Chapter 1
Twenty-First Century Skills: From Theory to Action

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Abstract This chapter provides a general introduction to issues and initiatives in the assessment of twenty-first century skills, the implications of assessment for the teacher and teacher training, the role played by technologies not only for demonstration of skills but for their measurement, and a look to the future. Frameworks that have informed a gradual shift in the aspirations of education systems for their students are described, followed by evidence of implementations globally and regionally. The role of the Assessment and Teaching of 21st Century Skills (ATC21S; Griffin et al. (Eds.) (2012), Assessment and teaching of 21st century skills. Springer, Dordrecht) in reflecting and acting on a call by global consortia is outlined. This provides the context for the book contents, with the chapters briefly described within their thematic parts. The chapters provide a clear picture of the complexities of the introduction of teaching and assessment strategies based on skills rather than content.

The Assessment and Teaching of 21st Century Skills (ATC21S; Griffin et al. 2012) initiative was stimulated by a coalition of global commercial organisations and engaged in by six countries in its research phase. Reflecting concerns about generating future workforces with the "21st century" skills that their workplaces required, Kozma (2011) discussed an aspiration for education reform which was information communications and technology-centric. The global discourse has moved toward a broader concern around global citizenship and global competence, but underpinning these concepts are the myriad twenty-first century skills identified in seminal frameworks of human characteristics. Each framework approaches the question of what people need to function effectively in society, and takes a variety of perspectives from high-level to detailed, and from inclusion of a vast array of human characteristics to skills or competencies alone. This is the context for the assessment and teaching of twenty-first century skills.

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Frameworks

The frameworks, notwithstanding similarities (Voogt and Roblin 2012), also reveal very different ways of conceptualising human characteristics and the human condition. There are more differences across ways of framing these than there are in identifying the actual skills themselves. For example, some frameworks (e.g. Delors et al. 1996) take a very high-level perspective, echoing generic human learning targets – to know, to do, to be, to live together. Others such as OECD's DeSeCo Report (Rychen and Salganik 2001) take into account the twenty-first century context more explicitly and provide more detail in identification of competencies. Similarly Partnerships 21 (www.p21.org) and the European Commission (Gordon et al. 2009) comprehend both the high-level concepts as well as specific competencies. The ATC21S framework (Binkley et al. 2012) follows this model but explicitly acknowledges competencies beyond skills, identifying knowledge, and the cluster set of attitudes, values and ethics. This perspective was prescient given the growing emphasis on global competency (OECD 2016) and global citizenship which clearly tap cognitive and social skills as well as morals, ethics, attitudes and values. Another influential framework, focussed on skills and abilities, was presented by Pellegrino and Hilton through the US National Research Council (2012). More recently, at the 2015 World Economic Forum core twenty-first century capabilities were again confirmed across the categories of foundational literacies (how students apply core skills to everyday tasks – e.g. literacy, ICT literacy), competencies (how students approach complex challenges – e.g. problem solving, communication), and character qualities (how students approach their environment – e.g. persistence, leadership).

In terms of the particular competencies that populate these frameworks, and that are identified as salient to twenty-first century education, there is strong consistency across global organisations and research groups. The majority of identified competencies generally fall within the cognitive and social domains, although a variety of classification systems is used. Since release of the aspirations that are the Sustainable Development Goals (UNESCO 2015a), a solid platform for consideration of a broader curricular approach has been established. Of particular interest in this context, Sustainable Development Goal 4 calls for skills beyond literacy and numeracy – including readiness for primary education (4.2), technical and vocational skills (4.4), and skills needed to promote global citizenship and sustainable development (4.7). These targets signal an emphasis on the breadth of skills necessary to prepare children, youth and adults comprehensively for twenty-first century citizenship and life. In order to capture an indication of how regions or countries, as opposed to global consortia and academia, are investing in a breadth-of-skills perspective in considering education reform, three initiatives illuminate the current state.

