Chapter 6
Policy and Pedagogy: International Reform and Design Challenges for Science and STEM Education

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6.1 Beyond Knowledge – 21st Century Competencies: Skills, Character and Meta-Learning

The models and frameworks for education are changing, and rapidly. Globalization, rapid technological changes, and emerging markets along with the national standardization of education systems are raising important questions and issues about educational goals and outcomes. Policy, standards, and research syntheses documents, while addressing important epistemic, equitable and ethical complexities for the design of STEM learning environments and ecosystems, are nonetheless serving as disruptive agents posing significant policy and pedagogy challenges. Moreover,

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an emerging concern is that the introduction of policy agendas such as those found across Asia/Pacific nations, in the European Union Science Framework and the US Next Generation Science Standards (NGSS) as well as those among state and local educational systems are being challenged by (1) innovation and improvement efforts borne out of workforce needs and (2) research on learning, teaching, and designing curriculum, assessments, and learning environments.

Learning progressions, incorporation of engineering into science standards, characterizations of scientific evidence, styles of reasoning, scientific practices, student engagement in knowledge construction, and teacher professional learning communities are the topics and themes taken up in a *Journal of Research in Science Teaching* Special Issue on the NGSS (NGSS Lead States, 2013). The *JRST* editors sought to engender scholarly reflections on educational policy and reform efforts. The lead editors state:

> Given the significance of the NGSS for the field of science education … .it is incumbent upon the science education research community to engage in critical examination of the NGSS, its underlying framework (NRC 2012), and its cascading effects… Our goal in putting together the issue was to encourage thoughtful, critical, and constructive examination of the NGSS … [that] can and should inform international policy around science standards, state and district-level decision making, design of curricula and assessments, and classroom implementations. (Sadler & Brown, 2018)

Richard Duschl's motivation for proposing the NARST sponsored ESERA session, reported here, was his personal reaction to the articles in the *JRST* NGSS Special Issue. While he agreed with many of the comments and positions taken by the authors and editors, he was struck by implications for policy and policy processes. As a member of the National Assessment of Education Progress (NAEP) 2009 SCIENCE (NAGB, 2008) redesign planning committee, Chair of the committee that produced the NRC *Taking Science to School* (2007) synthesis research report and then served as a member of the NGSS Leadership Writing Team, co-chair of the Earth/Space Sciences writing group he became informed about guidelines and polices, as well as the audiences of policymakers (ministries, departments of education, schools, etc.) that needed to be considered and adhered to when preparing documents and protocols for national standards and tests.

As such, while the *JRST* NGSS Special Issue authors' and editors' comments and criticisms are well founded, many of them could not be considered when preparing the NAEP and NGSS documents. The cardinal rule was to avoid any language regarding how to teach, how to sequence instruction, or otherwise attempt to guide instructional implementation decisions. That was to be left up to local decision making of the States and Districts. Thus, of the many criticisms leveled in the *JRST* NGSS Special Issue while cogent for subsequent implementation and design recommendations for States and Districts, it raises questions and issues about the framing and writing of policy documents as well as the adopted development procedures and objective-setting goals therein. Thus, there are questions about how reform documents attending to standards and assessment are constituted. Others have weighed in on this, too. Ault's *Challenging science standards* (2015) and Rudolph's *How we teach science: What's changed and why it matters* (2019) both examine 20th century deliberations regarding how accountability-driven standards determine what science should be taught and how fluctuating curriculum designs favoring either content/knowledge or process/inquiry over the last century has influenced the policies, practices, and images of how science is done.

Standards documents are inherently political documents, inasmuch as they are forged out of numerous compromises and tradeoffs to accommodate differences of opinion regarding 'what counts' as the right curriculum, instruction, and assessment models. In the case of the United States Next Generation Science Standards (NGSS, 2015), determining and negotiating the design and content of science standards were influenced right from the beginning by several factors. One factor was the Framework document (NRC, 2012) that set down the 'Three Dimensional' teaching and learning guidelines for K-12 science education: Science & Engineering Practices, Disciplinary Core Ideas, Crosscutting Concepts, as mentioned in the above quote.

