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EDITORIAL

Possible futures for science and engineering education

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Introduction

The understanding that the science, engineering, technology and mathematics disciplines (STEM) have a significant and directly causal role to play in economic productivity and innovation has driven an increased focus on these fields in higher education. Innovation in this context is a shorthand for the harnessing of the knowledge economy and the provision of products with novel significant 'added value'. The assumption in both developed and developing economies alike is that STEM will drive national growth (World Bank 2002; UNESCO 2009), and this impacts on demands that universities provide competent graduates in sufficient numbers. However, exactly what 'competency' might mean in this context is open to debate.

Of concern, given the increasing relative cost of higher education, is that there is a persistent murmur from industry that graduates are not fully prepared to work in STEM fields. The issue seems to be concentrated around what Johan Muller terms *procedural know how* (Muller 2015) where the neophyte must assimilate new knowledge and apply it effectively. Science and engineering curricula are expected to respond to such concerns in an era of mass data gathered in international testing schemes such as PISA and TIMMS. Against this backdrop, coupled with the information explosion of recent decades and the challenges of increasing specialisation and differentiation in STEM domains (Muller

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2015), educators at the tertiary level are grappling with what it means to be educated in a STEM discipline.

Such educators must also take cognisance of the positioning of higher education in the wider socio-political economy. The relationship between STEM and economic and technological progress is often taken as given (e.g. Boateng et al. 2012; Chowdury and Alam 2012; Sharabati-Shahin and Thiruchelvam 2013). Yet Hunter (2013) argues that the normalisation of this link constrains our thinking about the role of higher education in society and how this should be achieved.

Soudien (2011) has called for the 'recovery of the debate about what good education is' (p. 1). In the past three decades, discourses around the role of higher education have shifted from issues of massification and concerns about both unemployment and developing a critical citizenry, to a sharper focus on the knowledge economy, innovation and concerns about human capital and skills (Walsh et al. 2013). Thus, higher education is expected to be responsive by improving access and success for disadvantaged groups, building capacity for innovation (in STEM in particular), building partnerships with industry and community, and producing knowledge that is socially and economically relevant (Hunter 2013). This is to be achieved within a context of financial constraint, playing out in demands for greater quality, efficiency and accountability from higher education institutions. In addition, since STEM is implicated in issues of environmental sustainability and social justice (Brauer 2013), curricula in these disciplines need to look beyond technical expertise alone, to the role of the disciplines in transforming society.

The role given to higher education and how this plays out in practice is, of course, sensitive to geographical region (e.g. Carnoy and Dossani 2013; Liu 2012). Higher education institutions are not only challenged to respond to the economic and development needs of a country but in South Africa, where this Special Issue originated, a response to the socio-economic challenges posed by rising poverty, inequality, violence, social unrest, and threats to democracy is also needed (Brown-Luthango 2013; Council on Higher Education 2013). In South Africa, the words 'massification' and 'non-traditional students' have come to refer to improving access to and success in higher education for those who were and continue to be educationally disadvantaged on the basis of the related constructs of race, language and socio-economic class (Soudien 2012). Enrolments into higher education have increased significantly in the past 20 years, with government calls for further enrolments, particularly in STEM disciplines (National Planning Commission 2011). Yet, high attrition and low, racially skewed graduation rates have militated against the gains made in access. In other words, physical access has not translated into epistemic access (Morrow 2007) and social access, that is, whether students see themselves as belonging in higher education (Walker 2015). These issues are overtly articulated in South Africa because of our history, and this is evident in the papers in this collection that emerge from this context (Case and Marshall, Shay, Vahed, McKenna and Singh herein). However, the issue of broadening access and high attrition is, of course, not unique to South Africa, and while the definition of 'non-traditional' varies across contexts, concerns about success in STEM disciplines for these students is of concern internationally (e.g. Cole and Espinoza 2008; Powell et al. 2012).

