Reframing Resources in Engineering Teaching and Learning

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Abstract

The notion of 'resources' is often framed in an economic sense: money, time, equipment and the like. We reconceptualise this notion, situating resources as embedded in curricular frameworks, teacher practice and student experience. This leads us to define resources as *the potential to participate in socio-cultural action*. We illustrate this through a series of reflections on the part of the authors, all within the context of engineering education. First, we demonstrate that curriculum can be productively thought of as a route marker for the development of resources that students need in order to enact their role as professional engineers. Thereafter, we show that lecturers bring tacit resources of trust, care, creativity and credibility to the teaching and learning space, and that these are necessary to overcome the inertia that often resists the transformation of teaching and learning practice. Finally, we reflect on how students' prior learning experiences can be harnessed as a resource for teaching and learning. In so doing, we present resources as tied to sociocultural practices and personal and institutional histories, and encourage others to take up these ideas so as to consider how resources, viewed in our sense, are valued within (engineering) education.

Keywords: engineering education; higher education studies; teaching and learning; resources; curriculum

1. INTRODUCTION

Few will disagree with the fact that economic and physical factors enhance teaching and learning. For instance, it has been shown that providing learners with sanitation and meals will increase educational outcomes when these are not in place to begin with (Hochfeld, Graham, Patel, Moodley and Ross 2016; Jasper, Le and Bartram 2012). Similarly, some universities in South Africa (and internationally) have attempted to ensure that all students have access to a personal computer and free campus Wi-Fi. Indeed, readers of *Africa Education Review* may be familiar with a recently published paper that argues for initiatives that enhance technological access and digital literacy (Oyedemi and Mogano 2018). Furthermore, much funding and infrastructure has been devoted to providing instructors with better tools (improved Learning Management Systems, smart boards and the like) (Querios and de Villiers 2016). At the same time, ICTs in education are increasingly playing a vital role in teaching and learning and in the socio-economic development of Africa (Carrim and Taruvinga 2015).

Neoliberal views of education have sought to locate teaching and learning success within market values (McClennen 2008-9; Tronto 2018). More often than not, these values promote allocation of economic rewards: they take the form of money, staff, laboratory space, classrooms, bandwidth and so on. Within this view, the challenges that (higher) education faces are couched in the language of scarcity: teachers, schools, universities and students are seen to lack the economic, physical and cognitive requirements for academic success. For example, students are constructed as "digitally disadvantaged" (Oyedemi and Mogano 2018) where they lack access to the necessary technologies for learning. While we accept that such scarcity exists and that it has significant consequences for teaching and learning, we nonetheless caution against the "disintegration of the university as a site of social agency and critical engagement" (McClennen 2008-9, 461).

In opposition to managerial and neoliberal approaches, we seek to define the notion of resource, such that it includes not only economic considerations, but also the curriculum, lecturer and student. Furthermore, we seek to install these aspects as resource-laden, in an attempt to overcome deficit views of curricula, lecturers and, in particular, students. In each instance, we draw upon our own reflections as engineering educators in a variety of contexts. These reflections are used as a basis for thinking about how the notion of resource, which we define as *the potential for participation in socio-cultural action*, can be productive for thinking about teaching and learning in engineering.

We arrived at the notion of resource through a series of conversations between the three authors, who come from three different departments across two universities. All of us, in the first semester of 2017, were engaged in teaching second year courses to engineering students. In the context of the previous years' #feesmustfall protests, our discussions were initially centred on the urgent calls for the decolonisation of knowledge within engineering education. We felt that effecting transformation within our curricula required that we engage in a project of 'recognition' (Fataar 2018; Fraser 2009), which we saw as being in contrast to the rhetoric that labels students as 'poorly-resourced' and 'disadvantaged'. We thus embarked on a project to understand the idea of resource.

We chose to use the second-year courses in which each of us were teaching as sites for exploration and reflection. Helen, based in Pretoria, teaches a dynamics course common to various engineering disciplines. Helen reflects on the position of the course within the curriculum and argues that when we think about the resources associated with a course, we must interrogate these at multiple levels. Carl, also in Pretoria, teaches within the specific discipline of chemical engineering. He reflects on his experience taking over a course from an experienced and respected professor. Carl argues that lecturers and the relationship between lecturers and students are resource-laden, and that these resources tacitly inform classroom practice. Finally, Zach, writing from Johannesburg, teaches a course in academic and professional communication. In his reflections, he makes the point that students possess myriad resources, and that it is the job of both lecturers and the curriculum to harness these student resources for effective teaching and learning.

