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Sustainable School-Improvement in Complex Adaptive Systems: A Scoping Review

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Abstract

School-improvement initiatives are implemented with admirable goals, often requiring substantial human and material resources. However, many fail to sustain beyond short-term funding cycles or the enthusiasm of local initiators. Typically, implementation and improvement are viewed linearly and as static end-products that fail to consider that schools are complex adaptive systems (CAS) that are continuously and recursively challenged with change. To investigate sustainable school-improvement within CAS, we used PRISMA-SR guidelines to conduct a scoping review of peer-reviewed journal articles extracted from 6 databases using keywords synonymous with “complex or adaptive system”, “sustain”, “school” and “initiative”. The search process yielded 1146 articles but only 16 of those articles met our inclusion/exclusion criteria that specified that authors present an integrated view of sustainable implementation in schools conceptualised as CAS. Within the selected 16 articles, key components for sustainability in schools described as CAS included access to adequate funding and resources, engagement and involvement of stakeholders, the ability of stakeholders to adapt to change, formation of collaborative partnerships, and the development of supportive policies and procedures. Some important issues arose, such as the tendency of the ‘whole school approach’ to be reduced to information dissemination activities that do not adequately deal with components of complex systems, and the increasing recognition that older implementation models that seek ‘institutionalisation’ fail to appreciate that sustainability is a process, not an end goal. This scoping review highlights the need to recognise the complexity and adaptivity of school systems for successful and sustained implementation of school-improvement initiatives.

Keywords: sustainable school-improvement, complex systems, adaptation, emergence

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Introduction

Despite decades of implementing school-improvement initiatives, sustaining change in schools is extraordinarily difficult (Hargreaves, 2005). Schools are caught in an endless cycle of reform (Cuban, 1990; Trombly, 2014) with reports of ineffective resource use (Lennox et al., 2018) and marginal effects observed in various settings (Chambers et al., 2013; Levin, 2004; Trombly, 2014). More recent studies have also reported that many otherwise well-designed effective school-based initiatives have failed to sustain, especially when start-up resources are depleted (Askell-Williams, 2017; Preiser et al., 2014; Trombly, 2014). Despite efforts to bring change and innovations into schools, the larger context and operations of schools are rarely challenged because their mission depends on a stable culture that dictates what a school should do and be (Levin, 2004). As a result, sustainable school-improvement remains an important problem of translational research that is currently recognised as an understudied area in implementation science (Shelton et al., 2018).

During our earlier research with school principals and teachers (Askell-Williams, 2017; Askell-Williams & Murray-Harvey, 2016; Askell-Williams et al., 2013), it became evident that school-improvement initiatives were typically introduced as externally-designed, relatively stand-alone programs that did not fully account for the nature of schools: particularly that schools can be conceptualised as complex adaptive systems (CAS) in which school-improvement is a continuous, reciprocal process rather than an end-product of an intervention. Accordingly, the present scoping review investigates sustainable school-improvement initiatives that include explicit recognition and accommodation for schools as CAS.

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Defining and conceptualising sustainability

The term “sustainability” was first coined in the environmental field in the 1980s by Lester Brown who defined a sustainable society as “one that is able to satisfy its needs without diminishing the opportunities of future generations to meet theirs” (Hargreaves, 2005, p. 16). Since then, definitions and conceptualisations of sustainability have evolved. Outcomes from two recent systematic reviews on sustainability in the health sector yielded a diversity of sustainability terms such as, long-term, institutionalisation, durability, continuation, adoption, continued implementation, routinisation, capacity building, further development and recovering costs (Lennox et al., 2018; Wiltsey Stirman et al., 2012). Furthermore, Wiltsey Stirman et al. reported that more than half of the studies they reviewed did not have a working definition of sustainability. They concluded that sustainability can be broadly defined as the continuation of the program and practices after the initial implementation efforts or funding had ended.

In the field of education, Fullan (2005, p. ix) defined sustainability as “the capacity of a system to engage in the complexities of continuous improvement consistent with deep values of human purpose”. From this perspective, sustainability goes beyond maintaining good programs to include moral purpose, understanding of processes, building of knowledge and relationships, and coherence making (Fullan, 2001). Fullan’s (2005) definition posits that sustainability is not an endpoint of school change. Instead, sustainability is a dynamic process of school change.

Researchers, program designers and implementers have, however, typically conceptualised sustainability as an outcome or end-product of an intervention (Bopp et al., 2013; Scheirer & Dearing, 2011), although some have also included planning for future sustainability in the early stages of program delivery (Pluye et al., 2004). However, in keeping with Fullan’s (2001, 2005) view, sustainable school-improvement is increasingly being conceptualised as a

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dynamic process that incorporates concepts of adaptation, capacity building, change and evolution (Shelton et al., 2018). One such approach that combines the concepts of complexity, holism and emergence has recently gained the interest of educational scholars. Termed the *Complex Adaptive Systems (CAS)* approach, it shifts the focus from a linear reductionist approach to a non-linear and contextualised approach where a complex whole is greater than the sum of its parts (Mason, 2008; McQuillan, 2008).

The Complex Adaptive Systems (CAS) approach

The term *complex* in CAS originates from complexity science, which theorises that a complex system is built from large numbers of mutually interacting sub-units or agents whose repeated interactions result in the emergence of collective behaviour that feeds back into the behaviour of its individual parts (Ricklefs et al., 2007). Unlike *complicated* systems that can also have many parts, *complex* systems can survive the removal of parts by adapting to change. This is achieved through redundancy (e.g., by having many replicated versions of a part) in the system (Ricklefs et al., 2007). For example, the removal of teaching staff from a school due to budget cuts introduces a new event into the school system. For the school to maintain its operations, the remaining agents in the system would need to adapt and self-organise to compensate for the reduction in teaching staff. This may result in undesirable emergent products such as increased teaching workload, limitation of student enrolment and adoption of new teaching methods, to name a few. However, the adaptability and redundancy (e.g., having many teachers) in the complex school system has the potential to keep the system robust despite change, and it will be, at least on the surface, “business as usual” for the school.