A second factor was the influence of the first implementation of science education standards in the 1990s. By 2010, two-thirds of US States had developed State Science Standards guided by the National Academy of Science (NRC, 1996) *National Science Education Standards* (NSES). The other one-third of the States developed Science Standards guided by the American Association for the Advancement of Science (AAAS 1993) *Benchmarks for Science Education*. While surveys showed that the NAS and AAAS frameworks had 80% agreement with respect to conceptual content, one salient difference was the organization of Standards by grade levels in the NSES and by grade bands in the Benchmarks. The drafting of new NGSS needed to recognize this geographic distribution problem, and hence uptake of the new Three Dimensional guidelines by incorporating both the grade level NSES learning goals (K, 1, 2, 3, 4, 5… 12) and the grand band Benchmarks learning goals (K-2,3-5, 6-8,9-12). The NGSS leadership team and writers were instructed that the new NGSS framework, in order to accommodate State Department of Education adoption and transitioning, would need to embrace both grade level and grade band organizational formats. A third factor in shaping the NGSS documents was the politically charged atmosphere around States rights and the US tradition of local control of education. The dissemination and adoption of the Core Common Standards in mathematics and in English Language Arts was met with resistance by many States.

A moderated 'Symposium' was assembled to bring together seven panelists with expertise and experiences in international/national policy, standards, assessment, and/or leadership experiences in science learning and learning environment design. Panelists were asked to come prepared to examine and discuss the challenges/opportunities, tensions/agreements that arise when making policy and pedagogical decisions at school, district, state, and national levels.

Four reports bridging the domains of policy and pedagogy were examined and discussed (See Table 6.1). Two thorough and comprehensive reports focused on future 21st Century educational systems and on curriculum knowledge, literacy, and skill guidelines: OECD's *The Future of Education and Skills 2030*; and the Center for Curriculum Redesign's *Four-Dimensional Education: The Competencies*

Table 6.1 Four education policy reports

Report 1 – Rapid globalization and technological development pose social, economic and environmental challenges and opportunities for human development. Countries need help designing instructional systems that prepare students for an uncertain future world.	OECD 2030 Policy and Pedagogy: International Reform and Design Challenges of Science and STEM Education http://www.oecd.org/education/2030/
Report 2 – Students are not being prepared to "fit in with the world of the future, empowering them to actively work to improve it further." Education is not adapting quickly enough to a future consisting of greater volatility, uncertainty, complexity, and ambiguity	Center for Curriculum Design (2015) Four-Dimensional Education: The competencies learners need to succeed. https://curriculumredesign.org/our-work/four-dimensional-21st-century-education-learning-competencies-future-2030/
Report 3 – The NAE report examines international large-scale assessments (ILSA) and asks two questions: "What do the results of such assessments tell us about the strengths and the weaknesses of a nation's education system?" and recognizing that national education contexts and systems vary widely, "What do these assessments really tell us?"	National Academy of Education (2018) International Education Assessments: Cautions, conundrums, and common sense. https://naeducation.org/methods-and-policy-uses-of-international-large-scale-assessments/
Report 4 – Increasing the motivation and achievement of students studying STEM subjects poses challenges for European education systems. To augment the findings of the 2018 STEM Education Policies Report, Scientix used STEM Education Practices Survey, looking to assess how STEM teachers organize teaching practices.	Science, Technology, Engineering and Mathematics Education Practices in Europe. Scientix Observatory report. December 2018, European Schoolnet, Brussels http://www.scientix.eu/documents/10137/782005/STEM-Edu-Practices_DEF_WEB.pdf/b4847c2d-2fa8-438c-b080-3793fe26d0c8

Learners Need to Succeed. The OECD report poses two questions: What knowledge, skills, attitudes, and values will today's students need to thrive in and shape their world? How can instructional systems develop these knowledge, skills, attitudes, and values effectively? The CCR report presents a rethinking about the 'What' of education and does so with 'actionable' recommendations in mind regarding Four-Dimensions: Knowledge, Skills, Character, Meta-Learning. The two reports share commitments to the development of literacies and competencies: Health Literacy, Numeracy, Digital Literacy, Data Literacy, Global Literacy, Information Literacy, Environmental Literacy, among others skills.

