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ORIGINAL ARTICLE

Toward an educational view of scaling: sufficing standard and not a gold standard

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Abstract Educational innovations in Singapore have reached fruition. It is now important to consider different innovations and issues that enable innovations to scale and become widespread. This proposition paper outlines two views of scaling and its relation to education systems. We argue that a linear model used in the medical field stresses top-down replication of a "gold standard" to multiple contexts. This view is similar to scaling in centralized education settings. A project-oriented view stresses bottom-up spreading or diffusing innovations from localized settings to wider contexts. This view is more aligned with scaling in decentralized education systems. Instead of top-down or bottom-up views of scaling, this paper proposes an ecological model of scaling from a system's perspective. It emphasizes a sufficing standard that considers top-down and bottom-up structures as well as qualitative and quantitative dimensions. Accommodations are made to populate different innovations across the system. Top-down supports are given to enable bottom-up innovations. Qualitative dimensions in the form of tacit understandings are more important than replicating explicit or procedural knowledge. The spreading of education innovations is cultivated by nurturing professional learning communities, communities of practices, and keeping tabs of their growth within the system as well as identifying areas for improvement through quantitative, baseline studies.

Keywords Scaling and translation · Ecological model · Gold standards · Sufficing standards

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1 Introduction

The Singapore education landscape has evolved through different phases: survival driven (in the first two decades after 1965), efficiency driven (in the late 1970s), and ability driven (in the late 1990s onwards). The *Survival* phase aimed to develop every child's literacy and numeracy skills (Goh and Gopinathan 2008; Mourshed et al. 2010). The *Efficiency* phase (1979–1996) reduced performance variations by streaming students into academic tracks based on their aptitudes. In 1997, Singapore went into the *Ability* phase. This phase aimed to create a responsive education system with multiple pathways for different students (Goh and Gopinathan 2008; Mourshed et al. 2010). It stressed the importance for students to learn 21st century skills and cater to students' different interests and aptitudes (Ministry of Education, Singapore 2008, 2012). Various policy initiatives such as Thinking Schools Learning Nation (TSLN) in 1997, Teach Less Learn More in 2004, and integrated programmes since 2005 were implemented to move away from teacher-centered to student-centered pedagogies.

Singapore's trajectory stems from a centralized approach where controls of curriculum content, budget, resources, and educational facilities lies in a central body, the Ministry of Education, Singapore (MOE) (Leung 2004; Weiler 1990). Generally, education systems that belong to the West, such as the United States, take on a decentralized approach, where authority and governance are delegated to the local schools (Leung 2004). Individual schools make their own decisions on matters like finance, curriculum, and professional development (Dyer and Rose 2005; Weiler 1990).

The changing goals of each phase suggest that Singapore recognizes the need to embrace diversity and move toward more decentralized approaches. More autonomy is given to schools to manage resources and recruit teachers (Ng 2003). This development is in line with growing interests in educational decentralization in developing nations, such as South Asia, Latin American, and Eastern Europe (Leung 2004).

Although the Singapore government has repeatedly stated its intentions to decentralize power and create platforms for diversity and innovation in schools, its efforts may be more accurately described as centralized decentralization (Ng 2010, 2013). Singapore's approach is closely aligned with pragmatic considerations. Singapore perceives education as a critical vehicle for political and economic strategies. Schools support national, social, and political strategies. The government takes great responsibility in securing the nation's economic survival, achieving education outcomes, and careful fiscal spending (Ng 2010). This creates tensions because decentralization is associated with a risk of declining standards and a liberal view of education rather than a functionalist view. The liberal view stresses the intrinsic values of education for personal growth and not as economic gain (Tan and Ng 2007).

Thus, the Singapore education system faces a paradoxical trend of centralization within a decentralization paradigm. The government maintains high quality education by centralizing controls on strategic directions. Concurrently, the government promotes decentralization of tactical matters by empowering schools to accommodate diversity, be flexible, and be innovative. Schools need to think out of the box by engaging in pedagogical reforms, innovations, and at the same time, maintain students' content knowledge and grades. The challenge for schools and educators in Singapore is to embrace to this paradox and achieve the best of both worlds (Ng 2010, 2011).