On the contrary, if the reduction of teaching staff occurs in a small school that has only a handful of teachers (limited replicated parts), this may lead to the collapse of the school system

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and the school may cease to operate unless a new event (e.g., new budget, merger with a larger school) leads to emergent properties that can sustain the school. Therefore, a certain degree of adaptability and redundancy is required to achieve a critical level of complexity that is required for a school system to achieve a self-sustaining state. This concept is discussed by Mason (2008, p. 37) as achieving “critical mass” which is essential for the generation of emergent properties that will sustain a complex system.

Complex interventions versus complex systems

While interest has grown in applying complexity science in health and education research, confusion has occurred with the use of the term “complex”. It is important to clearly distinguish what is meant by “complex intervention” versus “complex systems” as they share many similarities but are two different concepts altogether. Shiell et al. (2008) argued that complexity is a property of a system not of an intervention. An intervention that has multiple components and levels is not complex, but complicated (Moore et al., 2019). For example, introducing a new technology such as laptops (an intervention) into classrooms is complicated. It involves a number of interacting components (e.g., resource availability, knowledge, agency) but it can be separated into definable and predictable actions.

By contrast, a complex system is adaptive to changes in its environment, composed of other supra and sub-systems, and behaves in a non-linear fashion (Shiell et al., 2008). Schools, for example, are complex systems. Schools are able to evolve in response to external pressures, new technologies or techniques, and changes in beliefs and perceptions (Moore et al., 2019). Using the previous example of introducing laptops into classrooms: this intervention introduces an event or disruption into the school system (Hawe et al., 2009) which may lead to emergent outcomes such as change in leadership structures, formation of parent-teacher collaborative

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groups, new professional development opportunities for teachers and new school policy regarding use of technology in classrooms as the school system self-organises to either maintain, evolve or wash out the laptop intervention from the school.

Conceptualising schools as Complex Adaptive Systems

Schools as social systems are full of uncertainty with numerous connections, networks and relationships (Fidan & Balci, 2017). Structurally, schools consist of sub-systems of diverse agents (e.g., principal, administration staff, teaching staff, parents, students) with formally structured and abstract components such as policies, guidelines, school ethos and social environment (Mason, 2008). Schools are also part of supra systems such as the State's education system and their local community (Keshavarz et al., 2010), and are deeply embedded in the external environments with which they interact (Fidan & Balci, 2017).

Schools consist of interconnected components that interact and adapt in self-organising ways (McQuillan, 2008). These interactions may be formal (e.g., interaction with the Department for Education) or informal (e.g., social interactions between teachers and parents), and the feedback loops from these interactions inform decisions (Keshavarz et al., 2010) that create the inertia, momentum and direction for the evolution of the school system (Fidan & Balci, 2017; Mason, 2008).

Individual agents in schools may also internalise formal (e.g., code of conduct) and informal (e.g., school ethos) rules differently, and introduce different values that shape the priorities, expectations and functions of the school (Keshavarz et al., 2010). For example, from a review of the implementation of the PATHS (Promoting Alternative THinking Skills) program in the UK, Lendrum & Askell-Williams (2019) rejected the view of teachers as reactive

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implementers of curricula, and instead positioned teachers as critical and reflective practitioners who actively and generatively used their professional knowledge and experience to differentiate the curriculum according to student and contextual characteristics. This led to a range of teacher-initiated modifications to the PATHS program, ranging from relatively simple rewording from an American to English context (e.g., sweets; cookies); rewriting story scripts to remove assumptions about the socio-economic status of the students in the class (e.g., that students would have access to pocket money); speeding up or slowing down recommended modules to meet students' capabilities; and removing modules that might aggravate current tensions in the school as a result of recent in-school events (such as bullying).

Moreover, diversity exists within schools and between schools so that what works in one school or class may not necessarily work in another (Trombly, 2014). Within schools, this diversity may lead to disagreements between agents that create disequilibrium or perturbations in the system, leading to emergent behaviours as agents self-organise, collectively learn and co-evolve which can then trigger change in another interdependent entity (Fidan & Balci, 2017; Trombly, 2014).

Sustaining Improvement Initiatives in Schools

Due to the interconnectedness of agents, components and other systems, a CAS cannot be considered in isolation and school-improvement efforts cannot be implemented as a "one size fits all" (Preiser et al., 2014). The open boundaries of a CAS mean that context is vital when initiatives are planned, implemented and evaluated in schools (Rosas, 2017). Therefore, leaders who wish to sustain improvement initiatives in schools should refrain from imposing standardisation or insisting on a top-down approach. This is because school-improvement is a developmental process not an act of compliance (Trombly, 2014). By way of example, Lendrum

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and Humphrey (2012) discussed how local micro-level adaptations to an educational initiative improved upon meso-level program designs, even though those adaptations might be viewed by evaluators as departures from fidelity.

School-improvement occurs incrementally and iteratively over time as a result of the concerted and sustained efforts of the agents in the school. Therefore, it takes time for emergent behaviours such as leadership and teaching practices to take hold and become a part of the daily working repertoire of agents in schools (Trombly, 2014). Moreover, a lack of sufficient documentation, assessment and attention to feedback about processes of change during program implementation has been noted by many authors (Domitrovich & Greenberg, 2000; Greenberg, 2011; Lee et al., 2008; Lendrum & Humphrey, 2012; Melde et al., 2006; Payne, 2009) with Resnick (2010, p. 187) proposing a need for “an organisational management system that is closer to systems engineering, one that examines ‘processes’ along a chain of linked policies and actions”.