Movement at Regional and Global Levels

The Learning Metrics Task Force (2013a, b) was convened in 2012 to investigate how learning progress can be tracked at a global level and to "improve the learning outcomes of all children and youth by strengthening assessment systems and the use of assessment data". The Task Force was coordinated by the UNESCO Institute for Statistics and the Brookings Institution. It conducted two phases of research work. In the first phase the task force completed several rounds of global consultation and technical development involving 1700 people from 118 countries. Through this consultation process, a series of recommendations for improving learning outcomes and measurement at the global level was put forward. A significant output of the consultation was the Global Framework of Learning Domains, which described seven domains of learning that should be available to all children: physical well-being, social and emotional, culture and the arts, literacy and communication, learning approaches and cognition, numeracy and mathematics, and science and technology. The focus on competencies across the domains of learning took a curricular approach to twenty-first century skills. The penetration of the LMTF initiative is in large part due to the strong engagement by countries as well as global partners.

Since 2013, the UNESCO-supported ERI-NET and NEQMAP groups have been exploring the status and reach of transversal competencies in the Asia Pacific region. The first report (UNESCO 2015b) describes transversal competencies arrived at through an ERI-NET consensus process. Ten countries (Australia, Shanghai [China], China, Hong Kong, Republic of Korea, Japan, Malaysia, Mongolia, Philippines, and Thailand) in the Asia-Pacific region participated in the study which documented the variety of approaches to transversal competencies that these countries took at policy and practice levels. The list represented core sets of skills (critical and innovative thinking, inter-personal skills, intra-personal skills, global citizenship) as well as allowing for national and cultural differences across countries in the region. The report concluded that "the ten education systems… have all recently introduced or moved to strengthen existing dimensions of transversal competencies in their education policies and curricula" (p. 21). The second study in the series (UNESCO 2016) addressed the links between policy and practice. The emergence of teaching practices which emphasised student-centred practical tasks was documented, as was also the lack of teacher training to support these practices. The majority of participating systems were of the view that existing mechanisms could be used for assessment of transversal competencies. This finding hinted at lack of deep understanding of the implications of introduction of competencies to the education process. This finding was supported in the fourth study supported by UNESCO through NEQMAP (Care and Luo 2016) which explored implementation of assessment of these skills. Across the nine participating countries in the fourth study, there was strong evidence of awareness at policy and school levels of the drive for assessment, but its implementation was hampered by lack of teacher understanding about the skills and relevant materials and resources.

In the third initiative, and taking an individual countries perspective, a scan of online national education websites representing 102 countries by the Brookings Institution (Care et al. 2016) demonstrated that 86% of sampled countries include twenty-first century skills in some aspect of their educational aspirations. The most frequently named skills drawn from the global scan were communication, creativity, critical thinking and problem solving. The congruence of these country-nominated skills with those identified in the global frameworks and elsewhere (e.g., Voogt and Roblin 2012; UNESCO 2016) is striking, and provides strong support for the stability of attitudes about what qualities are to be valued in twenty-first century education.

The second decade of the twenty-first century has thus seen evidence of increasing emphasis on twenty-first century skills, demonstrating that the conversations are not confined to global organisations or academic consortia, but are being addressed at regional and country levels.

Both the UNESCO NEQMAP initiative and the Brookings Institution global scan surface the big issue – implementation. The scan of the 102 countries represented information available in the second half of 2016, and is dynamically updated (www.skills.brookings.edu). It does not represent the total population of such information – merely that which is accessible through online search. The data were analysed across four levels. The first level explored vision or mission statements. Where these include a reference to a goal that is explicit concerning twenty-first century skills, or implicit by virtue of referring to a quality that requires such skills, this is taken as evidence of endorsement of the importance of twenty-first century skills. The second level explored whether a country identifies particular skills. The third level sought for evidence that would clarify that skills are a part of the curriculum; and the fourth sought for evidence of awareness that skills in their own right follow a learning progression and will therefore be taught and learnt at different stages and through different discipline areas. Meeting this final level would imply that the notion of development of skills as part of a sequence of learning is accepted. This would be a pre-requisite for adaptive integration of skills in the curriculum, in pedagogy and assessment.

The data demonstrate that most countries identify twenty-first century skills as part of their educational goals, while fewer countries identify skills development progressions and their integration through the curriculum (Fig. 1.1). In some cases, the commitments of national education authorities are to specific skills or competencies, and how these are included in the curriculum without information about learning progressions. In other cases, just mission or vision statements make explicit the valuing of the competencies.