In this issue we open up these conversations by asking education researchers to draw on theoretical and empirical work to answer the question, '*What should it mean to be educated in science and engineering in higher education?*' The issue developed out of discussions amongst education researchers affiliated to the Centre for Engineering and Science Education (CREE), located at the University of Cape Town in South Africa. To broaden the discussion beyond the empirical and theoretical work of the Centre, we began by asking

Johan Muller and Melanie Walker to draw on some of their earlier writing specifically to answer our question about science and engineering in higher education.[1] These tailored responses are published in Volume 70, Issue 3, of *Higher Education*. We followed this with a call to researchers in South Africa and beyond to respond to the positions taken by Walker and Muller by bringing theoretical and/or empirical work to the conversation.

In this Editorial we begin by summarising the Muller (2015) and Walker (2015) arguments in detail, before outlining the ways in which the five authors in this issue respond to the challenges the two pieces pose.

Muller (2015): The future of knowledge and skills in science and technology higher education

Muller (2015) draws on an earlier piece co-authored with Young (Young and Muller 2010) to bring a sociology of knowledge perspective to the context of science, technology, engineering and mathematics in higher education. In doing so, he undertakes an exercise in 'futures thinking' that presents the reader with three scenarios.

Muller begins with the uncontentious premise that there is an increasing specialisation of knowledge and this is acutely true in concept-rich domains like STEM. Furthermore, such domains are already taught through 'bursting at the seams' (p. 410) curricula. Muller argues that if the increased specialisation of knowledge is addressed in the classroom through increased pacing, whereby material is compressed and speeded up, then we will continue to see the privileging of already privileged students. Those students with linguistic, financial and educational advantage might continue to enjoy higher education success within such systems but those without such advantages will be excluded. Muller begins with the understanding that at its heart STEM education needs to find ways of educating that 'expand opportunities for students from less privileged educational backgrounds, not shut them down' (p. 410).

This increased specialisation of knowledge must also be understood, Muller argues, to occur alongside the unavoidable differentiatedness of knowledge. Different knowledges have 'different epistemic and social properties' (p. 410). Complex professional programmes in the STEM domain bring together a 'dynamic conglomeration of different socio-epistemic communities each with their distinct cognitive and cultural styles' which need to be acknowledged and managed if they are 'not to bump ceaselessly into one another' (p. 410).

Building on this premise of specialisation and differentiation of knowledge, Muller posits three educational response scenarios. The first is what he and Young call 'traditionalism', which is based on an under-socialised concept of knowledge and the second they call 'progressivism', where there is an over-socialisation of knowledge (Young and Muller 2010).

Traditionalism works to elevate theory and disciplines through a validating of empiricism. In many ways this scenario is the 'bedrock' (p. 411) of science and engineering but, Muller argues, it fosters elitism because it attends only to the knowledge and neglects to pay attention to high levels of student drop out. In this way 'it replicates enduring patterns of social privilege' (p. 411).

The second scenario, progressivism, shifts the focus to the activity. The focus on social and educational hierarchies was initially liberating. This scenario promised to make success more accessible to all. It was largely premised on the notion of constructivism whereby anyone could be supported to construct their own versions of knowledge. But scenario 2's attempt to socialise knowledge and move away from scenario 1's 'static and

[1] Walker (2008) and Young and Muller (2010).

ahistorical view of knowledge' (p. 412) brought with it a slip into relativism as 'knowledge, truth, and objectivity' (p. 412) so at the heart of scenario 1, were neglected. The focus on activity, or 'practice' tended to 'draw a veil over the knowledge base on which successful action depends, and hence most crucially, over the differential curriculum requirements of specialised knowledge' (p. 412).

Muller is careful not to entirely dismiss the two powerful scenarios of traditionalism and progressivism as each is a movement of its time with its own 'rational kernel' (p. 411). Traditionalism's kernel 'was lost sight of in the enthusiasms of scenario 2' (p. 411) and Muller argues that we need to retrieve what is good in each as we cast them under the social realist alternative of scenario 3.

Scenario 3 is the name Young and Muller gave to the combination of the positive features of each, while avoiding the weaknesses of either. This is not, however, a simple task of merging the two scenarios for they are 'thoroughly socio-historical phenomena and they leave behind specific historical sediments and path dependencies' (p. 413).