Reviews have been conducted to identify sustainability definitions and approaches in healthcare (Lennox et al., 2018; Wiltsey Stirman et al., 2012) and how systems thinking can be applied to global health practices (Wilkinson et al., 2018). However, no reviews, to our knowledge, have been conducted on the synergy between sustaining school-improvement initiatives and conceptualising schools as CAS. The present scoping review addresses this gap in the literature by focusing on schools as the CAS of interest. We address the following five research questions:

- 1) What are the descriptions and definitions of sustainable implementation of school-improvement initiatives?

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- 2) What are the descriptions and definitions of schools as CAS?
- 3) Why is it essential to conceptualise schools as CAS for achieving sustainable implementation of school-improvement initiatives?
- 4) What components of sustainability are identified as necessary to address in order to achieve sustainable implementation in schools as CAS?
- 5) Are there any apparent gaps in identifying components of sustainability in schools as CAS that may be necessary to achieve sustainable implementation of school-improvement initiatives?

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Method

Search procedure

We conducted a scoping review according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews (PRISMA-ScR) reporting standards (Tricco et al., 2018). The selection of databases, search terms and search strategy were supported by a research librarian. A logic grid was constructed based on the discrete concepts aligned with each element of the research questions (Population, Concept, Context) to aid development of the search strategy. Key words included a combination of sustainability, CAS, school and initiative terms. All search terms used for all six databases can be found in the form of an example syntax in Supporting Information 1. The terms were used consistently for all six databases with no alteration. The search was carried out on ProQuest, Scopus, PsycINFO, Ovid MEDLINE, PubMed and CINAHL between May 2019 to April 2020 to ensure quality and coverage of articles reporting on educational improvement initiatives implemented in schools.

We undertook an initial three-phase search strategy. The first author completed a preliminary search of ProQuest and PsycINFO, followed by the analysis of keywords in the titles and abstracts (Phase 1). Next, the first author searched for the identified keywords across all six databases mentioned above (Phase 2). Finally, the first and second authors reviewed the reference lists of all studies retrieved for analysis (Phase 3).

Screening and selection process

All papers found from the abovementioned initial identification process were imported into Endnote X7 software and duplicates were removed. We used a two-stage screening process to select the papers that were included in our data charting process. In the first stage, papers

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published in languages other than English, commentaries, posters, protocols, conference proceedings and editorials were excluded. Only peer-reviewed papers were included to ensure academic integrity and quality of evidence. In the second stage, both authors re-screened the remaining articles to ensure that only papers that considered both sustainability as a fundamental implementation issue, *and* that substantively conceptualised schools as CAS were included in the review. Therefore, the following papers were excluded from the data charting process:

- (a) Papers only defining or describing concepts of sustainability
- (b) Papers only defining or describing concepts of CAS
- (c) Papers reporting or describing the improvement initiative (but not the school) as “complex”
- (d) Papers considering schools as CAS but only mentioning sustainability in passing or as a peripheral downstream outcome
- (e) Papers considering sustainability but only mentioning CAS in passing as a generic background concept
- (f) Papers referring to adopting a ‘whole-school approach’ that included involving all stakeholders in information dissemination but did not conceptualise schools as CAS.

Any differences between the two authors in the selection of articles were discussed, and the inclusion and exclusion criteria were refined to reflect those discussions.

The search strategy identified 1146 publications from the databases. An additional five articles were included from the hand searching process. Duplicates were removed, and the titles and abstracts of the remaining papers were examined leading to the selection of 117 articles for

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full text retrieval. Analysis of the full texts resulted in the removal of 101 articles for the following reasons:

- (a) Not examining or clearly describing or defining sustainable implementation ($n= 37$)
- (b) Not using the CAS approach ($n= 20$)
- (c) Not conceptualising schools as the CAS of interest ($n= 50$)

There were six articles that had more than one reason for exclusion. As a result, sixteen papers were included in the final scoping review (Figure 1).

Place Figure 1: PRISMA Flow Diagram for the Scoping Review Process.

Data Charting Process

We designed a data charting form to report characteristics of studies included in the review and to capture data related to our research questions. Data charted included author(s), year, country, aim(s) of the study, study design, article type, study population, school, initiative, type of initiative, definition of sustainability, definition of CAS, rationale for using the CAS approach, key components of CAS for sustainability, and gaps in identifying components of CAS for sustainability. The first author charted the study characteristics data. This information was then checked against the full text by the second author. Both authors independently charted the data pertaining to the five research questions. Discrepancies were discussed between the authors and resolved via consensus.

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Data synthesis and presentation

Full texts included in the review were exported from Endnote X7 software into NVivo 12 software for analysis. Predefined codes were used to create a baseline template for coding. These codes were sourced from the following:

- (a) Definition /description of sustainability (Lennox et al., 2018; Mason, 2008; Wiltsey Stirman et al., 2012)
- (b) Definition/description of CAS (Wilkinson et al., 2018)
- (c) Key components of sustainability (Lennox et al., 2018).

The baseline coding structure was then iteratively developed as emerging codes from the data were added to the coding template. Both authors independently coded the data.

Discrepancies were discussed and used to further refine the codes pertaining to each research question. To assess interrater reliability, Cohen's Kappa (κ) was calculated for all coded themes corresponding to research questions 1 to 4, using agreement indicators proposed by McHugh (2012). In the section that follows, results are presented using tables, figures and narrative summaries.