The third report from the US National Academy of Education addressed International Large-Scale Assessments (ILSA) results which can be alarming and followed closely by academics, policy makers, business and industry leaders and members of the press. The report grew out of two workshops: (1) Methodological issues related to design, analysis and reporting of ILSAs; (2) Reporting, interpretation and policy uses for ILSAs. Of particular interest, is the international benchmarking and comparisons among nations. The fourth report from the European Union reports findings from two comprehensive surveys examining STEM teaching policies and practices and the transformation of education processes. Thirty-eight European nations participated and the research was conducted by European Schoolnet, a network of 34 Ministries of Education, and Scientix, the community for science education in Europe.

Panel members when reviewing their assigned policy reports were asked to summarize issues and recommendations. Additionally, they were asked to generate a set of questions and issues that would be shared at the NARST/ESERA- Bologna Invited Panel. Three panel members were assigned the role of commentators and asked to reflect on how the reports did or did not address issues from their regions of the world – South Africa, Asia/Pacific, European Union.

6.2 Policy Reports

Report 1 – *The Future of Education and Skills 2030 Project* **OECD (2018), Professors Jonathan Osborne & Audrey Msimanga** The report argues for a vision of education that will be needed for students in 2030 and the following decades. The report envisions a context where students will have to "abandon the notion that resources are limitless and are there to be exploited", rather "they will need to value common prosperity, sustainability and well-being." To achieve this goal, "they will need to be responsible and empowered, placing collaboration above division, and sustainability above short-term gain". Meeting such a goal, the report argues, will require curricula to evolve. The singular focus on curriculum is possibly rather narrow given that pedagogy may yet be transformed by technology, particularly the use of artificial intelligence, and Natural Language Processing to improve assessment which is the tail that drives much of what happens in classrooms.

The report sees three challenges that need to be met. The first challenge is environmental and the demands of living in a context of changing climate and depleted resources. The second is economic and the challenge of an ever-changing society arising from new emerging technologies and the sense of risk associated with lack of stability and changing contexts. The third is social – a product of increasing migration, urbanization and widening inequity. In this context, the report argues that education is about more than developing the capability of students for employment but "the need to equip students with the skills they need to become active, responsible and engaged citizens".

To navigate through a "complex and uncertain world", this report places an emphasis on the need to develop the capability of students' sense of agency. Two factors are prioritized for developing agency – the use of personalized learning environments and the building of a solid foundation in literacy and numeracy – in particular, digital and data literacy.

The basis of the learning framework they advance to achieve all of this is essentially a competency based model to which systems of education are increasingly moving (Koeppen et al., 2008; National Research Council, 2012). Competencies are seen as being an amalgam of knowledge, skills, and attitudes and values.

When it comes to the first of these elements, disciplinary knowledge is seen as important but epistemic– that is knowing how to think like a scientist, historian or mathematician – is also considered to be important. Likewise, some procedural knowledge will be required – knowing how something is done. For instance, in the case of science, knowing how to design and evaluate an appropriate investigation. The OECD thinks this is best developed by problem solving, and design and systems thinking. Pre-eminence is given to three competencies – the ability to create new value, to reconcile tension and dilemmas, and to take responsibility. To meet this challenge, the report advances a set of design principles which are giving students agency, ensuring rigor, providing focus through a relatively small number of topics in each grade, ensuring coherence such that any curriculum reflects the logic of the discipline, alignment between curricula, teaching and assessment, transferability of skills across disciplinary contexts and an element of choice.

The process of designing such curricula must empower teachers; ensure that the student experience has relevance which will require interdisciplinary learning; be based on constructing a curriculum which is "adaptable and dynamic"; and engage teachers, students and other relevant stakeholders to ensure ownership.