Muller suggests as a start to the task, looking specifically at the de-differentiating features of scenario 2. The ways in which scenario 2 socialised the 'basically ahistorical orientation of scenario 1' (p. 413) through its practice orientation had the unfortunate effect of valorising 'agent-centred experience' (p. 413) at the expense of knowledge differences and led to the call for generic pedagogy (such as outcomes-based education, problems-based learning, competency-based education etc.) where engagement was valued over a consideration of the ways in which pedagogies emerge from specific kinds of knowledge. Crucially, scenario 2 valorised 'skills at the expense of knowledge' (p. 413).

Muller then uses the rest of his paper to engage with the particular issue of skills in this scenario. The term 'skills', or 'techniques' or 'outcomes', 'obscures the speciality and differentiation of the knowledgeable practice in question (p. 414). Muller draws on Winch (2013, 2014) to differentiate between *know that* (propositional knowledge) and *know how* (procedural knowledge). He then goes on to differentiate three different kinds of *know how* knowledge. *Inferential know how* which allows for a negotiation of the ways in which various pieces of conceptual knowledge 'hang together' (p. 414). *Procedural know how* is when the novice takes risks and works out how to find out things, and 'forms new judgements that lead to solutions that work in the world' (p. 414). Thirdly, there is *personal know how*, 'which is the idiosyncratic knowledge accumulated through diverse experiences in the process of actually 'doing it'' (p. 414). Further to this are a range of more practical *know hows* that are conflated when we speak generically of 'skills' or 'practical expertise'.

Muller makes the point that these different knowledges are cumulative. A student needs some grasp of the conceptual content (*know that*) before she can begin to understand how the *know how* works. She also needs to understand the inferences and inferential relations before she can 'venture out into uncertain territory with the *procedural know how* with any confidence' (p. 415). Furthermore, the various *know hows* are nested and have features of greater or lesser complexity and so must be 'correctly sequenced in a coherent curriculum' (p. 415). Calling all of these kinds of knowledge 'skills' is to flatten out the ways in which they are epistemically different, requiring different recognition and realisation rules and entailing different pedagogic relations.

Muller (2015) argues that, since it is likely that STEM domains will continue to advance and specialise at the rates they are currently doing, demands for access to these knowledges by an increasingly diverse student body will continue apace. This process is increasingly showing that the scenario 1 arrangement is unworkable. The spotlight thus falls to scenario 2 efforts, 'which will probably become bolder and more ambitious' (p. 415). But this will fall foul of the problems of its own knowledge blindness if it fails to ask which parts students manage with ease and which prove more problematic and thereby 'make more visible the epistemic obstacle course that is the evolving science and engineering curriculum. To do so will require illuminating the differential *internal epistemic and pedagogic architecture* that we require students to negotiate' (p. 415, emphasis in original).

Through such illumination, Muller concludes, scenario 2 will begin 'to make way for an emergent alternative scenario, for a more robust scenario 3, that is better equipped to negotiate the specialising future' (p. 415).

Walker (2015): Imagining STEM higher education futures: advancing human well-being

Walker (2015) is concerned with how STEM higher education can prepare graduates whose professional contributions to society will have a positive impact on equity and human well-being. In this paper she draws on her earlier work (e.g. Walker 2008; Walker and McLean 2013) founded on the work of Sen and Nussbaum.

Walker begins by situating her paper politically and historically. She notes a strong global political argument for the centrality of scientific and technological education in the economic development of countries. Walker then localises her argument to the South African context. As has been the case in many countries, there has been a significant increase in enrolment in higher education in recent decades. In South Africa, the quest for equity following profoundly unjust education policies of the apartheid era has required a particular focus on the racial profile of both enrolled students and graduating students. While the enrolment figures show a dramatic improvement in access for non-white students, the completion rates show that there is still much work to be done to help students from disadvantaged backgrounds succeed. That South Africa is one of the most unequal countries in the world with respect to wealth distribution adds complexity to the challenge of the social transformation of society through education.