The remainder of this paper is structured such that it begins with an introduction to our notion of resource in engineering education. Thereafter, in successive sections, we present reflections on how curriculum, lecturers and students can be seen as resource-laden. It should be noted that this paper does not seek to present a formal, empirical investigation into the notion of resources. Rather, it is a position paper that draws on the authors anecdotal reflections and invites readers to take these ideas forward in more empirical ways.

2. Thinking about Resources in Engineering Education

Building on the work of Vygotsky, learning has come to be understood as a process of 'becoming', that is, of changing the nature of one's participation in the sociocultural activities of one's communities (Ivanič 1998; Rogoff 2003). This is significant because it implies that the activities in which learners engage cannot be separated from the social and cultural institutions with which they are affiliated, and with which they seek to become affiliated. Learning is thus conceived as coming to adopt the sociocultural tools for acting on the world that are valued by these institutions (Rogoff 2003), such as the professional institution of engineering that is of concern in this paper. As individuals participate in these new institutions, they harness new ways of being in all spheres of their identity (Ivanič 1998), as they move from their initial self to the self that knows more, and that can do more in the world.

These new ways of being are resources with which learners are able to act upon and within the social world. Such resources are not economic (though they can be as well), but are tools for participation in social institutions. They take the form of enhanced content knowledge, specific attributes, and the mastery of representational codes. However, such individuals never enter learning experiences as blank slates: instead, they bring with them resources from the home, school, church, and other sociocultural institutions in the form of what Gee (1996) calls 'primary Discourses', and what Bourdieu (1986) calls 'cultural capital'. It is important to note that resources are not abilities; rather, they exist as potential in that they only gain value when accorded such value within particular communities. As such, resources are always relational.

Higher education, as a sociocultural institution, has historically sought to normalize the resources within its ambit and, as such, has privileged certain discursive identities, amongst students and staff, at the expense of others (Burke, Crozier and Misiaszek 2017). In contrast, the resource perspective we present here is concerned with valuing and acknowledging different resources rather than aiming for uniformity of resources. When individuals enter learning experiences, they bring myriad resources with them, and these resources should be developed and promoted as part of their learning. The problem of resource inequality requires re-thinking the ways in which resources are valued in specific social contexts.

Some work in this regard has already been undertaken. For example, Setlogelo (2008) draws on the notion of cultural capital and demonstrates how students' cultural capital either aligns or does not align with institutional standards. More importantly, Setlogelo (2008) shows how students with aligned cultural capital perform better than those with non-aligned cultural capital, thus demonstrating how the institution acts as a site of potential exclusion. In a paper similar in structure and intent to our present paper, albeit focused on the development of professional engineering identities, Allie et al. (2008) provide three vignettes that demonstrate how the discursive identities with which students enter into the engineering classroom can be used productively to nurture the kinds of identities privileged in the world of engineering work. Finally, Smit (2012) has outlined the dangers of a deficit-view of students in higher education. Indeed, the present paper is in part a response to Smit's (2012, 369) call for ways "to value the pre-higher education contexts from which students come".

In engineering, the content knowledge that students are expected to acquire in order to participate meaningfully within engineering institutions requires them to develop ways of engaging with the physical world through abstract means. Put more simply, engineering students are expected to develop particular forms of engagement that move between concrete and abstract representations. As can be seen in Figure 1, the realm of science moves from engagement with tools for capturing observations of the physical world, and transforming those observations into abstract representations of the principles underlying the physical world. Engineering, as the application of science, moves in the reverse direction: using abstract representations to effect changes in the physical world (Juhl and Lindegaard 2013; Simpson 2015). This requires the acquisition, development and/or mastery of myriad resources: for meaning-making, for learning, and for participation. But, it can also build on the forms of engagement with the world that students may have acquired prior to their entry into higher education, those forms of engagement fostered in the home, community and other sociocultural institutions.