The creation of an educational research funding further signals Singapore's recognition of research to inform reforms, enact new pedagogies, and create a culture of innovation in schools. The education research funding in Singapore spans two time periods (2002–2007, 2008–2012) accumulating to about 150 million Singapore dollars. In the first period (2002–2007), the primary goal was on establishing research centers at the National Institute of

Education (NIE). Another was to change and enact new pedagogies with a focus on culturing student-centered pedagogies and participations in classrooms and beyond. In the second period, funding continued to sustain the kinds of education research populated across the Singapore education system. Research began to play an inevitable role in the change-reform process. These research efforts brought about various successful educational innovations in schools, such as Group Scribbles (Chen and Looi 2011), Seamless Learning (Wong and Looi 2011), and Productive Failure (Kapur 2010). These examples and many others, both from MOE and NIE, laid the foundation for a rich and diverse culture of innovation in schools and across the Singapore education system. Furthermore, it also enabled the recognition of Singapore's educational innovations among international research communities, practitioners, and policy makers.

With a relatively large investment on research in the last decade, educational innovations in Singapore have reached fruition. It is now important to consider possibilities for different innovations as well as issues that enable innovations to scale and become widespread. In this paper, we outline two dominant views of scaling and its relation to education systems. We emphasize that a linear model of scaling and translation commonly used in the medical field emphasizes top-down replication to multiple contexts (Woolf 2009). We argue that this view is akin to scaling efforts in centralized education settings. A project-oriented view of scaling and translation focuses on bottom-up spreading or diffusing innovations from localized settings to wider contexts (Coburn 2003; Dede 2006). This view is more aligned with decentralized education systems.

We attempt to highlight limitations of these views and propose an ecological model of scaling that considers Singapore's education landscape. Instead of top-down or bottom-up views of scaling, accommodations are made to populate various innovations across the education system. Top-down supports, by MOE, are given to enable bottom-up innovations (by schools). Different structural supports are provided to incentivize teachers to adopt, adapt, and embrace tested innovations and hence make them more widespread. The spreading of education innovations is cultivated by nurturing professional learning communities and communities of practices. It is also important to observe their growth within the system as well as identify areas for improvement. This proposition paper, therefore, proposes a way forward by postulating an ecological model to describe the scaling efforts in the Singapore education landscape, from a system's level of analysis, as exemplified by existing research projects from NIE.

2 Scaling and translation research: from top-down to bottom-up perspectives

In the natural sciences, including that of the medical field (see Fig. 1), scaling and translation from research to everyday practices is a linear and staged process (Woolf 2009). Stage 1 of the translation research (T1) focuses on testing in laboratory settings. The aim is to develop new methods for diagnosis, therapy, and prevention (Woolf 2009). In T1 research, clinical scientists work in laboratories with supportive infrastructures within the institution. This research occurs in community and ambulatory settings. The Institute of Medicine's Clinical Research Roundtable positions stage 2 of translation research (T2) as translating results from clinical studies into clinical practice and decision making (Sung et al. 2003). In T2, research moves out of the laboratory into real world settings. This is the first attempt to bring T1 research to public settings. T2 research yields knowledge about efficacy of intervention in various controlled real world settings. It focuses on how infrastructure, resource constraints, human behavior, and organizational issues affect the efficacy of interventions.