Walker's ultimate goal is the establishment of a more just society and therefore this broader perspective underpins her perspective on education, and STEM higher education in particular in this paper. Thus Walker (2015) asks, 'Specifically what would science and engineering education that took human development values of equity, empowerment, participation and sustainability (Boni and Walker 2013) seriously look like? What would students have reason to value doing and being now and as future persons, informed and shaped by their education and experiences at university?' (p. 418)

Walker is not content to simply create a curriculum and higher education system which empowers science and engineering graduates with knowledge, skills and effective power to capitalise on employment opportunities. She advocates for an education system which will shape students in such a way that they will have the capacity and the will to make a substantial difference in the world, precisely to establish a system of greater justice (Walker and McLean 2013). While acknowledging the socio-historical context of the university and its role in reproducing social hierarchies, Walker argues strongly that higher education can potentially play a transformative role in society.

Walker (2015) grounds the description of the context with a description of an engineering student she has named Ntebo:

> Consider Ntebo, a black student studying engineering. She has the financial resources (commodities) and the grades (schooling outcomes) to come to university. On the surface, she appears to have well-being and good opportunities which have enabled

> her to access higher education. But now she is struggling because she feels that she does not belong to the University or in the programme, which seem far removed from her upbringing in a poor urban township. She feels alienated. She feels she cannot ask questions of her lecturers or turn to other students for help, or say that she does not understand or try out her own ideas in dialogue. (p. 419)

Walker goes on to ask, 'What theoretical approach would help us to explain Ntebo's situation and the inequalities she faces? Do we give her more money and resources? Do we ask how satisfied she is? Or do we ask what she can be and do?' (p. 419)

Walker pursues the last approach in her 2015 paper, turning to Sen's (1979, 1999, 2008, 2009) capabilities approach to human well-being and human development to theorise Ntebo's situation. This approach has been applied to education specifically by Nussbaum (2000, 2010, 2011).

Walker notes that, according to Sen, one cannot determine well-being on the basis of GDP or average income. Resources are a necessary means of development, but they are not the end. Likewise, offering differentiated support to students merely on the basis of access to resources will not necessarily change Ntebo's capacity to participate and succeed in her higher education degree. This method 'would still not tell us about Ntebo's ability to convert her bundle of resources into actual achievements' (p. 420)

Walker argues further that simply asking the student about her contentment is not sufficient, for human beings are adept at adapting to a vast array of circumstances:

> Generally in adapting to the bad they ask and expect less, or if better off people are very satisfied and some very poor people are not, the overall satisfaction calculus will not tell us this. For example, Ntebo decides not to try hard in her course because she thinks she will fail and rather aims for a low passing grade, because, she says that she knew that if she got 50 % she would be happy. She ends up setting a low goal for her success, but she adapts her preferences (Nussbaum 2000) so as to be satisfied with this reduced goal. If we were to ask if she were satisfied with her study achievements, she would then say she was indeed 'happy'. Have we then done enough for the well-being of Ntebo and other students? (p. 420)

Sen's capabilities approach requires that we consider what people value being and doing, and work to support a person's freedom such that those things can be magnified. To help situate this in an educational setting Walker goes on to make a distinction between functioning achievements and capabilities.

> Functioning achievements (beings and doings) indicate what a person manages to do or to be in comparison with others. Thus, the functioning may be critical thinking, and the real opportunity for critical thinking is the corresponding capability. Education allows the functioning to be exercised, so that the capability is effectively possible (Robeyns 2011). Having the freedom to choose functionings from an individual's capabilities set is also intrinsically valuable. But we do not look only at a single functioning (e.g. thinking critically) and then say that a student has well-being. Capabilities are the freedoms each person has to choose and exercise a *combination* of ways of beings and doings they have reason to value. The opportunity overall to choose a good life is then constituted of many different functionings. A student or graduate with a wide capability set of values, knowledge and skills is empowered to do more with their life, to have more well-being. (p. 420–421, emphasis in original)

Individuals are able to convert resources into functionings through three conversion factors: personal, social and environmental factors. Walker suggests that in order to evaluate Ntebo's well-being we need to consider how well she is using the three conversion factors to develop functionings from the available resources. Until we ask this deeper question, she argues, we are likely to fail in our quest to educate in a meaningful way. The capabilities approach allows for diversity in the ways in which any individual may actually use the plurality of functionings.