In cases where the mission is not supported by information at all the levels, it may well be due to natural lag between intention and action. Notwithstanding, it is clear from the patterns of penetration of the "skills agenda", as well as from the richer information derived from the ERI-NET and NEQMAP studies (2015, 2016), that some national systems face challenges in addressing what amounts to a considerable education reform. The challenges can be ascribed to many factors that play into reform generally – political, procedural, and technical. Beyond these are factors

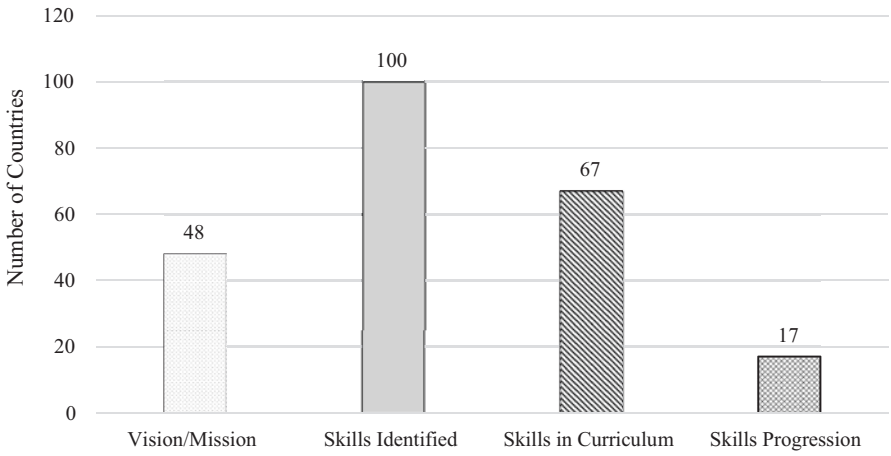

Fig. 1.1 Skills across layers of country documentation (Adapted and updated from Care et al. 2016)

associated with this particular reform. Introduction of a competencies focus in education requires a shift from the content focus that characterises many national curricula. This shift relies not only on curriculum reform, but also changed approaches to pedagogy and assessment. What is to be taught dictates best methods for teaching and best methods for assessment. And this is the area which currently challenges us.

The Assessment and Teaching of 21st Century Skills Project

The ATC21S project was sited very much in this space, of establishing frameworks within which to link assessment and teaching. The project closed formally in 2012 with the development and delivery of a conceptual framework for twenty-first century skills (Griffin et al. 2012); a focus on two skills areas – collaborative problem solving and ICT literacy in digital networks; an approach to formative assessment; and teacher professional development modules (Griffin and Care 2015). Since that time, interest has peaked in collaborative problem solving, mainly as a result of the 2015 PISA study in which collaborative problem solving was assessed in up to 65 countries.

ATC21S provided an approach to assess students as they engaged with tasks online and collaborated. Student navigation of digital networks and problem solving behaviour was captured electronically in activity log files for synchronous scoring and reporting against developmental progressions. The progressions provided guidelines for teachers about how students might demonstrate the skills at increasing levels of sophistication and competence such that these could be integrated into their teaching. How the insights into these complex twenty-first century skills might

be translated into classroom practice is the challenge for national education systems globally.

Technology permeates our living and working. If education is to prepare students for the future, technology is an integral component. If, however, technology is to realise its potential, it needs to be better integrated at the classroom level, as part of instructional delivery, formative assessment, and appropriate intervention and tracking of outcomes and learning. At the system level, technology can be embedded into the broader educational policy decisions that align standards and objectives with twenty-first century skills.

A great deal of current research and system monitoring programs focus on basic skills such as reading comprehension, writing, mathematics, and scientific literacy, which are taught in schools under pressure of traditional curriculum demands. Little progress in terms of international comparative studies that examine the processes by which cognitive and social skills are developed had been made either at the student or the system level until 2015 when the OECD through its PISA project measured student performance in collaborative problem solving. Building on the ATC21S research across six countries on collaborative problem solving and digital literacy in social networks, the measurement and identification of collaborative problem solving assumes an important status in twenty-first century skills education. Collaborative problem solving (Hesse et al. 2015) incorporates the cognitive skills of task analysis (problem analysis, goal setting resource management, flexibility and ambiguity, collecting information and systematicity), and problem resolution (representing and formulating relationships, forming rules and generalisation and testing hypotheses), as well as interpersonal skills such as participation (action, interaction and perseverance), perspective taking (adaptive responsiveness, and audience awareness [mutual modelling]) and social regulation (negotiation, meta-memory, transactive memory, and responsibility initiative). These non-cognitive skills are increasingly important and the identification of ways to focus attention on them in terms of their measurement and development at student and system level is becoming increasingly urgent.