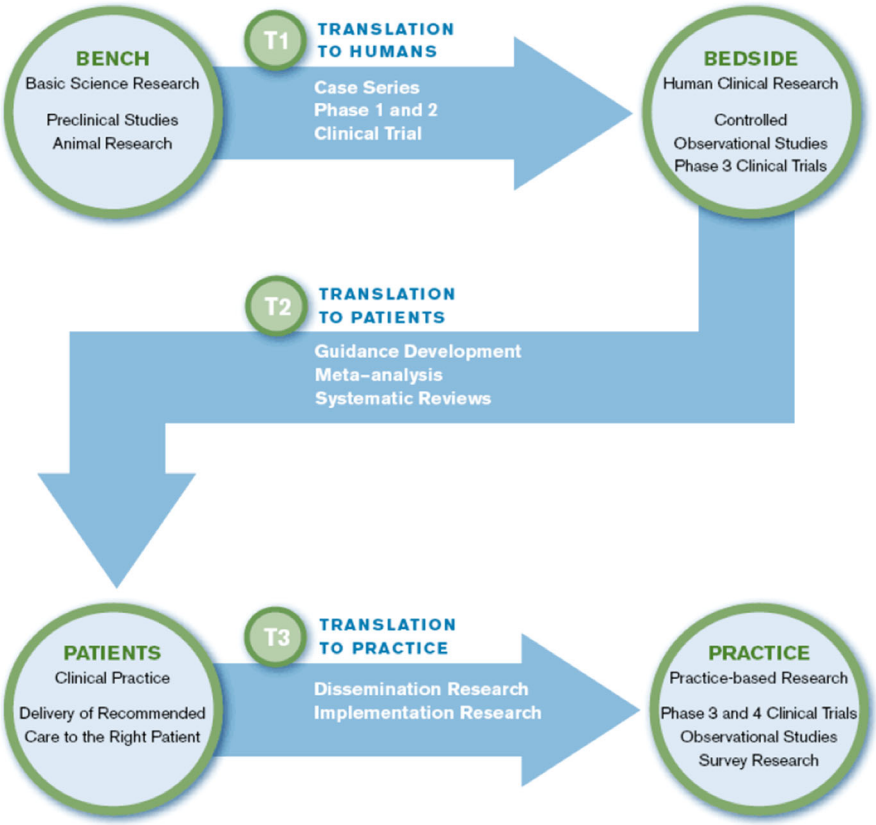

Fig. 1 Linear translation model in medical research University of Miami (2013)

It recognizes that translating interventions is a socially complex phenomenon. Stage 3 of translation research (T3) is about disseminating the intervention from controlled real world settings to the general population. In T3, researchers explore ways to apply recommendations into everyday practices (Westfall et al. 2007). The focus is on how interventions work in real world settings. Medical research, as described from the stages, moves linearly from the laboratory to the mass market. The default model is to look for a proof of concept also known as "*gold standard*" of an innovation, bring this through the T1, T2, and T3 processes, and focus on quantitative outcomes. This dominant thinking is also found in programs such as the i3 (Innovation through Institutional Integration) model of the National Science Foundation (NSF) (The National Science Foundation 2006) see Fig. 1.

Different educational studies discuss what "scaling" means and what it entails (see for instance, Bocconi et al. 2013; Coburn 2003; Fullan 2000; Hargreaves and Fink 2000; Klinger et al. 2013). Scaling as defined in the medical sciences seems to bear some resemblance to centralized education systems—scaling is about replicating an innovation from one context to the masses (Klinger et al. 2013; Sternberg et al. 2006). There is an inherent emphasis on quantitative outcomes.

To a certain extent, limitations of this view of scaling are aligned with constraints of centralized education systems. This view of scaling is efficient in making an innovation more widespread. However, replicating the innovation across contexts is decontextualized

because it does not consider appropriateness of the innovation or adapting the innovation for the context. The assumption is that all contexts are similar. There is an innate emphasis on explicit knowledge (that is, the gold standard). Little emphasis is made on educating people (that is, tacit knowledge) to sustain and enact the innovation (Fullan 1994). This perspective of scaling seems concerned with quantitative dimensions by first establishing a proof of concept (that is, the gold standard) and then quickly replicating it to multiple contexts.

2.1 Variability due to student-centeredness

Scaling and spreading innovations in decentralized education systems are different from the medical field and centralized education systems. Decentralized education systems seem to emphasize student-centered learning processes and variability in education settings (Dyer and Rose 2005; Weiler 1990). The focus is on cultivating student-centered process-in-learning such as inquiry and knowledge building. Student-centered processes assume variability in different situations rather than adopt a "one-size fits all" form of instruction.

Based on this assumption, we posit that attempts to scale, if consistent to student-centeredness and decentralized education systems, should not be a mere replication or duplication from the original intervention. Variations should be allowed based on differences in student profiles, curriculum, teacher dispositions, and others. To maintain the integrity and identity of the innovation, however, there need to be core design principles or fundamentals that should be upheld. Or as Locke and Ableidinger (2013) posits "*the essence … is sticking with a set of non-negotiable elements that were central to the success of the initial effort, in order to retain the benefits of those elements in the expanded initiative.*"

2.2 Educational settings are socially messy and tacit knowledge is needed

In medicine and centralized education systems, research starts in laboratories or experimental classes in a context vastly different from the real world when a successful product or innovation will be consumed. Transfer of innovations to everyday practices is fixed on a set of procedures. In educational science, the social context is more complicated (Clarke and Dede 2009), and hence socially messy. The education environment is varied and learning is a socio-cultural process (Beach 1999).

Our proposition about an ecological model of scaling is that there should be a balance on quantitative dimensions emphasized in the linear scaling approach, such as the number of sites an innovation has spread to, as well as the kinds of tacit knowledge related to an innovation. Qualitative dimensions related to tacit knowledge are important due to the dynamic interactions between teachers, students, and the situated context, where the learning and instruction arise. This is in essence the student-centeredness which MOE is advocating and is in alignment with the centralized decentralization perspective that MOE adopts.