It is impossible to escape the feeling that this is an aspirational list. Taken seriously though, there are a number of challenges for those involved in science curriculum development. Current curricula, with the exception of the Next Generation Science Standards, are not competency based. Even the Next Generation Science Standards fail to specify the procedural and epistemic knowledge that should be attained. Too often curricula are overloaded with content, providing no opportunity for student agency, and placing little emphasis on competencies which are transferable such as the ability to read and interpret informational text, developing the facility to analyze and interpret data critically, or evaluate competing experimental designs. As for coherence, the school science curriculum has been searching for a narrative that might bind the sciences ever since its inception and current efforts are still wanting (Osborne et al., 2018). What would it mean to focus on fewer topics at each grade and how would these be selected?

When it comes to technology and developing data literacy, much science education still has not engaged fully with the affordances of what is offered by platforms such as Tuva Labs or the various tools emerging from the Concord Consortium. Whether science education is simply failing to prepare students for the needs of the coming decades and how it might change are clearly questions to be discussed at this symposium.

In the ensuing discussion, participants raised a number of issues. One is that the singular focus on curriculum may be rather narrow, given that pedagogy may be yet transformed by technology and the greater use of artificial intelligence. Another is the question of how these ideas could be transformed into a set of design principles that could be applied across different contexts. Inevitably with such calls, there is the issue of how decisions will be made to excise content and focus on fewer topics possibly of an interdisciplinary nature without damaging the coherence and the underlying logic of the discipline. And, given that competencies are knowledge dependent and acquired in a specific context how can they be transferred across disciplines? In short, while the report offers some challenges to contemporary curriculum and guidelines, it falls short of providing the structure necessary for immediate action.

Report 2 – *Four-Dimensional Education: The Competencies Learners Need to Succeed,* **Center for Curriculum Redesign (2015) Professors Richard Duschl & Fang-Ying Yang** The Keywords for the CCR report shed light on the CCR's ambitions: Curriculum, Standards, Competencies, Competency, Computer-Based Learning, Deeper Learning, Knowledge, Skills, Character, Metacognition, Meta-Learning, 21st Century Education, Education Technology, EdTech, Social-Emotional Skills, 21st Century Competencies, Education Redesign, 21st Century Curriculum, Pedagogy, Learning, Jobs, Employment, Employability, Eduployment, Education 2030, Mindset.

The CCR report proposes adopting a four-component sequence of reforms 1 – Educational Goals; 2 – Standards/Assessments; 3 – Curriculum; and 4 – Professional Development. The recommended Theory of Change for achieving goals is to begin with an initial focus on steps 1&2: Goals, Standards and Assessments and then Curriculum and Professional Development.

The three main drivers for the CCR Educational Goals and Standards Steps1&2 are (i) Personal development of individuals, (ii) Challenges of society, and (iii) Shifting needs of local and global workforces. The broader CCR agenda is to bring about reforms for how precollege and further education might address interdisciplinary Modern Knowledge agendas; "It is the job of standards and curricula to instill competencies to choose content that has depth, and to approach it intelligently. We must realign education goals, standards, and curricula to reflect our changing knowledge and the dynamic transformations happening in our world." (p. 26).

The CCR maintains "that our current, knowledge-focused curriculum does not adequately prepare students for today's workforces, much less tomorrow's and that students should practice applying their knowledge using skills." (p. 41). Thus, the 'Beyond Knowledge' competencies framework incorporates **Knowledge** "What we know and understand" but adds in **Skills** "How we use what we know", **Character** "How we behave and engage in the world", and **Meta-Learning** "How we reflect and adapt". The CCR recommendation is to focus on Modern (Interdisciplinary) Knowledge topics and themes such as Global Literacy, Information Literacy, Systems Thinking, Design Thinking, Environmental Literacy, Digital Literacy and actionable skills that focus on four Cs: Creativity, Critical Thinking, Communication, Collaboration.

The CCR report identifies two 'Tensions' regarding the realignment of education goals, standards, and curricula within the regimes of accreditation and standardized testing: that testing may create a focus on external goals of performance that sorts students and undermines attainment of personal learning goals; and that reforms may create an economic focus on education (e.g., students as customers and institutions as businesses) that shifts dynamics further away from personal mastery of learning competencies toward extrinsic goals and competition between students and among educational institutions.