As such, when considering resources in engineering education, there is a semiotic dimension to this discussion. Indeed, our conceptualisation of resource borrows heavily from the notion of 'semiotic resource' in the social semiotics literature (see Halliday 1978 and van Leeuwen 2005 as seminal texts within this literature). Engineering students use mathematics, physical models, statistical models, diagrams and myriad other representational forms as resources for accomplishing their work. Mastery of these resources offers enhanced potential for participation within engineering institutions, but these should be developed in tandem with existing representational and symbolic forms of knowledge that can deepen this potential for social participation.

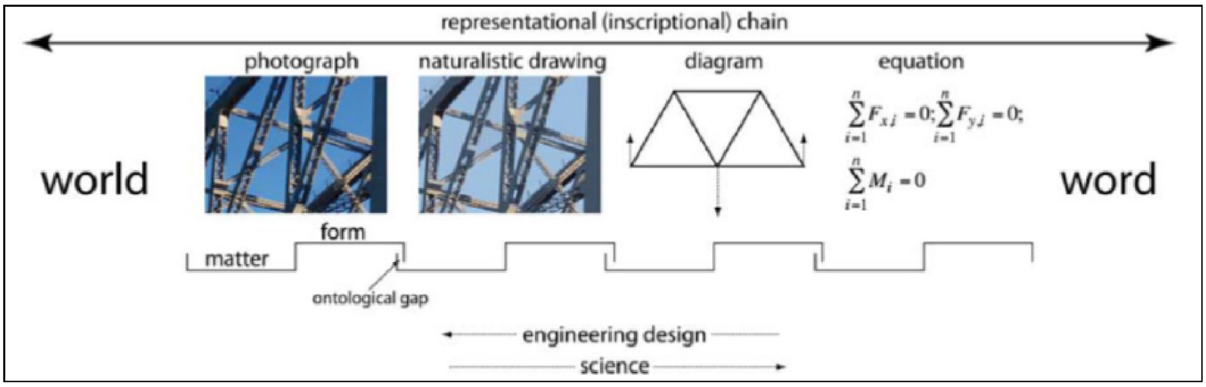

Figure 1. Representational chain in science and engineering design (Juhl and Lindegaard 2013, 9)

Participation depends on sociocultural values and norms as well as on content knowledge. In the engineering disciplines, this means that participation should be enacted in ways that are respectful of the social and environmental systems existent in the physical world, as is stated in the various codes and standards regarding engineering work and engineering education (ECSA 2012; ECSA 2014). Values and attitudes such as environmental awareness, ethics, social engagement, professionalism, lifelong learning and the like are not simply complementary to engineering. Rather, they are the attributes that guide the participation of engineers in the practical accomplishment of their work. As such, they too are resources that engineers, engineering students and, crucially, engineering educators could draw upon. In this regard, the knowledge that students might bring with them from the home and community represent a complex history of the "interplay between distinct cultures and specific local environments" (Odora Hoppers 2008, 10), and can be harnessed as a resource in the development of these attributes.

Resources, therefore, can take many forms and include, inter alia, semiotic, professional and content aspects. In the reflections that follow, we hope to demonstrate how such a view can inform teaching and learning. It should be noted, however, that this paper does not seek to provide a taxonomy of resources. Rather, it serves as an introduction to the broader term and its usefulness in thinking about teaching and learning in engineering. Taxonomic classification of resources could be a logical next step in this work but would require extensive empirical data collection.

3. CURRICULUM AND THE DEVELOPMENT OF RESOURCES

From an institutional perspective, individual courses are drawn upon in service of obtaining a larger engineering qualification. Explicit here is the idea of progression from one level to another. The curriculum, by which we mean the formal, explicit curriculum as stated in official documentation, is designed to assist students in the development of resources for use within engineering institutions. As they progress through a degree or diploma programme, students develop fluency in these disciplinary resources, and undergo a process of change and growth: from novice toward expert. This deepens their potential for participation in social action. If students are to participate actively in their own processes of 'becoming' (Rogoff 2003), the curriculum cannot be deployed as a form of 'symbolic violence', in which individuals are forced to conform to dominant values, identities and practices (Burke, Crozier and Misiaszek 2017) through what has been termed the 'hidden curriculum' (Jackson 1986).

Course outcomes, as documented in study guides, are not endpoints, but route markers towards the development of the resources that students need in order to become effective engineering professionals. For example, Helen teaches a dynamics course, which can be simultaneously understood as a credit towards obtaining a degree, as providing prerequisite knowledge for later courses, and as developing reasoning and problem-solving skills within the context of the discipline. The dynamics course, therefore, is not merely a credit that exists for accumulation, but a means by which curricular, content knowledge and student attribute resources are developed.