Walker argues that the capabilities approach could create science and engineering that is 'instrumentally, intrinsically and socially valuable' (p. 421). This would allow for the coexistence of study for the love of the subject, a real preparation for a rapidly changing world where adaptation to newly emerging technology is vital, and a genuine concern for the development social and economic justice. Walker argues that educators must agree upon the core valuable capabilities which must comprise science and engineering education, and this is where, she notes, Sen and Nussbaum part ways slightly. For Nussbaum there is a core set of non-negotiable capabilities which must be developed in order to establish the philosophical notion of 'the good life'. In the absence of any of these capabilities, 'the good life' necessarily cannot be established. Sen takes a different route allowing for the negotiation of the set of capabilities which are to be used to determine quality of life.

Walker takes a middle route between one list and no list of capabilities, arguing for workable agreements around core valuable higher education capabilities which could draw on the lists of others and on empirical investigations. In an earlier study, Walker and McLean (2013) brought together 'elements of public reasoning, the idea of a partial ranking—some professional capabilities which can be agreed are valuable for a comparative assessment of justice—and an ideal value of human dignity, which morally guides the right thing to do in concrete professional situations' (Walker 2015, p. 423).

Walker (2015) refers to a list of eight professional capabilities linked to empirical functionings developed by her and McLean: 'informed vision; affiliation (solidarity); resilience; social and collective struggle; emotional reflexivity; integrity; assurance and confidence; knowledge and skills' (p. 423). Walker (2015) notes that this is clearly a far wider list than many science and engineering educators would usually choose. The challenge is to broaden the horizon of our educational imagination and to recognise what is at stake.

> To be sure, what is at stake is not any educational future for science and engineering, but a direction of travel which is towards 'redressable injustices' (Sen 2009, p. vii). Concerns for equity in higher education and society and decent lives would direct students, graduates, researchers and university teachers as bearers of knowledge (basic, 'blue skies' and applied), technology and information to economic and social development which promotes human capabilities and well-being for all. How science and engineering in higher education actually does this, with what effects, would need to be evaluated empirically according to a capabilities metric to understand how well students were doing in the space of educational arrangements and graduate identity formation.(p. 424)

'What should it mean to be educated in science and engineering in higher education?'

The theoretical approaches offered by Muller and Walker require some translation into real world scenarios. Muller distinguishes between *know that propositional* knowledge and *know how procedural* knowledge. Within the broad canopy of science and engineering education, the propositional knowledge which makes it into an undergraduate curriculum is not usually contested knowledge and is not dependent on social capital per se. Although issues of language, educational preparedness, familiarity with the tools of information transfer and social etiquette in the lecture hall and tutorial venue may influence heavily the rate of assimilation of this propositional knowledge, it is on the level of procedural knowledge, which is itself divided into *inferential know how*, *procedural know how* and *personal know how*, that issues of student agency and social capital most clearly become linked with success.

Walker's (2015) fundamental question is 'What would science and engineering education that took the human development values of equity, empowerment, participation and sustainability seriously look like?' Walker looks for inspiration in the capabilities approach and calls for university educators to 'evaluate public-good functionings in order that students might develop and enhance their capabilities' (p. 422) precisely because evidence of these functionings provide a proxy for assessing whether the student possesses the necessary capabilities. Walker lists eight professional capabilities: informed vision, affiliation (solidarity); resilience; social and collective struggle; emotional reflexivity; integrity; assurance and confidence; knowledge and skills. While it might be assumed that some of these functionings would be part of any professionally audited engineering curriculum, it would be somewhat remarkable to find any programme that reliably attends to all of them. And there is far less assurance that any functionings beyond the last (knowledge and skills) would be found routinely in any non-professional STEM programme.

In many universities, the major resistance to the emerging discourse of graduate attributes often comes from the STEM fields precisely because they are knowledge codes with an emphasis on the mastery of specialised procedures rather than knower codes with an emphasis on the social attributes of the subject (drawing on Maton's Legitimation Code Theory, 2013). Graduate attributes, Walker's eight capabilities and calls for critical citizenship can all appear as a threat to the accepted identity of those involved in STEM fields. Introducing capabilities or any person-centred language appears at first to be a clash of codes. Most science and engineering educators will agree that the capabilities approach is worthwhile but the stumbling block is usually what form it will take and where it will appear in the curriculum, the subtext is usually 'Not in my subject!'