An Explicit Shift in Education

What we are seeing is not a revolution in education. It is better understood as a shift in how we recognize the importance of developing generic skills and competencies during basic and secondary education. We are making explicit our expectations of education in terms of these generic outcomes. The point of education has always been to equip students to function effectively in society. As our society has changed, we are re-visiting this expectation, and focusing more explicitly on the particular skills and competencies that have been highlighted as essential for functioning in our technological world.

Intrinsic to this move toward the explicit, countries are including twenty-first century skills in their curricula, looking at the implications for teaching, and exploring assessment approaches that might both capture and support the skills. There is

clearly major interest in twenty-first century skills at country, regional and global levels. Lagging behind the interest is knowledge about how to assess and teach the skills. In this volume we see initiatives to redress this balance.

Description of This Volume

The chapters in this volume are organised within three main themes. These are assessment of twenty-first century skills, country initiatives with a focus on implications of the twenty-first century skills agenda for teachers and teacher education, and the measurement and applications of information technologies. The final chapter provides a comprehensive systemic view on the phenomenon.

Part 1, Assessment of 21st Century Skills, opens with this chapter, and is followed by a chapter exploring the authenticity of assessments of twenty-first century skills. Care and Kim (2018) highlight the challenges associated with the measurement of skills in a general education context. Taking the position that assessment should reflect as closely as possible the way in which the object of that assessment will be demonstrated, they highlight the consequences of the nature of twenty-first century skills for assessment. The practical and adaptive nature of skills is identified as a primary challenge to their assessment, since it is the capacity to respond to different situations and non-routine scenarios that is the goal, while the nature of assessment typically requires that a situation is known and that there is a finite number of responses to ensure objective evaluation. To illustrate their argument Care and Kim use Gulikers et al. (2004) principles of authenticity as a framework to review a selection of assessments of twenty-first century skills. They conclude on a note of major concern about lack of progress in the assessment of complex constructs, thereby raising challenges which authors of the subsequent chapters explore from different perspectives.

The following three papers delve into the history of technology-supported problem solving and its move into complex and collaborative variants. The perspective of these papers distinguishes the concerns of assessment specialists rather than practitioners, and traverse terrain far removed from assessment in the classroom.

Funke et al. (2018) focus on complexity. Rather than seeing problem solving as a simple model in which a number of processes combine to facilitate a desired outcome, their approach considers the role played by non-cognitive factors such as motivation and self-regulation. This moves the discussion past recent views which have focussed on problem solving solely as a cognitive set of processes. Constructs such as collaborative problem solving have considered the additional role of social processes but primarily due to the need to make interactive processes explicit as part of group approaches to problem solving. The authors express some impatience with the slowness of technical progress in assessment of problem solving, dare to refer to the invisible elephant, “g”, although without resolution of its role, and suggest expansion of the computer-simulated microworlds approach to assess their postulated “systems competence”. Although this may provide the potential to capture

communication as well as the cognitive processes in problem solving, social characteristics such as self-regulation or motivation, initially identified as clearly important by the authors, remain to be addressed. As researchers struggle to theorise and measure increasing complexity as knowledge about that complexity increases, this chapter raises questions about whether systems competence is merely about acting on a complex problem space that requires a multiplicity of different problem solving processes, or whether it is something qualitatively different.

Krkovic et al. (2018) follow the iterations in online assessment of problem solving. They introduce their work with reference to the ambiguous and non-routine nature of complex and collaborative problem solving. Grounding much of their discussion in the MicroDYN tasks designed as minimal complex systems (Funke 2010) where respondents manipulate input variables and monitor effects on outcome variables, the authors move from assessment of the individual to the collaborative. Noting the challenges inherent in trying to capture both social and cognitive processes in online assessment environments, the authors contrast the PISA human-to-agent approach with the ATC21S human-to-human approach. Krkovic et al. point out that large scale assessments of problem solving processes have now been implemented for over 15 years. The history of these processes makes clear the early progress in online capture through dynamic systems, and the complexities that arise as our understanding of the cognitive and social competencies becomes successively more comprehensive.