One of the issues raised about the CCR proposed curriculum reforms concerns the frameworks and methodologies for designing education systems. Missing are considerations for the Macro, Meso, and Micro levels within educational systems as characterized by Improvement Science (Bryk et al., 2015) and the Research + Practice Partnerships that undergird Design-Based Implementation Research (Bevan et al., 2018; Fishman & Penuel, 2018). The decision to focus on Educational Goals and Standards/Assessment first and foremost, immediately raises questions and issues about the synergy between policy and pedagogy. Both the what (Standards and Assessment), and the how (Curriculum and Professional Development) need to change together over time. Not one and then the other. Leaving out the how as part of the initial conversations omits promising frameworks and methodologies for designing educational systems (e.g., R + P (Research + Practice) Partnerships, (Bevan et al., 2018) Design-Based Implementation Research (DBIR) (Fishman & Penuel, 2018) as well as important stakeholders' engagements with curriculum design/redesign efforts with Learning Progressions (Duschl, 2019) and Improvement Science/Network Improvement Communities (Bryk et al., 2015).

A related second issue is not co-developing standards and assessment along with curriculum materials and teacher professional development. Stakeholders' such as teachers and members Network Improvement Communities should be at the table. Many of the same OECD 2030 curriculum, instruction, and assessment issues and questions regarding knowledge, skills, and values and attitudes pertain here, too. Questions arose pertaining to leadership and teacher Professional Development; to coordinating and implementing the design of Curriculum, Instruction and Assessment when adopting Evidence Center Design and Learning Progression frameworks; and to creating curriculum contexts that adopt Twenty-First Century Information Literacy Tools; Systems Thinking; Design Thinking; Environmental Literacy; and the 4 C Skills: Creativity, Critical Thinking, Communication, Collaboration.

Report 3 – *International Education Assessments: Cautions, Conundrums and Common Sense* **National Academy of Education (2018) – Professors Doris Jorde & Costas Constantinou** The report summarizes two workshops to examine the future directions for International Large-Scale Assessments (ILSAs) from a variety of disciplinary aspects (including educational policy, journalism, research design and statistical analysis). Participants agreed that ILSAs provide valuable resources for countries. However, one needs to consider interpretations at all levels. The purposes of ILSAs (summary chapter, p. 69) include:

1. Describe and compare student achievement and examine relevant contextual factors across nations

2. Track changes over time in student achievement, contextual factors and their mutual relationships, within and across nations.
3. Disturb complacency about a nation's educational system and to spur educational reforms.
4. Create de facto international benchmarking by identifying top performing nations and jurisdictions, or those making unusually large gains, and suggesting ways to learn from this array of practices.
5. Evaluate the effectiveness of curricula, instructional strategies, and educational policies, while understanding that many of them are deeply contextualized.
6. Explore casual relationships between contextual factors (e.g., demographic, social, economic, and educational variables) and student achievement.

There is general Agreement on purposes 1, 2, & 3 but widespread Concerns and Disagreements on purposes 4, 5, & 6. Especially concerning to committee members was the pursuit of establishing casual relationships from ILSA data. Given the large number of factors affecting student achievement, as well as the fact that nations are so very different from one another with respect to size of population, history, culture, and politics; seeking casual relationships would never be a realistic goal for ILSA's as presently designed.

The report also took up issues with the ways media are reporting results, which can often be misleading. When sharing results with the public, there are only a few questions that are of importance: 1) Why did our country do so badly? 2) Why did another country do better? and 3) What is the other country doing that we can try in our country? Educational researchers assert that the tests are not able to provide such information. Nonetheless, this is what is communicated to the public.

In a web-seminar that launched the report in 2018, panel discussions brought up additional issues and concerns about the use of ILSA's. Again, the misuse of casual inference was discussed as a problem with this type of testing. However, results could be used to alert policy makers about promising topics that need more rigorous types of experimental designs (RCT or quasi) for the country.

The end comment is that "ILSA's are here to stay. Indeed, not only are they here to stay, they are likely to become even more salient to educational policy discussions as the world becomes increasingly globalized. For this to be a good outcome, technical issues must be addressed and policy makers, the press, and the public must be more aware of the data's limitations." (p. 77).