The ideas of Muller and Walker suggest a conjunction of three elements—science and engineering student agency, STEM knowledge and the social situatedness of both. While Walker may call for more focus on agency and Muller may privilege knowledge, both pieces have a strong sense of the socially contextualised nature of science and engineering programmes. Part of the task of this special issue is to explore ways in which different individuals located in different contexts have tried to answer the large societal imperative envisioned by Walker, against a context which is too often still in Muller's scenario 1. The relatively high degree of heterogeneity across the pieces in some senses reflects the complex and varied nature of the field, but there is also possible unification to be found around the concern with agency, knowledge and social context and the avoidance of the conflation of the same.

Responses to Muller and Walker in this special issue

The papers in this issue all address aspects of the pieces by Muller (2015) and Walker (2015), and in doing so consider how varied contexts might elucidate the implications of their arguments.

Suellen Shay's concern is with the kinds of 'false choices' that can emerge when we polarise 'capabilities' and 'knowledge' in debates about the purposes of higher education and STEM curricula in particular. She is equally concerned about the dichotomy of 'pure' and 'applied' that often characterises these debates, a dichotomy which she suggests hides deeper issues about the knowledge base of curricula. Shay's contribution is to foreground the 'stakes' in the curriculum reform debate illustrated in Walker (2015) and Muller (2015). Drawing on Maton's Legitimation Code Theory, she offers a conceptual framework for understanding curriculum contestation. She illustrates the use of the framework by focusing on 'curricular on the boundaries' that face both inwards to disciplines and outwards to professional or workplace practice—environmental management, and apparel and textile—in a South African context of frequent policy changes on institutional differentiation. Shay uses this illustration to confirm Muller's (2015) argument that 'different knowledges (disciplines and curricula carriers) have different epistemic and social properties' (p. 410), but offers additional insight into how curricula in STEM are specialised in different ways at both the macro-structural level and the meso-level of curriculum coherence. Possibilities and constraints for curriculum reform will thus vary according to the type and purpose of curriculum.

Anisa Vahed, Sioux McKenna and Shalini Singh set out to give meaning to Muller's (2015) scenario 3 in professionally accredited programmes that aim to balance disciplinary knowledge and professional practice. The empirical context of their work is a dental technology programme at a university of technology in South Africa. Drawing on Maton and Bernstein, they argue that discipline-specific games, conceptualised from a games literacy perspective, can facilitate access to the required specialised disciplinary knowledge, while backgrounding personal attributes and dispositions. Like Shay, Vahed, McKenna and Singh emphasise the contextualised nature of responses.

Alejandra Boni-Aristizábal and Carola Calabuig-Tormo support the transformative public-good professional capabilities approach of Walker, as opposed to the commonly used reproductive notion of professional skills and competences, contributing a particular focus on engineering education. Drawing on the work of Nussbaum, Sen and Walker, they refer to public-good professionalism as the expansion of 'capabilities, functionings and agency within a framework of respect for the core values of human development' (Boni-Aristizábal and Calabuig-Tormo 2016, p. 14), not just amongst those who enrol for an engineering degree, but for all citizens. To give readers a sense of what the a pro-public-good professionalism approach may look like in practice, the authors put to work these concepts in their empirical work in two long-running learning spaces—one student-led and the other course-based—for engineering students at a higher education institution in Spain. Boni-Aristizábal and Calabuig-Tormo argue that the different spaces have, to varying degrees, the potential to foster capabilities—participation, commitment, empathy, critical thinking and self-reflexivity—that can be understood as a mix of Muller's (2015) *procedural know how* and *personal know how*. The authors acknowledge, however, that the answer to the question 'What should it mean to be educated in science and engineering in higher education?' that they offer has to take into account institutional culture and power.