2.3 Educational models of scaling from a bottom-up perspective

Current literature discusses on issues about scaling educational innovation and possible ways to address them (Bodilly et al. 2004; Clarke and Dede 2009; Elmore 1996; Klinger et al. 2013). These discussions mostly take the respective innovation or *project as the focus*. We postulate this to be more aligned with scaling from a decentralized education system's perspective, where bottom-up innovations are encouraged. Coburn (2003) and Dede (2006) develop a conception of scale that has four interrelated dimensions: depth, sustainability, spread, and shift in reform ownership to the teacher and the school. To elaborate:

- Depth looks at the nature of change, whether change is affected by the organization's beliefs, whether individuals' beliefs and thereafter practices have evolved; whether these changes are merely superficial. It is also important to consider the owner responsible for the change.
- Sustainability is about endurance; how long will the change endure; what strategies are in place to assure sustainability of the change.
- Spread refers to the norms, principles, beliefs understood by greater numbers of people. It asks "How widespread is the change?," "Who is involved in the change?," "Who should be involved?," and "Who will benefit from the change?"
- Ownership is the attempt to shift reform ownership in terms of knowledge and authority to implementers; the schools who should ultimately "own" the process.

We see this conception of scale as focusing on the spread and reach from an innovation-oriented, local-project instantiation point of view rather than understanding how to spread innovations at the system's level of analysis which is inherently more complex and non-linear. We argue that the above conception of scale relates more to a bottom-up orientation of scaling that seems aligned with decentralized education systems. Although they provide detailed accounts about scaling individual innovations from a bottom-up perspective, the inherent limitation is that bottom-up innovations take time to cultivate substantive change before it can spread to other contexts. Even if substantive amounts of change have taken place, lessons learnt from the innovation are contextualized to the specific context and may not be easily replicated to another context. There is not just one model for successful implementation—there are probably as many models as there are the unique contexts (Leusner et al. 2008). In fact, certain amount of adaptation is needed when the innovation is translated to another context. There is, thus, some inefficiency in this approach because 1) time is needed for substantial traction to grow before an innovation can spread and 2) best practices learnt about an innovation may be localized and require time to be translated to another context.

Linear, centralized, or bottom-up, decentralized approaches of scaling have its inherent strengths and limitations. We, therefore, argue for an ecological model of scaling that takes on a balanced and systemic approach. Education systems, particularly in the Singapore context, are neither solely centralized nor decentralized. Thus, a balanced approach embracing both top-down and bottom-up efforts is useful to look at how innovations can spread to develop a culture of innovation (Dyer and Rose 2005; Fullan 1994). In the East Asia context like Singapore, decentralization does not sit well. Thus, a balanced approach toward creating the ecology is needed so centralization enables control and decentralization enables efficiency (Leung 2004).

Understanding scaling at the system's level informs policymakers of different scaling patterns, teachers' and students' needs on the ground, and facilitates resource allocations. The process of large-scale adoption of innovations is not simply about "rubber-stamping" the same innovation into multiple contexts, but on empowering teachers in the design process of student-centered lessons, fitting, and adapting for local circumstances (Barab and Luehmann 2003), and others. Much greater complexity is involved when educational professionals seek to understand and improve the enactment of innovations, and take it to scale. A systemic approach is needed to spread educational innovations by considering the interconnected relations between curriculum standards, curriculum materials, learning activities, formative and summative assessments, professional development practices, and educational leadership (Looi et al. 2011; Pea and Collins 2008), as well as taking into account the aspects of organizational learning (Spillane et al. 2009). In essence, "*scaling up promising reforms requires a holistic approach…"* (Samoff et al. 2001).

Table 1 Key characteristics of scaling in top-down and bottom-up approaches

Characteristics	Centralized, linear approach	Decentralized, bottom-up approach
Scaling	Replication "gold standard" or proof of concept from one to multiple contexts without translation	Spreading out from local instantiation/innovation Requires translation to adapt and spread to other contexts
Direction	Linear from laboratory to mass market/from top to bottom	Bottom-up spread or diffusion from local instantiation to other contexts
Knowledge	Proof of concept as gold standard Emphasis on decontextualized, explicit knowledge	Lessons learnt are contextualized Emphasis on tacit knowledge
Outcome	Quantitative dimensions focusing on numbers	Qualitative dimensions in terms of depth, sustainability, spread, and shift
Time	Efficient due to focus on decontextualized replication	Takes time to cultivate substantive amounts of change before spreading to other contexts
Relationship to education system	Centralized education systems	Decentralized education systems