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Results

Characteristics of papers

The earliest paper that emerged from the review was published in 2006. Five papers were published between 2010 and 2015 and seven were published after 2015. Researchers based in North America contributed the most to the found literature in this area of study (6/16 papers) followed by researchers from Europe (5/16), Australia (2/16), South Africa (2/16), Asia (2/16) and South America (1/16). Case studies were the most reported study design (8/16 in Australia, Canada, Hong Kong, Spain, Brazil, US and South Africa) followed by observational studies (3/16 in Canada, Australia and the UK). Two of the reviewed papers were longitudinally designed experimental studies (Bartelink et al., 2019a; Bartelink et al., 2019b) with both originating from the Healthy Primary School of the Future (HPSF) project in the Netherlands. One reviewed paper used an iterative experience-based co-production study design to develop a framework for sustaining physical activity initiatives in UK schools (Daly-Smith et al., 2020). Nine of the reviewed papers from the UK, Netherlands, Canada, Australia, South Africa and the US reported on health and wellbeing initiatives (Table 1); two from the US on special education initiatives (Bal et al., 2014; Bal et al., 2016); two from the US and Brazil on teaching methods initiatives (Magalhães de Barros et al., 2017; Minnema et al., 2006); one on an international professional development initiative involving schools in Canada, Hong Kong and Spain (Laferrière et al., 2012); one from the US on an educational change initiative (Mason, 2008) and one from South Africa on a technology integration initiative (Thomas & Cronje, 2007). Summarised details of the characteristics of the reviewed papers, including dates of publication, country of origin, type of study and aims of each study are shown in Table 1. In the next section we address each of our research questions in turn.

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Place Table 1: Characteristics of studies included in this review (n=16).

Research question 1: What are the descriptions and definitions of sustainable implementation of school-improvement initiatives?

We identified nine definitions of sustainability in the reviewed papers. Inter-rater reliability ranged from $\kappa = 0.50$ to $\kappa = 1.00$ with an averaged reliability of $\kappa = 0.76$ (substantial agreement) for this coding category (Table 2). From the results presented in Table 2, the two most common definitions were “continue” (12/16) and “embed” (10/16). “Continue” refers to on-going emergent behaviours or elements that were conducive for the growth of the initiative, such as continuous systemic improvement and capacity building (Bal et al., 2014); continuous adaptations (Keshavarz et al., 2010; Rosas, 2017); continued participation (Bal et al., 2014); continued partnership (Bal et al., 2014; Laferrière et al., 2012); continued use of resources or tools (Thomas & Cronje, 2007); continued program activities (Bisset & Potvin, 2007); maintenance or sustainment of positive or productive relationships or partnerships (Bal et al., 2014; Bartelink et al., 2019a; Butler et al., 2010); maintenance or continuation of the inertia or momentum towards positive change (Mason, 2008; Rosas, 2017); maintenance of system coherence (Magalhães de Barros et al., 2017); and sustaining innovations (Laferrière et al., 2012). Initiatives were described as being “embedded” in the school when they were planted or combined into the school curriculum (Bartelink et al., 2019a); school system (Bartelink et al., 2019b; Murphy et al., 2018; Thomas & Cronje, 2007); policy frameworks (Butler et al., 2010; Murphy et al., 2018); and organisational relationships (Rosas, 2017). The least common term used to describe sustainability in schools as complex adaptive systems was “institutionalised” (3/16) (Table 2).

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Place Table 2: Descriptions and references to sustainability terms in schools as Complex Adaptive Systems (n=16).

Research question 2: What are the descriptions and definitions of schools as CAS?

We identified nineteen terms in the reviewed papers that described the CAS nature of schools (Table 3). Inter-rater reliability ranged from $\kappa = 0.10$ to $\kappa = 1.00$, with an averaged reliability of $\kappa = 0.45$ (moderate agreement) for this coding category (Table 3). As evident from Table 3, the most frequent terms were “dynamic” (15/16) and “inter-dependent” (15/16). Alternate terms were “non-static” (Thomas & Cronje, 2007); “changing” (Bartelink et al., 2019b; Bisset & Potvin, 2007; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Rosas, 2017); “evolving” (Bisset & Potvin, 2007; Daly-Smith et al., 2020; Preiser et al., 2014); and “transformational” (Bal et al., 2014; Bal et al., 2016; Magalhães de Barros et al., 2017; Mason, 2008). These terms describe the changing nature of schools. “Inter-dependent” refers to the reliant interactions (Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Keshavarz et al., 2010; Magalhães de Barros et al., 2017; Minnema et al., 2006; Preiser et al., 2014) and relationships (Butler et al., 2010; Mason, 2008; Rosas, 2017) between agents in schools and their associated supra and sub-systems (Butler et al., 2010; Magalhães de Barros et al., 2017; Murphy et al., 2018). Other frequently used terms were “agents” (13/16), “contextual” (12/16), “emergence” (10/16), “non-linear” (10/16) and “networks” (9/16) (Table 3).

Place Table 3: Definitions, related terms and references to schools as Complex Adaptive Systems (n=16).

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Research question 3: Why is it essential to conceptualise schools as CAS for achieving sustainable implementation of school-improvement initiatives?

The most common reasons given for using the CAS approach to sustain improvement initiatives in schools were the importance of considering the changing dynamics of schools (12/16) and to consider the school context (9/16) when implementing improvement initiatives (Table 4). Of the nine papers that examined the sustainability of health and wellbeing improvement initiatives in schools, six proposed that the “whole-school approach” outlined in the WHO Health Promoting School framework (World Health Organization, 1996) is limited for delivering and sustaining significant intervention impact (Table 4); hence conceptualising schools as CAS was argued as necessary for the sustainability of health and wellbeing initiatives in schools. Moderate interrater agreement ($\kappa = 0.50$ to 0.60) was achieved with an averaged reliability of $\kappa = 0.54$ for the coding of reasons given for using the CAS approach.

Place Table 4: Rationale for using the Complex Adaptive Systems approach to sustain improvement initiatives in schools (n=16).

Research Question 4: What components of sustainability are identified as necessary to address in order to achieve sustainable implementation in schools as CAS?