On paper, all students are expected to bring the same resources to bear on the dynamics course. However, this is never the case in practice, in part because students will have achieved different levels of mastery of the prerequisite knowledge. For instance, it is assumed that all students have fluency with mathematical concepts like trigonometric identities and geometric reasoning, but these are taught unevenly across the secondary schooling system. Furthermore, in many courses and curricula, the way material is presented builds on assumptions about students' experiences and prior sociocultural resources. If Helen were to say "imagine you are walking from one side of a boat to another", she may be expecting students to leverage prior experience as a resource for teaching and learning but, may in fact be exacerbating the resource inequalities present if, for example, a student has never been on a boat. Too often, this is framed as a deficit within students which interferes with the effective 'transfer' of resources from lecturer to student. However, by asking students to supply their own examples to illustrate abstract concepts, a lecturer can acknowledge and mobilize the variety of student resources in the classroom. In so doing, the lecturer can deploy an additive view of resources, as opposed to a deficit (or subtractive) view.

As discussed in our framing of the notion of resource, engineering education is not merely about the acquisition of content, but about the development of students as engineering professionals. Within many courses, including the dynamics course taught by Helen, students often resort to using formula-based approaches to solving problems. This is in contrast to the fact that experts, which our students will ultimately become, construct multiple qualitative representations (pictorial, free body diagram, mathematical) from which they are able to reason about physical processes in a robust fashion (Van Heuvelen 1991). Indeed, this is one of the key differences between experts and novices, as argued by Fredlund et al. (2014): representations that are laden with meaning for experts are often ambiguous to students. That is to say, these representations do not offer students sufficient potential for participation in disciplinary activity. It is the role of the lecturer, therefore, to 'unpack' these representations, and make them accessible to students, thus allowing students deeper access to disciplinary knowledge and broader potential for participation. This requires that the lecturer consciously set aside some of the formal representations of the discipline, at least initially, so as to assist students in accessing these formalisms (see Airey and Eriksson, in press, for an excellent example of this, albeit in the field of astronomy). The lecturer must thus recognise the competition between coverage and conceptual development, and must acknowledge the diverse conceptual backgrounds with which students approach a course.

The notion of resources is thus important, as it positions the curriculum as but one set of resources among many, and allows lecturers, departments and faculties to exercise their effort productively by acknowledging and valuing a diversity of potentials for participation within the classroom.

4. LECTURER RESOURCES

The need to develop inclusive pedagogies requires that we consider teacher resources, as well as those of students (Burke, Crozier and Misiaszek 2017). Educators draw on rhetorical strategies, in addition to their knowledge of subject matter. Aristotle's work on rhetoric provides an enduring nomenclature for rhetorical strategies. He codifies three rhetorical appeals: ethos, pathos and logos: the appeal to ethics, emotion and reason (Honeycutt 2011). Although it may seem that only logos has any place in engineering education, reasoning is more persuasive if it contains all of these elements. An appeal to ethics often forms the basis for a persuasive argument, in that interlocutors need to establish their own trustworthiness. When an educator has built a reputation on a particular subject, there is a tacit acknowledgement of their credibility: an esteemed and well-regarded professor may be more likely to inspire belief in their teaching and recommendations than a less well-known member of staff delivering the same lecture. Furthermore, an appeal to emotion is also important, and also largely remains tacit. Students often give accounts of being afraid of 'letting lecturers down' when they believe that the lecturer in question takes active emotional care for the outcomes students achieve (Avis and Bathmaker 2007). People learn better when they experience an emotional bond with their teacher (Bransford, Brown and Cocking 2000, 148).

This was evident in the case upon which Carl reflects, in which he, a younger lecturer, was tasked with taking over a second-year chemical engineering course from a highly esteemed professor. The professor had taught this particular course for over 30 years and was well known to students and alumni. Carl deployed a style of lecturing that differed significantly from that of his predecessor, and introduced a flipped classroom approach (Mazur 1997). He also used an online reading tool (Perusall, another, later development by Mazur) to assign readings that covered relevant theory and provided worked examples. This system allows students to ask questions directly on the PDF in an online viewer. The collected questions were then used to drive peer instruction and focused teaching in the lectures.