Graesser et al. (2018) identify differences between problem solving and collaborative problem solving as based primarily in need for multiple resources, division of labour, and diverse perspectives. Their focus is on these needs rather than on what characterises the two sets of activities – to wit, that collaborative problem solving requires the processes to be explicit due to the need to communicate. Their approach leads directly to the issue of whether the team or the individual needs to be the focus of assessment. Aligned with OECD's PISA (2013) approach to assessment of the construct, Graesser et al. provide a comprehensive justification for assessment of the individual within the collaborative dynamic – primarily on logistic grounds. Notwithstanding a matrix approach of 12 skills to identify the structure of the construct for PISA, the authors describe the main task as working toward a unidimensional scale for collaborative problem solving. This tension between complexity and the desire for simplicity is reflected more broadly in other efforts in measurement of skills – for example in OECD's efforts to measure global competency (2016), or current attempts to determine a universal global metric for education. Graesser et al. describe the approach taken by the PISA Collaborative Problem Solving Expert Group and following the ATC21S method of initially identifying three levels of functioning to guide task development and measurement. Issues of interdependence and symmetry are also highlighted although the human-agent nature of the PISA approach nullifies some of the measurement issues associated with these (Scoular et al. 2017). Moving to the challenges in assessment and measurement of complex skills, Graesser et al. highlight discourse management, group composition, and the use of computer agents in assessments. An extensive discussion of the complexities of communication makes clear the huge challenge in

attempting to capture this phenomenon in a standard and automated way. This challenge of course is inextricably linked to decisions concerning use of agents in online assessment platforms, an issue that Graesser et al. inform.

Both the circumscribing of capacity to stimulate human processes and collect the emanating data, as well as the potential of that data capture, are highlighted. Notwithstanding aspirations to identify sets of complex processes as unidimensional constructs, it is not yet clear that our methods or data can support these. These chapters reflect concern with assessment issues in a space far from the use of results by teachers to enhance student skills.

The chapters in Part 2 illustrate applications and exploration of assessment of twenty-first century skills from founder countries in ATC21S. From the focus on assessment which characterised the original project, these chapters reflect transition to deeper exploration of skills and their implications for teaching and learning. The authors respond to the global uptake of the notion of skills education, and focus on how implementation of these complex constructs might be seen, monitored, and enhanced in the classroom.

Tan et al. (2018) jump right into this conundrum, hypothesising associations between collective creativity and collaborative problem solving with a focus on students. Using Assessment and Teaching of twenty-first Century Skills (ATC21S) project data, Tan and colleagues argue that creativity is central to problem solving, implicitly drawing on creativity's cognitive dimensions such as divergent thinking, and explore the degree to which the assessment data support the association. Tan et al.'s definition of collective creativity identifies dimensions similar to those that were hypothesized by Hesse et al. (2015) as contributing to collaborative problem solving, thereby providing a rationale for associations between the two constructs. The complexity of the model proposed highlights the challenge of assessment of interactive problem solving behaviour. The authors' finding of lack of impact of metacognition needs to be considered within the wider question of whether knowledge-building necessarily has immediate impact on the learning task itself, as opposed to longer-term impact. Tan et al.'s contribution confirms the value of deconstruction of complex constructs to components that can be brought to the attention of teachers for instructional purposes.

Ahonen et al. (2018) reflect upon the demand for better assessment of twenty-first century skills as a result of Finland's emphasis on interdisciplinary and generic skills and competencies. Introduction of more inquiry-based learning approaches and reliance on small group learning and teaching assumes teachers' own understanding of these approaches and their own skills. Ahonen et al. seek in particular to understand teachers' teamwork and collaborative dispositions given the centrality of these to Finland's vision for inquiry-based learning approaches that rely on collaborative as well as technology-enhanced modes of working. Within a large scale study of training needs of pre-service teachers, the authors focus on a small group of pre-service teachers, and analyse self-report across components of collaboration, such as negotiation and cooperation, as well as their performance on ATC21S tasks. Lack of consistency across the data sources raises both methodological and substantive questions. Do collaborative skills necessarily contribute to outcomes in a

collaborative problem solving context? To what extent are self evaluations valid forms of assessment of characteristics such as collaborative dispositions? The PREP21 project provides a valuable context through which to understand the preparation needed to ensure that teachers can shift from their own learning experiences to a twenty-first century learning and teaching environment.