Alan Cheville's concern is how to resolve the tension between supporting existing structures of disciplinary knowledge so that students can develop societally meaningful capabilities (Muller 2015), and relaxing these sufficiently to enable students to connect capabilities to personally meaningful and potentially emergent functions (Walker 2015). This tension, he argues, cannot be resolved within existing curriculum structures. His contribution is to propose two lenses for viewing curriculum. The first, *curriculum mode* or intent of learning, has three modes—knowing, acting, being—and the second, *structural* *scale* captures how learning is aggregated into credentials. He argues that the structural tension needs to be made visible to students and that this can be achieved through an emphasis on the curriculum mode of being as self-narrative. He presents three speculative models in engineering education to suggest how role-playing games could be used to engage students in actively creating their own story that links both to meaningful learning experiences and to earning a credential. Cheville also engages reflexively with the possible constraints of implementing this proposal within current institutional structures.

Jenni Case and Delia Marshall argue that what Muller (2015) and Walker (2015) propose offer but partial answers to the question of what it means to be educated in STEM in times of rapid technological and social change. Their response draws empirically on longitudinal interviews with engineering students considered educationally disadvantaged in the South African context whom the authors followed into the workplace. Case and Marshall use these graduates' accounts of their professional and personal development to explore what they value being and doing, the role of knowledge in their development, and how this knowledge relates to capabilities. These authors bring to the conversation a nuanced view of 'graduateness' that synthesises what Muller and Walker propose. This view includes the significance of disciplinary knowledge but also holds a place for student agency in the formation of the graduate professional, for it is the engagement with knowledge that is central to the development of capabilities such as resilience and confidence.

Each paper in this issue is part of a wider debate 'about what good education is' (Soudien 2011, p. 1) in science and engineering in higher education. What the papers seek to contribute to this debate is both theoretical perspectives with which we can conduct our discussions and empirical studies in a variety of contexts suggesting what these educational futures might look like in practice. The format of the issue in which the five respondents engage with the ideas of Muller (2015) and Walker (2015) means that the conversations between the pieces are as generative of discussion as the individual papers themselves.

Each paper brings a particular theoretical lens to the engagement with Muller (2015) and Walker (2015). Each also provides different tools for the task of entering the conversation. Shay's paper on curriculum will help in the critique of existing curricula. Case and Marshall draw on empirical interviews with graduated students to bring the student voice to the conversation about knowledge and capabilities. Some real world alternatives may well be developed, especially if read in the light of the empirical cases provided by Boni-Aristizábal and Calabuig-Tormo and by Vahed, McKenna and Singh, and the models proposed by Cheville.

It is clear that there are several important discourses playing into science and engineering education: the economic pressure towards innovation; higher education pressure towards student agency; discipline pressure from an ever increasing knowledge burden; industry pressure towards competent graduates; student pressure towards employability. Emerging from these pressures, the challenge communicated through the pieces in this issue is for science and engineering in higher education to bring together the focus on student capabilities and STEM knowledge while attending to the social situatedness of both.

References

Boateng, C. D., Bensah, E. C., & Ahiekpor, J. C. (2012). Assessing the higher national diploma chemical engineering programme in Ghana: Students' perspective. *European Journal of Engineering Education, 37*(2), 205–215.