Considerations of "scale" are a key challenge for school reform. Definitions have traditionally focused on an innovation-oriented perspective that emphasizes the expanding number of schools reached by a reform or innovation. There are, however, complex challenges of reaching out broadly, while simultaneously cultivating the depth of change necessary to support and sustain consequential change. Understanding reform, spread, and (out)reach of an innovation from a systemic perspective is inherently more complex and non-linear. Table 1 summarizes the key characteristics of centralized, top-down, and localized, bottom-up views of scaling. Our thesis is on neither of these views individually but to propose an ecological model of scaling that emphasizes a balanced approach—looking at quantitative and qualitative dimensions with a systemic perspective toward scaling. Rather than aiming for gold, par excellence standard, our proposition is to focus on a sufficing standard characterized on maintaining core kernel designs (that is, best practices) of an innovation, while allowing space for adaptations and building a sociality to sustain the innovation.

In the next section, we leverage on our understandings of existing NIE research projects and attempt to unpack the characteristics and types of innovations related to our proposition of an ecological model of scaling from a system's level of analysis.

3 Proposing an ecological model for scaling and translation

In Singapore's education context, the path toward a greater adoption of educational innovation is complex and cannot be assumed to be linear. We envision a model where various types of innovations (see Fig. 2 below) happen concurrently. These innovations "flourish" under different conditions with various structural supports. Innovations have varying levels of complexities. Innovations that can more easily spread would be those that have established and socially accepted core kernel designs. When such innovations are implemented in different situations, with resources well disseminated, and a sociality of teachers built around it (such as through professional learning communities and communities of practice), we can expect more of such innovations to be taken up by teachers for implementation in their classrooms. There are currently a considerable number of *teacher-led projects* populated throughout the

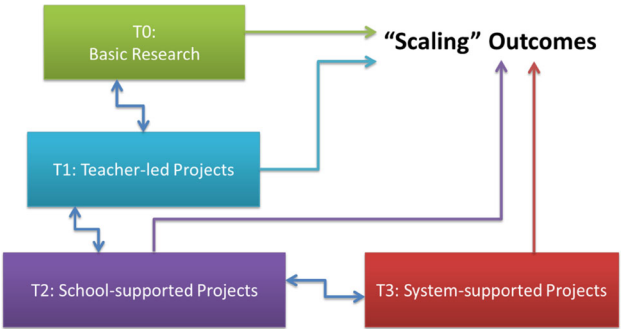

Fig. 2 Non-linear model of scaling

Singapore education system. Some of these projects have been more successful in spreading across different classrooms and moving toward a school-oriented innovation, while others have been less successful. This could be due to a number of factors: the complexity of the innovation, the readiness of teachers, etc. Examples of these teacher-led projects can be found in MOE–NIE initiatives such as eduLab. The eduLab initiative is designed to surface and push ground-up Information and Communication Technology (ICT)-enriched pedagogical innovations across schools (eduLab 2009).

MOE and NIE stand ready to engage teachers to spread these teacher-led innovations. We envisage that innovations that are less complex would require less support. To a certain extent, if the sociality built around the innovation is strong, the innovation could grow. Of course, if school-based supports are given, the spreading could happen more quickly at the school-wide and across-school levels. We refer to these as *school-led or school-supported projects* (see Fig. 2). MOE and NIE also recognize that more complex innovations could require higher levels of support to enable it to spread. Such innovations would require the commitment of schools and principals to rally school-based support from more teachers and to make resources available in order to better support such innovations to grow. Likewise, school principals who opt to undertake these more challenging innovations will be supported and partnered with NIE researchers (in specific instances). Given the more complex nature of these projects, a richer partnership is envisaged.

Another kind of innovation could be for projects that grew from teacher-levels or school-levels to system-wide levels, or when MOE initiates *system-wide projects* or initiatives due to the need to regulate local level initiatives or when certain reforms are needed due to a system's view to narrow gaps in achievement. We thus propose that three types of innovations could be populated across the Singapore education system:

- *Teacher-led,*
- *School-led,* and
- *System-led.*

Teachers and researchers can also take a theoretical basis and work around it in classroom (or equivalent) settings and these become teacher-led projects. *All three types of innovations happen concurrently for a healthy ecology to occur.* In line with our balanced approach toward an ecological model of scaling, growth and spread of teacher-led and school-led innovations happen locally and the state of play can be understood from a qualitative perspective according to Coburn (2003) and Dede (2006) frameworks and criteria.