The general conclusion of the report is that ILSA's are here to stay. However, it is important that the "users" of the tests understand the nature of the data produced – possibilities and limitations. Used in the correct way, the data allows nations to follow their own trends in student achievement and to look critically at policy and areas of the curriculum demanding change. Benchmarking against other nations may be a valuable tool for learning about what works (including curriculum and policy), but only if used correctly, taking into consideration country context. There is consensus that longitudinal research using RCT or quasi experimentation is required if data is to provide information on casual relationships. Finally, helping the media understand the nature of the data is important for all countries.

Report 4 – *Science, Technology, Engineering and Mathematics Education Practices in Europe.* **Scientix Observatory Report. December 2018, European Schoolnet, Brussels Professor Eilish McLoughlin** The Scientix report STEM Education Practices in Europe draws on the analysis of 3780 responses (representing over 4500 classes) to the STEM Education Practices Survey, answered by teachers in 38 European countries (Scientix Observatory, 2018). The aim of this report was to provide a grassroots, European-wide perspective on how STEM teachers organise their teaching, in terms of resources and pedagogical approaches used, on the current state of teachers' professional development and support, and on their opinions and attitudes, particularly in relation to their school environment and their openness to cooperation with STEM industries. It must be noted that the findings presented in this report were based on teachers' self-reporting regarding their practices, needs and opinions on various aspects of STEM education. The report's findings were discussed under five areas addressing (i) pedagogical approaches used in STEM teaching, (ii) access to and use of resources and materials, (iii) professional development and support for STEM teachers, (iv) teachers experience and educational level in STEM teaching and (v) teachers' attitudes and influence of the environment.

Generally, the STEM teachers reported the use of a variety of pedagogical approaches, with very high use of formative and summative assessment methods, collaborative learning, differentiated instruction and project/problem-based approaches. The high reporting of formative assessment is encouraging, indicating that teachers are mindful of the need to monitor and evaluate learning outcomes and not exclusively focused on final evaluations. However, the report highlights a high use of traditional direct instruction compared with other, student-centred pedagogies, such as flipped classroom, Inquiry-based science education (IBSE) or peer teaching. The fact that STEM teachers report considerably more traditional instruction than IBSE is of particular concern – given that the use of IBSE has been widely promoted across Europe as a more effective pedagogy than traditional direct instruction. Mathematics classes, in particular, appear to be delivered through more teacher-focused, less innovative, and less contextualized pedagogies than the other STEM disciplines.

In terms of access to and use of resources, teachers reported, except when teaching ICT, an extensive use of paper-based materials in their teaching, followed by audio/video materials and slideshow presentations. In addition to reporting low use of ICT tools and specialised software/equipment in their STEM classes, teachers also indicated low use of resources for personalised learning and special needs learning. The majority of teachers surveyed do not subscribe to information channels – either of national and international educational projects – as a source of STEM resources or utilize resources published by companies operating in STEM fields.

According to the European Commission's Eurydice report on Teaching Careers in Europe (2018), in most European educational systems teachers' continuous professional development (CPD) is either compulsory or considered a professional duty (it is compulsory, but the number of hours is not defined). Additionally, in many educational systems, a certain number of hours or credits in CPD is required for career progression. The majority of teachers surveyed indicated they had not completed professional development of any kind during the previous two years. Teachers reported that they generally update their knowledge online and in their own time and rely on technological and pedagogical support from their peers that teach the same or other STEM subjects.

The extent of STEM teachers experience in the classroom and the educational level of the students were both reported to have an effect on teacher's use of innovative pedagogical strategies. With more experience, teachers were more willing to integrate more constructivist pedagogical approaches in their classes and limit the use of traditional direct instruction. A steady decrease in the use of student-centred pedagogies as the students approach the end of upper second level education, i.e. as national end-of-second-level evaluations approach, was also observed.

Overall, STEM teachers identified the pressure to prepare students for exams, inadequate school space organisation, lack of pedagogical strategies to teach STEM in an attractive way and insufficient technical support for teachers as the key factors that impact their teaching practices. Teachers generally indicated openness towards collaboration with STEM industries and towards bringing more innovation into their classrooms and expressed that this is best achieved when STEM teachers and their school administration share a common vision about innovative STEM teaching.