Boni, A., & Walker, M. (2013). *Universities and human development. A new imaginary for the university of the XXI century*. London: Routledge.
Boni-Aristizábal, A., & Calabuig-Tormo, C. (2016). Enhancing pro-public-good professionalism in technical studies. *Higher Education*, 1–14. doi:10.1007/s10734-015-9916-4.
Brauer, C. S. (2013). Just sustainability? Sustainability and social justice in professional codes of ethics for engineers. *Science and Engineering Ethics, 19*, 875–889.
Brown-Luthango, M. (2013). Community-university engagement: The Philippi CityLab in Cape Town and the challenge of collaboration across boundaries. *Higher Education, 65*, 309–324.
Carnoy, M., & Dossani, R. (2013). Goals and governance of higher education in India. *Higher Education, 65*, 595–612.
Chowdhury, H., & Alam, F. (2012). Engineering education in Bangladesh—an indicator of economic development. *European Journal of Engineering Education, 37*(2), 217–228.
Cole, D., & Espinoza, A. (2008). Examining the academic success of Latino students in science technology engineering and mathematics (STEM) majors. *Journal of College Student Development, 49*(4), 285–300.
Council on Higher Education (CHE). (2013). *Undergraduate curriculum reform in South Africa: The case for a flexible curriculum structure (Draft document)*. Pretoria: Council on Higher Education.
Hunter, C. P. (2013). Shifting themes in OECD country reviews of higher education. *Higher Education, 66*, 707–723.
Liu, J. (2012). Examining massification policies and their consequences for equality in Chinese higher education: A cultural perspective. *Higher Education, 64*, 647–660.
Maton, K. (2013). *Knowledge and knowers*. London: Routledge.
Morrow, W. (2007). *Learning to teach in South Africa*. Pretoria: Human Sciences Research Council.
Muller, J. (2015). The future of knowledge and skills in science and technology higher education. *Higher Education, 70*, 409–416.
National Planning Commission (2011). *National Development Plan—Vision for 2030*. http://heaids.org.za/site/assets/files/1267/npc_national_development_plan_vision_2030_-lo-res.pdf. Accessed 7 Dec 2015.
Nussbaum, M. (2000). *Women and human development*. Cambridge: Cambridge University Press.
Nussbaum, M. (2010). *Not for profit*. Princeton: Princeton University Press.
Nussbaum, M. (2011). *Creating capabilities. The human development approach*. Cambridge, MA: The Belknap Press.
Powell, A., Dainty, A., & Bagilhole, B. (2012). Gender stereotypes among women engineering and technology students in the UK: Lessons from career choice narratives. *European Journal of Engineering Education, 37*(6), 541–556.
Robeyns, I. (2011). The capability approach. In E. N. Zalta (Ed.), *Stanford Encyclopedia of Philosophy* (Summer 2011 Edn.). http://plato.stanford.edu/entries/capability-approach. Accessed 18 Sept 2011.
Sen, A. (1979). *Tanner lecture on human values. Tanner lectures*. Stanford: Stanford University.
Sen, A. (1999). *Development as freedom*. Oxford: Oxford University Press.
Sen, A. (2008). The idea of justice. *Journal of Human Development, 9*(3), 331–342.
Sen, A. (2009). *The idea of justice*. London: Allen Lane.
Sharabati-Shahin, M. H. N., & Thiruchelvam, K. (2013). The role of diaspora in university–industry relationships in globalised knowledge economy: The case of Palestine. *Higher Education, 65*, 613–629.
Soudien, C. (2011). *A pedagogy of care: No 'ifs' and 'buts'. Address given to the Common Ground Learning Conference, July 4–8, 2011*. Port Louis, Mauritius: University of Mauritius.
Soudien, C. (2012). *Realising the dream: Unlearning the logic of race in the South African school*. Cape Town: HSRC Press.
UNESCO. (2009). *Trends in global higher education: Tracking an academic revolution*. Paris: UNESCO.
Walker, M. (2008). Human capability, mild perfectionism and thickened educational praxis. *Pedagogy, Culture and Society, 16*(2), 149–162.
Walker, M. (2015). Imagining STEM higher education futures: Advancing human well-being. *Higher Education, 70*, 417–425.
Walker, M., & McLean, M. (2013). *Professional education, capabilities and the public good: The role of universities in promoting human development*. London: Routledge.
Walsh, E., Anders, K., Hancock, S., & Elvidge, L. (2013). Reclaiming creativity in the era of impact: Exploring ideas about creative research in science and engineering. *Studies in Higher Education, 38*, 1259–1273.
Winch, C. (2013). Curriculum design and epistemic ascent. *Journal of Philosophy of Education, 47*(1), 128–146.
Winch, C. (2014). Know-how and knowledge in the professional curriculum. In M. Young & J. Muller (Eds.), *Knowedge, expertise and the professions* (pp. 47–60). London: Routledge.

World Bank. (2002). *Constructing knowledge societies. New challenges for tertiary education*. Washington: World Bank.

Young, M., & Muller, J. (2010). Three educational scenarios for the future: Lessons from the sociology of knowledge. *European Journal of Education, 45*(1), 11–27.