A summary of the components of sustainability identified in the retrieved articles is shown in Table 5. Results from the interrater reliability tests ranged from $\kappa = 0.26$ to $\kappa = 1.00$ with an averaged reliability of $\kappa = 0.63$ (substantial agreement) (Table 5). Two prominent conditions for sustainability were identified, namely resource adequacy (including funding) for the continued implementation of initiatives in schools (15/16), and engaging stakeholders in the implementation of the initiative (15/16) (Table 5). Other conditions included the adaptability and flexibility of schools and its stakeholders to manage the changing needs of the school community

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(14/16); the formation of collaborative partnerships between schools and external stakeholders such as universities and community agencies (14/16); the existence of school and external policies that supported the implementation and sustainment of the improvement initiatives (14/16); and having access to evaluation data (13/16) (Table 5).

Place Table 5: Components of sustainability of improvement initiatives in schools as Complex Adaptive Systems (n=16).

Research Question 5: Are there any apparent gaps in identifying components of sustainability in schools as CAS that may be necessary to achieve sustainable implementation of school-improvement initiatives?

Across the whole cohort of reviewed papers there appeared to be substantial coverage of components of sustainable implementation, and of components of CAS. However, our charting of knowledge across the papers highlighted that none of the articles presented a comprehensive view of sustainability nor of CAS. Components such as leadership and administration (7/16); prioritisation (7/16); commitment and ownership (5/16); adequate staffing (4/16); reflection and refinement (5/16); involvement in selection of the initiative (2/16); and resilience (1/16); seemed particularly limited in representation in the papers in this scoping review (Table 5).

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Discussion

The emerging field of studying sustainability as an emergent process and product of CAS

In this paper we have argued that schools are CAS, and that the design of school-improvement initiatives must account for schools' systemic nature, including concepts such as agency, context, and emergence. Our scoping review highlights that the integration between school-improvement and CAS has been under-conceptualised and under-researched. Our extensive search of data bases uncovered only 16 articles that substantively conceptualised schools as complex and evolving social systems, although our assessment is that none of the papers in our review presented a comprehensive exposition of schools as CAS. It is important to note that a large number of studies did not meet the inclusion criteria of this review because they failed to adequately conceptualise schools as CAS or may have loosely used the term "complex" to describe schools, highlighting the diverse ways the term "complex" is used in the literature. In the following section we provide our synthesis of key findings from the analyses presented in the above results section.

The need for consistent terminology when describing sustainability in the CAS framework

Studying sustainability in CAS highlights a need for terms to describe sustainable school-improvement that are consistent with concepts of a CAS framework. Most papers in our review used terms such as "continue" and "embed" to describe sustainability. Authors who used these terms described sustainability as a continuous systemic improvement and capacity building process that triggers a continuous cycle of change and adaptations (Bal et al., 2014; Keshavarz et al., 2010). This then becomes a part of the dynamics of the school system where desired emergent products such as healthy behaviours (Bartelink et al., 2019a; Bartelink et al., 2019b; Daly-Smith et al., 2020) and knowledge building (Laferrière et al., 2012) are embedded into the

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school system. Describing sustainability in this manner sees a shift from a centralised-controlled school system to an emergent-controlled school system that is responsive to feedback from agents in the school system (Magalhães de Barros et al., 2017). School systems are thus sustained by feedback loops that may be positive reinforcing, leading to the continuation of a way of working, or negative-balancing, leading to discontinuation (Murphy et al., 2018). Conceiving that sustainable school improvement is ‘transformational’ captures the concept of dynamic change in a CAS.

By contrast, “institutionalisation” was rarely mentioned in the literature we reviewed. The three papers in our review that did mention institutionalisation considered it to be an inappropriate or outdated concept for sustaining improvement initiatives in schools (Bal et al., 2014; Bisset & Potvin, 2007; Laferrière et al., 2012). This is because institutionalisation is usually described as the final stage of an innovation diffusion process (Goodman & Steckler, 1989). This final-stage perspective is based on a linear cause-effect model and postulates that sustainability is a static and endpoint process of the spreading of standardised innovations in the system (Rogers, 2003). Hence, despite being used in literature to describe sustainability (Wiltsey Stirman et al., 2012), “institutionalisation” is limited in its usefulness for describing sustainable improvement initiatives in a CAS framework.

The dynamic and contextual social systems in schools cannot be ignored when school-improvement initiatives are introduced

From a CAS perspective, there is a strong emphasis in viewing schools as dynamic and evolving social systems that consist of inter-dependent interactions between agents in schools (Bal et al., 2014; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Murphy et al., 2018; Preiser et al., 2014). The foci of most of the articles in our scoping review were on the changing

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nature of relationships between agents in schools which led to co-learning (Magalhães de Barros et al., 2017), co-production (Daly-Smith et al., 2020), adaptability (Bartelink et al., 2019a), complexity (Preiser et al., 2014) and sustainability (Laferrrière et al., 2012). Because each school acts in a unique way and reacts differently to changes, context is important when implementing and sustaining initiatives in schools (Bartelink et al., 2019a; Keshavarz et al., 2010; Mason, 2008; Rosas, 2017).

However, describing schools as dynamic and evolving systems only partially conceptualises schools as CAS. For instance, in the papers we reviewed, relatively little emphasis was given to discussing the unpredictability of CAS or how the various interactions amongst agents do not necessarily predict the condition and outcomes of the CAS and its related systems. Although interactions amongst agents were often mentioned, less than half of the articles we reviewed modelled or discussed the feedback loops of those agentic interactions, or how order emerges from the collective actions of agents within the system rather than from a central control (Murphy et al., 2018).

