is a shift towards models of schooling that are reductionist and exam-based to models that are more human-centered in their understanding of education which focus on meaning-making, innovation, and social relevance. In this regard, STEAM education is harmonized with the modern global and national educational reforms that aim at equipping the learner not with employment only, but also with the responsible citizenship and lifelong learning.

10. Conclusion

The shift in STEM to STEAM education indicates the radical conceptual and theoretical reorientation of school education. Although STEM education has been part and parcel in the creation of scientific

literacy and technical competence, its diversification to STEAM indicates an increased acknowledgment of the value of creativity, arts and human values in significant learning and innovation. STEAM education can provide a more comprehensive and inclusive structure of multidisciplinary education by combining artistic processes with scientific and technological investigation.

The chapter has conceptually and theoretically discussed the idea of STEAM education by looking at its roots, theoretical basis, adherence to the multidisciplinary learning concepts, and applicability in the modern day educational setting including NEP 2020. As noted in the discussion, STEAM is not an additive model but a transformative model of education which breaks disciplinary boundaries and facilitates the creation of knowledge through integration.

Although curriculum rigidity, teacher readiness, and assessment practices are challenging aspects of STEAM education, the theoretical potential of the approach continues to be inviting. The best way to overcome these obstacles is through a systemic re-evaluation of the curriculum design, pedagogical strategies, and professional development patterns. In a theoretical sense, STEAM is an approach that provides a way to rethink the idea of school education as an interactive, imaginative, and human-focused venture.

To sum up, STEAM education has great potential to change the way school learning is conducted as it leads to the development of creativity, critical thinking, collaboration, and holistic growth. With the global education system trying to adapt to the culture of the 21st Century, STEAM is a theoretically sound and multidisciplinary model that can produce future-recommended learners who are capable of dealing with complexity with a degree of creativity, compassion, and intent.

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