However, a vocal minority of the class experienced these changes negatively. When the first semester test yielded poor results, the students demanded a return to the 'traditional' lecture approach via their class representatives. A prominent theme in their demands was the availability of worked examples and old papers. This may be because a large bank of old examination papers had been an effective resource for students trying to understand the assessment styles and strategies of the previous lecturer.

Carl reflects on this experience in two ways. First, students navigate through their studies using not only the materials provided by individual lecturers, but also materials which are available outside the classroom, sometimes through institutional means and sometimes not. This includes large sets of worked problems from previous years, along with old papers and folk knowledge about strategies for success. Although Carl addressed this early on in communication with students, these behaviours carry significant inertia, which was underestimated. It is thus important to consider these unseen resources in thinking about classroom and assessment practice. Second, presenting material in a 'traditional' fashion makes it easier to *appear* competent and hence build student trust. Modelling problem solving in class achieves much in terms of ethos. This is because it creates an illusion of effortlessness that builds tacit trust in the lecturer.

These insights were used to formulate a response to the students' concerns. In order to model problem solving, videos were recorded which specifically referenced the problem-solving strategies that Carl used and contrasted these with those previously used. This addressed the fact that the students possessed embedded prior knowledge, and drew students' attention to the fact that there are multiple approaches to the solution of problems. In addition, problem-solving processes were modelled in class (including errors and false starts). Although these in-class demonstrations lacked the repeatability offered by the videos, class attendance was higher than the video views. Carl concluded that the in-class demonstrations were important in building trust in the lecturer.

Online learning tools can appear to be a labour-saving device for lecturers, with the implication, therefore, that they require less care on the part of lecturers. To show that care and effort goes into using such tools, the 'behind the scenes' work involved in analysing the online questions and relating it to coursework was shown during class time and, in more detail, outside of class time to student representatives. This helped to reduce the students' concerns and demonstrated to them that the tasks designed were for their own pedagogical benefit.

Finally, the quality and quantity of interaction outside of class via the course's instant messaging group increased as the students increasingly came to rely on this new channel. There was initial distrust of online channels on the part of the students, and some used it as an opportunity to complain about the changes. Carl made a mental shift to understand complaints as signs of participation and responded to every message in the channel with a consistently positive acknowledgement of this participation before addressing the actual issue. Since this happened in a public forum, other students could see the consistency of positive response and seemed to become more likely to interact.

We argue that thinking about these tacit resources and the levels of trust and care within the design of a course can make a significant difference. It is all too easy to imagine that the decisions made by a lecturer will automatically be perceived by students to be in their own interests, but this is not the case. Lecturers need to spend time demonstrating to students that the decisions they make with respect to classroom practice are not made arbitrarily, or for the purposes of expediency. Lecturers need to take time to obtain student buy-in regarding these strategies, thus enhancing the lecturer's relatability and obtaining students' trust.

What this incident also illustrates is that lecturers bring resources of creativity as well as knowledge to the classroom. Although the strategies they deploy may not always be entirely successful, it is important that there is institutional support for such creativity. Institutions need to demonstrate trust in, and support for, their teaching staff. Indeed, the pressures facing lecturing staff often serve to constrain opportunities and possibilities for them to engage meaningfully with their students (Burke, Crozier and Misiaszek 2017). Trust in and care from teaching staff are important tacit resources within teaching and learning. Moreover, these tacit resources brought to bear on teaching and learning by an individual lecturer can come to influence entire departments. Just as individual lecturers establish and build trust and care with students, so too can departments, faculties and institutions (Tronto 2018).

5. STUDENT RESOURCES

Students do not enter an engineering (or other) education experience as blank slates. Instead, they bring with them a myriad of prior experiences and understandings. This has, inter alia, been termed students' cultural capital (Bourdieu 1986) or primary Discourses (Gee 1996). In this final section, we consider how these prior experiences and understandings can be harnessed as productive resources for teaching and learning in engineering.