3.1 Gradual and evolutionary growth

At the systemic level of analysis, with the three types of innovations (Teacher-, School-, and System- led innovations) populated across the system, we envisage that as teachers and schools adopt, adapt, and implement innovations (with MOE's support and other school-based structures), local cultures of innovation would be nurtured. Due to the complexity of innovations and the nature of support required, it would be reasonable to assume that our education landscape would be one which is populated with more teacher-led and school-led innovations than system-led initiatives, especially in the milieu of student-centered pedagogies. The *more radical and complex* the innovation compared to conventional practices, the *greater the need for local instantiation and spread* in order to develop and cultivate the tacit knowledge underpinnings of the innovation.

As change, growth, and eventual impact of innovations to the community would be gradual, an evolutionary rather than a radical change process should be expected. Teachers and schools can begin the scaling-adoption process at different starting points. Teacher-led or teacher-supported innovations relate to experimentations at the local (classroom) level in small instantiations. The focus of these innovations relates to the identification and contextualization of innovations to meet students' needs and address issues in classrooms, especially of student-centered pedagogies and designs. Teachers work collectively toward refining innovations, identifying and implementing changes when needed, while preserving the core or kernel principles and building teaching resources that allow innovations to be implemented in classrooms. Through experimentations and consistent dialoging, teachers may begin to adapt innovations for use with their own students in different classroom contexts. Teacher-led innovations and experimentations could grow to influence more people in various local instantiations. In other words, teacher-led innovations could be *scaled or spread locally* to include more subjects, classes, different student profiles, and result in eventual "promotion" to school-led status. When spreading from teacher-led to school-supported status, implementation efforts are locally driven and emerged. These innovations could subsequently be taken up by MOE and these could be provided with financial and infrastructural supports to ensure innovations' spread and sustenance with greater efficiencies. As such, these efforts could eventually be system-led innovations. Examples of these innovations could include leveling up the base of core literacies in order to bridge achievement gaps or when local growth models may be too slow for certain policy priorities.

3.2 A sufficing standard (instead of gold standard)

It is important to recognize that when innovations spread in these ways, we do not seek to ask if a gold standard has been achieved before allowing for the spread to occur. This is because rather than looking for a model of excellence and then replicating it across contexts, we are seeking for adequate standards to enable the spreading of innovation and culture throughout different levels of the education system. In this sufficing standard, the focus is on *teachers' enthusiasm, commitment, and readiness* about the innovations. Teachers need to be able to take innovations to their own respective classrooms (or equivalent) and implement the core or kernel ideas of that intervention. *Resources are available at the school, cluster, or MOE levels* to support subsequent take-ups and support the spreading of innovations. *School leaders are also willing to support* teachers to experiment and permit possible implementation gaps to happen, if any. *Teachers are able to collect evidence-based data* for their experimentations to exemplify some form of rigor toward their innovations.

Table 2 Characteristics and indicators of a sufficing standard

A sufficing standard
Characteristics
Teachers' enthusiasm, commitment and readiness about the innovations
Resources are available at the school, cluster, or MOE levels
Schools leaders are willingly to support
Teachers are able to collect evidence-based data
Indicators
Adoption of school-led innovations by other schools
An increasing community of teachers
More dialog and sharing between schools and teachers

We connote the above characteristics as important issues around a *sufficing standard* for spreading of innovations, rather than a gold standard. The use of sufficing standard as opposed to gold standard is argued in this paper to shift the focus away from a par excellence model for optimal replication to the system at large. Instead indicators related to a sufficing standard are emphasized. Some possible *indicators of spread related to a sufficing standard* could be the adoption of school-led innovations by other schools, an increasing community of teachers involved around an innovation, more dialog and sharing between schools, and others. Thus indicators of a sufficing standard do not just focus on quantitative dimensions, such as achieving numbers and efficiency. Qualitative dimensions related to Coburn (2003) and Dede (2006) frameworks as well as building a sociality to support the spread and sustenance of an innovation are also emphasized. Characteristics and indicators of a sufficing standard are summarized in Table 2.

As we study into the various teacher- and school-led/supported innovations, we will elaborate on the sufficing standard to inform scaling efforts at the policy and research considerations of MOE and NIE, respectively.

4 System's level data of the growth and spread of student-centered innovations

In typical scaling efforts connoted by the sciences and centralized education systems, policy makers would roll out to the whole system or nation a certain proven drug or product. In this kind of linear, centralized scaling, quantitative data would be collected on its implementation efficacies and degrees of fidelity in terms of benefits to different user groups. Figure 3 shows the many combinations of contexts which have to be developed centrally in order to roll out an education program. LA, MA, HA in Fig. 3 represent low ability, medium ability, and high ability students, respectively. For example, the identified smaller cube in the larger cube below seeks to know how to scale curriculum in classrooms with low achieving (LA) students.