Sustainable improvement in CAS is simultaneously bottom-up, top-down and lateral

Interestingly, the term “bottom-up” was used to describe the CAS framework in six articles we reviewed. This term is often used to describe grassroots collective action in schools (Weare & Nind, 2011). The “bottom-up” approach is also often used in public health interventions. It is mainly concerned with changing the balance of power and monopoly of decision-making from policy makers and professional experts into the hands of health users and community members (Robinson et al., 2012). Caution is required when interpreting and discussing the bottom-up approach in a CAS framework because it too is a linear approach that inadequately describes CAS. De-centralisation in CAS refers to shared and distributed control amongst agents in the

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system (Keshavarz et al., 2010; Trombly, 2014). This concept does not preference players in social power hierarchies nor the direction from which change comes. This was evident in the literature we reviewed where authors noted that sustaining improvement initiatives in schools required the combined bottom-up, top-down and lateral involvement and support of all agents in schools and their related sub and supra systems (Bartelink et al., 2019a; Daly-Smith et al., 2020; Laferrière et al., 2012). In other words, change from all directions and at all levels is needed to sustain improvement initiatives in schools.

There is a need to re-define the meaning and application of the “whole-school” approach

Many school-improvement initiatives promulgate a ‘whole-school approach’. Due to failures of health promotion interventions to deliver the desired impact and to sustain in schools, the school context or the setting has been recognised as an essential influence when designing and implementing interventions. This became the basis for the settings approach of the Health Promoting Schools framework, whereby health is promoted through the whole school environment and not just through relatively stand-alone health education in the curriculum (Langford et al., 2014; World Health Organization, 1996). But despite how promising the whole-school approach sounded, suboptimal results have been observed even after over a decade of Health Promoting Schools interventions (Bartelink et al., 2019a), especially in developing countries (Fathi et al., 2014).

On the surface, a whole-school approach might imply a systems approach, but in practice it has become an approach that typically only involves school stakeholders in information dissemination and program diffusion processes. Consequently, stakeholders become viewed as the recipients of change and not as the generators of change, leading to reports of health promotion interventions performing worse in real world compared to controlled settings (Geng et

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al., 2017; Hailemariam et al., 2019). This is because under the currently flawed understanding of the ‘whole-school’ approach, health interventions have been implemented *on* schools, instead of *with* schools (Daly-Smith et al., 2020). An emphasis on validity to the scientific process has led to the rejection of programs that, during implementation, lacked fidelity to their original design (Geng et al., 2017): conditions Chambers et al. (2013) referred to as “voltage drop” (poorer performance than anticipated) and “program drift” (poor fidelity). This problem is further exacerbated in schools where health promotions are sometimes poorly coordinated and lowly prioritised over other topics conceived as core business, such as literacy and numeracy (Keshavarz et al., 2010).

It has become clear that although the whole-school approach has been promoted as a holistic approach, local interpretations of the Health Promoting Schools framework retain assumptions of linearity. As a result, Health Promoting Schools interventions are designed to consider multiple and complicated socio-environmental “factors” that may influence adoption of healthy lifestyles by students and school staff. The assumption is that if these “factors” are addressed, an intervention will have a better chance of delivering desired outcomes. The fallacy of this assumption and the omission by the whole-school approach to consider unpredictability and continuous change in schools are possible reasons why Health Promoting Schools interventions have not consistently achieved their anticipated high-level successes (Turunen et al., 2017). Augmenting the Health Promoting Schools framework with the CAS approach is therefore proposed as a possible solution to this problem (Bartelink et al., 2019a; Rosas, 2017).

Conditions for Sustainability

The conditions essential for sustainability are related to how schools are described as CAS and the structure of the intervention or initiative. Scheirer (2013) proposed six types of intervention

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structures, namely i) interventions implemented by individual providers, ii) interventions requiring coordination among multiple staff, iii) new policies, procedures and technologies, iv) capacity or infrastructure building, v) collaborative partnerships or coalitions, and vi) broad-scale system change, and hypothesised key components for sustainability based on these structures.

Almost all the studies included in our review focused on Scheirer's fourth and fifth structures, namely building capacity and partnerships, and required coordination among multiple levels of stakeholders. Initiatives such as the HPSF project (Bartelink et al., 2018), Little Cooks-Parental Network (Bisset & Potvin, 2007), the Gatehouse project (Butler et al., 2010), the Knowledge Building Network (Laferrière et al., 2012) and the SHRN project (Murphy et al., 2018) were also concerned with broad-scale system change. Initiatives that are structured to build capacity, form collaborative partnerships and broad system change typically require a long period of progressive implementation, diverse efforts to sustain, and are strongly influenced by the long-term availability of financial resources and changes in policy and procedures (Scheirer, 2013). These conditions are consistent to issues of funding, stakeholder engagement, building collaborations and supportive policies that were identified as key components for sustainability in our review.

Gaps in CAS frameworks

In the reviewed papers there was a strong emphasis on the dynamic relationships between agents in schools. However, these relationships were not frequently modelled by authors as feedback loops, nor was it made clear how changing relationships contribute to changes in CAS over time. This meant that sustainability components that relate to nested sub-systems and/or to individual agents, such as resilience, motivation, agency and commitment, and leadership, as well as organisational processes such as prioritisation, program selection and staff turnover may have been overlooked by authors holding a limited CAS focus. For example, a previous literature

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review on the sustainability of health interventions by Shelton et al. (2018) identified administrative support, consistent resources, and staff stability as being particularly important in the school context. All these components were identified in our review, but certain components such as administrative support and staff stability were less frequently mentioned in the papers we reviewed. Instead, components that were not identified as being important in the school context in the Shelton et al. (2018) review such as engagement and involvement of stakeholders, adaptability and flexibility to manage change, and formation of collaborative partnerships were found to be important components for sustainability in almost all the papers we reviewed. We postulate that this difference is due to the relatively partial CAS conceptualisation of schools found in each of the papers we reviewed. The particular systemic level (e.g., organisational, leaders, teachers) at which the reviewed authors described schools as CAS may also explain the gaps in identifying a broad range of components of sustainability in schools (Askell-Williams et al., 2013; Resnick, 2010).