Individuals represent meaning using the variety of semiotic resources at their disposal. As students gain disciplinary expertise, the range of semiotic resources upon which they can draw expands. For example, lecturers often complain about students' tendencies to incorporate so-called 'SMS speak' into their written reports. This is an instance of students transferring meaning-making practices from one domain to another due to the fact that the students may not, as yet, have acquired mastery over the expected meaning-making practices of higher education, specifically, the kind of essayist literacy privileged in academia (Lillis 2001). In such an instance, the imported meaning-making practices are incompatible with those that are expected, and the students' attempts are (generally) met with censure. Similar examples can be drawn from other representational modes, such as drawing, mathematics and the use of diagrams.

In this final reflection, Zach considers how the resources that students bring with them can be harnessed productively in the teaching and learning space. This can occur on various levels, and Archer's work on symbolic objects has been instrumental to this reflection (Archer 2008; 2009; 2010). Archer argues that a "curriculum which draws on students' experiences and discourses could provide an opportunity for students to begin to interrogate their past situations, as well as their future aspirations" (2009, 272-273).

Zach seeks to support students in strengthening their academic and professional communication practices. In order to do so, he has students, at least initially, engage in semi-formal, communication-intensive interactions that are unregulated. Zach does this by asking engineering students to engage with current high school students about the benefits (and challenges) of pursuing engineering study. The students are encouraged to reflect on the kinds of communication practices likely to yield success in this context, and are encouraged to use semiotic resources with which they and the high school students are familiar. Many of the schools they visit do not have projection facilities and, as such, the delivery of 'traditional', formal presentations is not possible. The students thus need to develop creative communication strategies. These presentations are unregulated in that they are not assessed. Instead, the students are assessed on the feedback they give, after the fact, about what they did, how it went, and what they learned.

In a separate example, engineering students were required to produce short videos about engineering innovations that have impacted upon their lives. Through using visual modes, and opening up possibilities to step outside of formal academic genres, the students were able to produce fascinating artefacts of learning. These artefacts demonstrated that the students had sophisticated awareness of visual genres (news reports, documentary features, game shows, and many others), and that this knowledge could be put to use in drawing students' attention to the genres privileged within academia. As Archer argues, "the visual mode can perhaps enable and accommodate mixed domains of practice more easily than the written mode" (2009, 273).

These two examples demonstrate that students' representational histories are rich with meaning-making potential and accessing this richness may require an expansion of the traditional genres and ways of meaning-making privileged within higher education. This does not need to involve replacing traditional genres, but using alternative genres and practices to scaffold student participation in traditional meaning-making practices. The school project, for example, can be used to facilitate reflection about audience and context awareness, just as the video project facilitated useful learning about genre awareness. Such efforts represent what Archer (2010) calls a reciprocal curriculum. Archer concedes, as do we, that this may be achieved more organically in the context of humanities and social sciences, or in a context such as that of a communication course. However, technical engineering subjects have significant relevance for students' lived experiences, and more attempts need to be made to tie this technical engineering content to the students' life worlds. Such efforts may enable students to "think critically of their prospective professions within their particular socio-economic contexts" (Archer 2010, 63).

6. CONCLUSION

We have deployed the notion of resource so as to consider questions of teaching and learning in engineering. In so doing, we argue that resources are not merely economic in nature. Instead, they are tied to sociocultural practices, and to personal and institutional histories. Resources can be, among others, semiotic as well as professional and content-based, and they are embedded in curricular frameworks.

We have presented our reflections in which the three authors, although operating in different types of courses, at different institutions, have each found value in using the notion of 'resource' to inform their teaching practice, and to understand 'what's going on' in their classrooms. In the case of Helen, these reflections show that curricula can be usefully conceived of through the lens of the development of resources, whether content knowledge or student attributes. Carl's reflection shows the institutional and historical nature of resources and the significant inertia that inhibits the transformation of classroom practice. However, through making explicit the tacit resources of trust and care, Carl was able to begin the process of overcoming such inertia. Finally, Zach has shown that students' previous learning experiences can be productively harnessed to facilitate new learning. We encourage individual lecturers and entire departments and faculties to consider how resources, viewed in the sense presented here, are allocated and deployed within engineering education.

ACKNOWLEDGEMENTS

We presented our discussion of resource at a panel at the SoTL in the South conference in Johannesburg in July 2017, where we invited interrogation and discussion. We would like to acknowledge the participation of all who attended that panel. In addition, we would like to thank the anonymous reviewers appointed by *Africa Education Review*, the feedback from whom added significantly to our original manuscript.

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