The concerns of policy makers are valid nevertheless. However, the strategy we are advocating in a sufficing standard focuses not only on numbers and quantitative dimensions but also on qualitative dimensions. The qualitative dimensions focus on contextualized pedagogy and designs to be developed and capacity of teachers to be built locally to enact student-centered inquiry and facilitation. Since teaching requires the interplay of tacit knowledge and developed resources, giving teachers time and space to work collaboratively with fellow teachers on crafting the lessons would be a great way forward toward fostering teacher agency and professionalism.

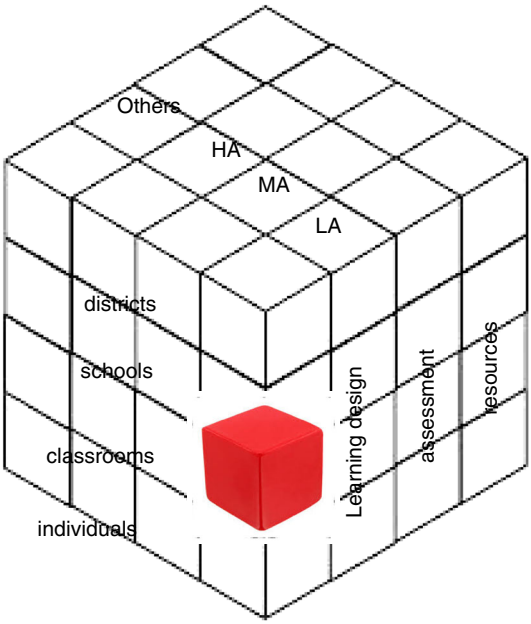

Fig. 3 Contexts to consider in scaling education programs

Nevertheless, if we were to argue for this bottom-up approach of scaling with top-down supports (for example, from MOE), policy makers would still want to have a system's view of what is happening with respect to the various teacher-led, school-led, and system-led innovations grown locally and supported at the various levels of the system. MOE would also want to know quantitative, baseline data. Examples of such data could be as follows: (1) the number of schools across the system which has these innovations, (2) the kinds of innovations, subject domains, grade levels in which innovations have been implemented, (3) the local spreading that have occurred or otherwise, (4) the number of teachers involved, and (5) the number of local teacher communities. Data for the spread of innovations across school clusters and zones are another example of system-wide quantitative data that are useful for policy makers, and NIE plays a role in providing such data. In other words, quantitative data are needed so top-down supports are created to generate thrust for bottom-up initiatives.

To provide a more concrete example, NIE's research landscape has constituted an array of teacher/researcher-led and school-led projects (see Fig. 4 below). NIE does not have system-led projects as yet. Categorizing each innovation into one of the research/teacher-led, teacher/school-led, and school/system-led stages and allowing for natural "growth and spread" of the innovations across various levels of the system (teacher, school, system) may be sufficient to create a diverse and rich culture of innovation in our schools.

- Researcher/teacher-led means that the researchers have worked with teachers to bring basic research ideas into the classroom, for example, Knowledge Building (Ng et al. 2008) and Productive Failure (Kapur 2010).
- Teacher/school-led means that the classroom intervention has moved to the school level.
- School/system-led means that the school's innovation has spread to other schools (but not to the whole system)

We envisage that the data for scaling or knowing what is happening as far as scaling interventions' attempts are concerned can be integrated with systems' wide quantitative,

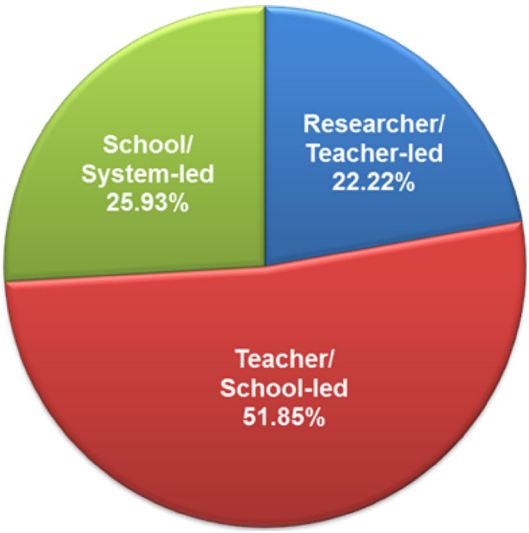

Fig. 4 Data on NIE's interventions

baseline research conducted by NIE and MOE in the future. When we are able to understand local phenomena and spread, we can further optimize the efficiencies and cost effectiveness such that subsequent instantiations can be done more economically, without compromising the core or kernel sufficing standards.