Strengths and limitations

In this project, we elected to focus on peer reviewed papers as a means of achieving academic integrity and quality. We therefore excluded posters, protocols, conference proceedings and editorials. Our search was also restricted to English language journals due to our own language capabilities and accessibility of journals.

The literature in this field of study is underdeveloped and fragmented. Although our review included various school-improvement initiatives and attempted to identify studies from various fields, the variety of terms used to describe sustainability, the ambiguity and subjectiveness of how sustainability is described and conceptualised in the literature, and the dispersed nature of the literature on sustainability may have limited our ability to conduct an

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exhaustive review. Moreover, the inclusion of a broad literature across fields of study meant that some of the findings in our review may not apply to any one initiative and/or school.

Conclusions and future directions

Poor sustainability of promising school-improvement initiatives is an ongoing drain on human and material resources. This is the first review, to our knowledge, to map definitions and descriptions used in a very specific literature that focuses on examining sustainability of initiatives in schools using the conceptual lens of CAS. Information generated from this review can inform researchers and stakeholders about what has been explored, how sustainability is conceptualised in the CAS framework in schools, and what components of sustainability should be considered when planning and implementing improvement initiatives in schools.

The outcomes from our review provide further evidence that implementation of new initiatives is not a linear process, and that a CAS approach has the potential to improve current and future efforts to sustain improvement initiatives in schools. Therefore, the terms “continue” and “embed” used by most authors in our review are appropriate terms to describe the continuous processes of systemic improvement and adaptability that are needed to sustain improvement initiatives in schools. However, the partial conceptualisations of schools as CAS and the reliance on snapshot data in the papers we reviewed limit what we can conclude about the evolving nature of sustainability and the changes in reciprocal relationships between components of sustainability in CAS over time. Notably, these include not only the components in the new initiative being introduced, but also the components of the CAS itself, such as stakeholders’ dispositions, actions and interactions.

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Most of the studies included in our review reported a cross-sectional or retrospective description of implementation, including challenges and what was done to address those challenges. The limitations of funding cycles and resources to monitor prospective change may contribute to the reliance on cross-sectional and retrospective study designs. However, more recent school-based initiatives such as The Healthy Primary School of the Future (HPSF) project (Bartelink et al., 2018); the WHO STOPS childhood obesity project (Allender et al., 2016); the Marathon Kids UK project (Chalkley et al., 2018); and the ‘It’s Your Move!’ project (Malakellis et al., 2017) have included complexity and systems thinking into their project planning and designs. Also notable is the inclusion of the CAS approach into the co-development of a sustainable whole school-based physical activity framework in the UK which resulted in the Creating Active Schools Framework (Daly-Smith et al., 2020). This latter framework has yet to be fully tested in real-life school settings but represents a positive development in the CAS area of study towards sustainable implementation of school-based improvement initiatives.

Nevertheless, it is still the case that many of the studies conducted in this field are conceptual and theoretical in nature. As a result, gaps still exist in our understanding of the real-world conditions essential for sustaining improvement initiatives in schools. Identifying components of sustainability is the first step, but how these components interact, which combinations are most effective, and the weighting or importance of certain components over others in various times and contexts remain largely unknown.

It is time to put theory to practice in order to break the cycle of unsustainable school reforms. Therefore, future studies should focus on further identifying and capitalising upon the synergies between schools as CAS and sustainable school-improvements, and to collect longitudinal practice-based evidence from real world school settings so that change and points of

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emergence can be monitored and modelled prospectively. Accordingly, we suggest the following three improvement points for future research:

- 1) To further define and conceptualise the processes of sustainability in a CAS framework
- 2) To conceptualise or model a CAS approach using appropriate method(s) relevant to specific interventions and schools
- (3) To monitor and model change, interactions and feedback loops over time in identified components of CAS during and following the introduction of school-improvement initiatives.

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TABLE 1*Characteristics of studies included in this review (n=16)*

Author(s)	Year	Country	Study design	Education initiative	Aim(s)
Bal et al.	2014	US	Case study	Learning Lab from Culturally Responsive Positive Behavioral Interventions and Supports (CRPBS)	To examine the implementation of Learning Lab, a new methodology of systemic transformation, for local stakeholders to collectively examine and address disproportionality in behavioral outcomes from the ground-up
Bal et al.	2016	US	Case study	Learning Lab from Culturally Responsive Positive Behavioral Interventions and Supports (CRPBS)	To provide specific guidelines and key considerations for practitioners on how to implement Learning Labs to facilitate authentic and productive family-school-community collaboration and systemic transformation in schools
Bartelink, N. et al.	2019a	Netherlands	Longitudinal, Quasi-experimental, Mixed methods	Healthy Primary School of the Future (HPSF)	To investigate the moderating role of the school context on the effects of a Dutch health promoting school initiative on children's health and health behaviors

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TABLE 1. (continued)

Author(s)	Year	Country	Study design	Education initiative	Aim(s)
Bartelink, N. et al.	2019b	Netherlands	Quasi-experimental, Mixed methods	Healthy Primary School of the Future (HPSF)	To generate and share knowledge and experiences on how to implement changes in the complex school system to integrate school health promotion
Bisset & Potvin	2007	Canada	Retrospective, Observational	Little Cooks-Parental Network	To present a theoretical framework in which health promotion and health education program implementation can be conceived as an open dynamic system
Butler et al.	2010	Australia	Prospective, Observational	The Gatehouse Project	To argue that health promotion dissemination needs to be rethought for school communities as complex systems and that this requires understanding and harnessing the dynamic ecology of the socio-political context