Comfort and Timms (2018) introduce their concerns about twenty-first century learning by alluding to the transmission model, through which teachers transmit factual knowledge to students but which does not necessarily facilitate students' capacity to understand and apply. They postulate that twenty-first century skills are not learnt unless explicitly taught. Comfort and Timms hold that despite large scale twenty-first century initiatives such as Partnerships21 and ATC21S, as well as development of the US-specific Common Core State Standards, teaching and assessment of twenty-first century skills in the US is minimal. Taking a particular interest in Next Generation Science Standards, the authors consider how learning activities in the classroom might be structured through the use of games, drawing on collaborative skills and focussed on inquiry, explanation, argumentation and evaluation. Expanding on a study by Bressler (2014), Comfort and Timms highlight the specific opportunities needed by teachers in order to develop the skills to model the learning that needs to take place in the twenty-first century classroom.

Scoular and Care (2018) focus on how systems might facilitate the teaching of twenty-first century skills, through looking at Australian approaches to teacher development. They draw attention to the issues generated by lack of understanding of the nature of the skills, and how and when the various skills might differentially be brought to bear across school subjects. Notwithstanding the Australian Curriculum, Assessment and Reporting Authority's (ACARA) development of the General Capabilities (ACARA 2013) which is accompanied by extensive online resources for teachers, the gap between policy and implementation is noted. With trans-disciplinary skills needing a coherent messaging across different teaching staff, school approaches rather than individual professional development for teachers need to be considered. Looking specifically at collaborative problem solving, Scoular and Care present three case studies which focus on preparation of teachers themselves, teacher resources, and higher education responsibilities. The diversity of the case studies across these topics is testament to the complexity of this education shift and the need for a systemic perspective.

Bujanda et al. (2018) position Costa Rica's education initiatives in the country's decision to prioritise needs and opportunities associated with technologies and technology-based learning since the 1980s. The National Program of Educational Informatics established in 1988 has moved from a learning-by-doing orientation to a learning-by-making approach. Its constructivist approach draws attention to evidence of learning, often enabled through technologies. Costa Rica's current curriculum emphasises project-based learning, and assessment is increasingly influenced by its formative purpose. Bujanda et al. identify the contributions of ATC21S to the country's increasing expertise through initiatives such as the National Program's assessment of Citizenship and Communication, Productivity and Research and Problem Solving. The 2017 announcement of Costa Rica's new curriculum identifies

the ATC21S framework as inspiring expected learning outcomes. The authors make clear the country's continuing emphasis on technologies and their use as an intrinsic component of twenty-first century education provision.

Together, the perspectives contributed by these authors who participated in the research active phase of ATC21S, demonstrate an increasing concern for translation of the theory into approaches to implementation. It is clear that despite varied performance in international large scale assessments across the countries, there is concensus at the actual delivery level to students for education systems to explore how to deliver opportunities to their students for acquisition of skills above and beyond traditional discipline achievements.

The chapters in Part 3 witness the multiple implications of information and communications technologies – for measurement and within the classroom. We follow the technical path taken by Wilson and colleagues in the context of the skills themselves, to insights from Ramalingam and Adams about how capture of process data further informs our understanding of the skills. Scalise follows with examples of student activities at differing levels of proficiency within an information literacy environment.

Wilson et al. (2018a) present a historical account of development of concepts of ICT literacy over the past two decades which form the framework for their work on ICT literacy in networks. In describing this framework Wilson et al. also provide contextual information about the ATC21S project at large providing a picture of the drivers for the project and its goals. From this base, Wilson et al. (2018b) raise some fascinating issues around complementarity of the measurement approach taken by Wilson et al. (2015) with learning analytics. They describe four principles that good assessment and measurement should adhere to: to be based on a developmental paradigm, to be aligned with instructional goals, to produce valid and reliable evidence, and to provide information useful to teachers and students. Wilson et al. (2018b) argue that a learning analytics approach can be used to explore data that remain inaccessible to most automated scoring methods, such as may be used in text analysis. Their "sentiment analysis" demonstrates reasonably strong alignment with handscoring methods, prompting their conclusion that learning analytics modules might reasonably be embedded within measurement models. Wilson et al. (2018b) also approach a vexed issue in the assessment of individuals operating within groups. Where individuals' responses cannot be regarded as independent, there are both measurement and substantive concerns. From modelling of results from ATC21S using both unidimensional and multidimensional item response models, and with and without random effects for groups, the authors propose that a combined measure of group and individual level performance provides the best estimates of ability. How these findings are to be explored in the context of the four principles of good assessment and measurement is part of the new vista for assessment.