Issues and questions that arise from this report include:

- What are appropriate models of professional learning to provide continuous support to teachers to embed more student-centered pedagogies in all STEM classrooms, in particular how can mathematics teaching be reformed?
- What policy changes are needed for curriculum innovation to support a more integrative approach to STEM teaching?
- How can national policies be reformed to promote the use of diverse pedagogies and formative evaluation methods – particularly at end-of-secondary level education?
- How can the teachers that engaged in these innovative projects be supported to mentor peers in IBSE and other innovative pedagogies?

6.3 Summary

Individually, the four reports place emphases on different aspects of domains of teaching and learning. For example, the first report, addresses three challenges: environmental, economic and social. The second report is grounded within three drivers: personal development, societal challenges, and the needs of the local and global workforces. The third report focuses on student achievement however, contextual factors are prominent. The fourth report is based on a five-component model that includes pedagogy, curriculum, teacher professional development and cooperation with STEM industries. These differences in foci, however, are not surprising given the fact that the reports were developed in different geopolitical contexts which have unique educational agendas, visions, and goals.

Collectively, some similarities exist across the reports. One similarity is that all reports consider the social nature of learning and they touch upon contextual aspects of learning as well as societal challenges. Two reports (OECD, CCD) make references to the context in which students learn, while two others (NAE, Scientix) make references to the sociopolitical contexts in which schools are functioning. Moreover, curriculum materials have a prominent role in all reports even if some receive less attention than others. Interestingly, technology is not present in all reports as part of neither the curriculum nor any innovative pedagogies. Third, assessment and evaluation issues appear in all four reports, are but discussed in different and unique ways.

When thinking about future education policy and practices, one panel discussion was framed in terms of 3 key 'stages' of education:

- Stage 1, Primary & Secondary Schooling (Grades 1–12), formative learner and generalized learning;
- Stage 2, Higher or Further Education, Degrees & Certifications, Undergraduate and Postgraduate;
- Stage 3, Career Education, World of Work, Professional & Licensing Bodies, Lifelong Learner.

Each Stage has a different focus of education and serves a different purpose. How Stages 1 & 2 interface with Stage 3 though is significant for the future designs of educational models and systems. A concern that was raised is educational reform thinking in the four reports is tending towards workplace oriented skills and competences. If Stage 3 is where such skills and competences inform education systems, then how do we envisage Stages 1 and 2 to continue to work in ways that instill the 'habits of mind' for reasoning in/about disciplinary knowledge. A second concern pertains to the strong focus on the mind – where is the heart? How will future education frameworks that are attending to rapid technological, environmental, and workforce developments also deal with matters of ethics and values? How do we guard against the potential for these workforce developments to widen the equity gap? In particular, the need to consider variance in economic and political stability among developing nations that are experiencing persistent conflict and issue of migration.

Another rich discussion among panelists and the audience focused on teacher professional development issues. One challenging problem nations are facing is how to equip teachers with knowledge, values, skills, and attitudes that will help promote students' competences for solving personal, social, and global issues. There are some enthusiastic teachers who believe in the reforms and are organizing teacher learning groups to develop new instructional models that reflect the new education frameworks. But levels of understanding about the new frameworks is limited and many teachers are waiting to see what is going to happen when the new curriculum are put in place. Teachers view the new learning frameworks and standards as sound but with respect to implementation in classrooms there is a lot of confusion and questions.

Yet another issue regarding teacher education is how college and university STEM faculty will adapt. Within colleges of science and engineering, university teaching is still traditional, focusing mainly on disciplinary content knowledge and on problem solving skills. Only few of STEM faculty are aware of the new education frameworks. The focus of many faculty is on developing critical thinking, reflective thinking and problem solving. But there is tension with senior professors who reject the curriculum reform in pre-college levels because they feel students will not learn enough discipline knowledge from the new curriculum. If the universities do not explicitly support the educational reforms, then high school teachers might be discouraged to take up the reform agendas. After all, a major goal for high school teachers is to prepare their students to attend top ranking universities.

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