5 Conclusion and future work

Educational settings differ across classrooms and contexts. In the milieu of student-centered pedagogies and designs, the celebration of diversity in student learning and participations is desired. Hence, there is no one-size-fits-all solution for scaling. Instead, we propose an ecological model of scaling. In this proposition paper, we advocate top-down supports for bottom-up initiatives, where flexibilities and adaptivities occur throughout the system with sufficing standards (as largely determined by teacher readiness, leadership supports, and infrastructural adequacies) as target goals at each local instantiation. While celebration of diversity is at local levels, the system keeps tab of this growth and spread of innovations with system's wide quantitative, baseline data in order to identify gaps, future work, and initiatives needed.

The proposed ecological model of scaling is aligned to the centralized decentralization view adopted in Singapore. Our thesis is to emphasize a balanced approach and create an ecology where centralization enables control and decentralization enables efficiency for scaling innovations. The Singapore education landscape similarly attempts to balance decentralization and centralization to achieve efficiency and effectiveness of governance. Centralization strengthens control over strategic agenda and educational outcomes, while decentralization helps achieve tactical implementation of efficiency (Ng 2013; Tan and Ng 2007). Balance is important because there may be propensity to move away from the existing system in pursuit of diversity and innovation. Rather than moving radically toward a different paradigm, the education system must recognize that what it has achieved is worthwhile (Ng 2008b, 2010). The proposed ecological model of scaling attempts to consider this paradox and be cognizant that any initiative has to be centrally driven and balanced rather than free-flowing and radi-

cal. This paper is insightful for other developing countries to highlight the delicate balance between qualitative and quantitative dimensions; conformity to procedures and diversity.

While we emphasize that we are proposing an ecological model of scaling from a system's view and attempt to unpack the sufficing standards and structures that may enable different innovations to spread, we are also cognizant that ours is a theoretical model. We acknowledge that scaling innovations are a complex agenda that needs to consider different issues, such as educational policy and implementation, accountability, cultural context, and government-school relationships. Scaling and sustaining innovations are more than just compliant implementation of structures and policies. Structural changes alone are insufficient (Ng 2008a). Thus, it is valuable that the proposed ecological model recognizes both qualitative and quantitative dimensions, top-down and bottom-up efforts. More than just aligning school resources and systemic structures to enable scaling, it is important to empower school leaders to chart direction for teachers. School leaders need to encourage dialog and participation among teachers to generate buy-in and develop teachers' reflective capacity to delve deeper where sustaining innovations change mindsets and their approach to education (Ng 2008a). However, these issues are beyond the scope of this proposition paper.

Moving forward, NIE is probably the best place to work among in-service teachers in bringing basic research ideas to the classroom. These could include new areas of learning theories informed by the learning sciences, neural sciences, and others. Taking basic research to the classroom is anything less than straightforward. It involves both researchers and teachers painstakingly implementing these ideas with evidence to support their work trajectories, trail blazing in "messy" classroom situations, till the innovation succeeds.

Qualitative dimensions such as school-based professional learning communities (PLCs) and cluster-based communities of practices (CoPs) can be leveraged to monitor and mentor teachers on their teacher- and school- led pathways. NIE researchers and their innovation/intervention projects should also be integrated into teachers' existing PLCs and CoPs. Through these partnerships, more concerted efforts can be made to advance 21*st* century pedagogies and literacies throughout the system.

MOE should be careful not to overly expect system roll-outs to be particularly high in fidelity and to be concerned if perception survey results show that these schemes and initiatives are working well. The tacit nature of educational settings requires time for interventions to take root, and for teachers to experiment and to change pedagogies. We need to acknowledge that teachers believe in what they do, and for very good reasons, and hence change and reform take time. The system should also know the "good work" that is happening at each local level before assuming that change is always for the better. Hence, the need for local and system's level data is imperative, going forward. Unpacking the sufficing standards at each local instantiation and supporting the spread of educational innovations would be a productive means to enable the system to optimize.

With the above instantiations, and with sufficient time, a natural, healthy ecology, and culture of innovations across schools in Singapore will develop in a gradual, evolving manner. MOE, NIE, and schools will undertake research and development efforts to further understand and implement the scaling process with a view to leveling up the base of 21*st* century learning and literacies, for all stakeholders, across the Singapore education system.

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