Ramalingam and Adams (2018) explore the nature of and the opportunities provided by data captured as part of online assessment of complex constructs. Drawing on the traditional item format also used by Graesser et al. (2018) – multiple choice items – Ramalingam and Adams interrogate PISA digital reading data to determine

the extent to which the logstream or "process" data can inform more accurate measurement. Whereas Graesser et al. describe decisions taken due to the limitations of online data capture, Ramalingam and Adams describe the opportunities provided by the medium. Their approach firmly aligns the potential of automated assessment with the nature of the target through focus on processes. In so doing, they identify the capacity of the medium to explore the nature of the target in ways not previously accessible. Since the focus on skills development and assessment is primarily a focus on processes rather than solutions, tracking of navigation behaviour for example can demonstrate that a task respondent is, or is not, activating certain processes. In turn, this demonstration can be recognised and valued, regardless of whether the process meets with success in terms of achieving a "correct" result.

Scalise (2018) brings together classroom based digital and collaboration skills to demonstrate the implications of the theoretical frameworks developed in ATC21S for practice. She demonstrates how teachers can use review of student work to evaluate patterns in student learning and link these with the strands of digital literacy. Through the process, teachers can develop strategies to guide their teaching and evaluation of impact. Using student work examples, Scalise identifies correspondence with skill levels across the *learning through digital networks* construct. Drawing on student responses to the ATC21S Arctic Trek task, Scalise mines the rich data from students working in an online collaborative learning environment. She traces student progress across Wilson et al.'s (2018a) four strands of literacy through the eyes of Roblyer's (2006) technology integration grid, providing strong links between the theoretical frameworks, the measurement, and the practice.

In the concluding Part 4, Nieveen and Plomp (2018) provide a model-based discussion of the elements to be considered in educations systems' change processes with a primary focus on the curriculum and the implications of its changes for pedagogies and system coherence. With particular reference to the ATC21S Binkley et al. (2012) framework, they explore implications at classroom, school, and system levels. Outlining different models for implementation of skills in curriculum – adding to existing curriculum, integration as cross-curricular competencies, or introducing new curricula – the authors adopt integration as the basis for their discussion. Implications of changes to one aspect of the curriculum for others is highlighted, as is the need for new approaches to assessment, to pedagogy, to the role of teachers, and the nature and use of information. The need to move from a group focus in terms of pedagogical strategies is elucidated with consequences for teacher beliefs. This leads to the intersections of curriculum development, teacher development and the organisation of the school. Reflecting the nature of the skills themselves, the mechanics of implementing the change are described as inherently collaborative and dynamic, in contrast to the view of teachers as silos within classrooms. Nieveen and Plomp then move to the wider context, and describe bottom-up and top-down models situating the levels of system, school, and classroom which in turn draws attention to the intended, implemented and achieved curriculum story. The critical theme of interdependence between layers of the system, between curriculum, assessment and pedagogy, and their dynamic nature runs strongly through the

discussion, providing a coherent overview of the landscape of the twenty-first century skills change phenomenon.

Conclusion

This volume, reflecting the concerns and questions of researchers and practitioners highlights five points: that the shift towards twenty-first century skills in national education systems is occurring; that the shift is raising implementation issues in terms of teacher education and strategies; that the opportunities provided by technologies also provide challenges; that the measurement world is engaging with new approaches; and that transfer of these new approaches remain to transition into the classroom. It is unrealistic to assume that curricular shift, and innovation in assessment to reflect current teaching and learning associated with that shift, will all happen at once. As this volume demonstrates, there is movement in classrooms and some higher education contexts. This presents researchers with a situation of some urgency in moving beyond the theoretical and conceptual toward pragmatic solutions to the teaching and assessment of twenty-first century skills that will enhance student growth.

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