(continued)

SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 1. (continued)

Author(s)	Year	Country	Study design	Education initiative	Aim(s)
Daly-Smith et al.	2020	UK	Iterative	Creating Active Schools Framework	To co-develop a whole-school approach framework using the Double Diamond Design approach
Keshavarz et al.	2010	Australia	Case study	Health Promoting Schools (HPS)	To report on the implementation of HPS programs in primary schools in Sydney, Australia
Laferrière et al.	2012	Canada Hong Kong Spain	Case study	Knowledge Building International Project (KBIP)	To present the results of the first phase (2007-2009) of the KBIP with focus on understanding the key environmental characteristics and design features of the KBIP project that nurture and sustain the innovations in schools
Magalhães de Barros et al.	2017	Brazil	Case study	Blended Learning Approach	To understand a blended learning environment from the perspective of complex systems
Mason	2008	Hong Kong	None	None	To consider questions of continuity and change in education from the perspective of complexity theory

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 1. (continued)

Author(s)	Year	Country	Study design	Education initiative	Aim(s)
Minnema, et al.	2006	US	Case study, Mixed methods	To include English learners with disabilities in state standards-based assessments and accountability program	To portray the complex issues surround including English Learners with disabilities in state assessment programs using a systems perspective
Murphy et al.	2018	UK	Retrospective, Observational	School Health Research Network (SHRN)	To discuss and reflect on a transdisciplinary complex adaptive system (T-CAS) approach to the development of SHRN in Wales
Preiser et al.	2014	South Africa	Case study	Health Promoting Schools (HPS)	To examine the role of two higher education institutions (as external stakeholders) in Western Cape, South Africa, and how their initiatives and collaboration brought about a HPS program in two resource-poor schools
Rosas	2017	US	None	Health Promoting Schools (HPS)	To introduce systems thinking into the whole-school approach for health promoting schools

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 1. (continued)

Author(s)	Year	Country	Study design	Education initiative	Aim(s)
Thomas & Cronje	2007	South Africa	Case study	Computer-Assisted Learning in Schools (CALIS) project	To investigate influences on the sustainability of a computers-in-schools project during the implementation phase of CALIS project

SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 2*Descriptions and references to sustainability terms in schools as Complex Adaptive Systems (n=16)*

Terms	Related term(s) [€]	Description	<i>n</i>	References	κ^*	95% CI**
Continue	On-going, Maintain, Sustain	The continued emergent behavior or element conducive for the growth of the initiative (e.g., continued participation, continued use of resources or tools, continued activities) in the school	12	Bal et al., 2014; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.88	0.64-1.00
Embed	Integrate, Synergised	To plant and combine the initiative into various parts of the school (e.g., embedded in the curriculum, embedded into school system)	10	Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2017; Butler et al., 2010; Daly-Smith et al., 2020; Laferrière et al., 2012; Minnema et al., 2006; Murphy et al., 2018; Rosas, 2017; Thomas & Cronje, 2007	0.90	0.70-1.00
Evolution	Change, Transformation, Refinement, Development, Reform	The changing form of the initiative, behaviors and practices over time as a result of new opportunities and challenges in the school	7	Bisset & Potvin, 2007; Keshavarz et al., 2010; Daly-Smith et al., 2020; Laferrière et al., 2012; Minnema et al., 2006; Murphy et al., 2018; Rosas, 2017	0.50	0.07-0.84

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 2. (continued)

Terms	Related term(s) ^e	Description	<i>n</i>	References	κ^*	95% CI**
Inertia	Momentum, Critical Mass, Snowball effect	The accumulation of a dominant inertial momentum that will sustain the direction and speed of that path in an autocatalytic manner	6	Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Daly- Smith et al., 2020; Mason, 2008; Thomas & Cronje, 2007	0.77	0.33-1.00
Diffusion	Dissemination	The distribution and transfer of program information and practices within and between schools and their stakeholders	5	Bisset & Potvin, 2007; Butler et al., 2010; Keshavarz et al., 2010; Laferrière et al., 2012; Murphy et al., 2018	0.86	0.60-1.00
Long-term	N/A	Emergent elements and behaviors from the initiative occurring over a long period of time	5	Butler et al., 2010; Bisset & Potvin, 2007; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017	0.67	0.27-1.00
Improvement	Progress	Continuous systemic, process and program outcomes improvement in the school	5	Bal et al., 2014; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Rosas, 2017	0.67	0.27-1.00

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 2. (continued)

Terms	Related term(s) [€]	Description	<i>n</i>	References	κ^*	95% CI**
Scale-up	Proliferation, Expansion, Elaboration, Extension	A deliberate effort to increase the impact and reach of a positive initiative within and between schools and their associated sub and supra systems (e.g., scaling up of the initiative to include policy change at the local level, expansion of the initiative to include all schools in the state)	4	Bartelink et al., 2019b; Laferrière et al., 2012; Minnema et al., 2006; Murphy et al., 2018	0.56	0.15-0.96
Institutionalised	Routinised	To spread and establish the initiative into the school practice, culture or norm	3	Bal et al., 2014; Bisset & Potvin, 2007; Laferrière et al., 2012	1.00	1.00-1.00

Note. [€] N/A = Not Applicable. *Kappa coefficient <0 = No agreement, 0.00 to 0.20 = Slight agreement, 0.21-0.40 = Fair agreement, 0.41-0.60 = Moderate agreement, 0.61-0.80 = Substantial agreement, 0.81-1.00 = Almost perfect agreement (McHugh, 2012). ** 95% Confidence Interval.

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TABLE 3*Definitions, related terms and references to schools as Complex Adaptive Systems (n=16)*

Term	Related term(s) [¶]	Definition	<i>n</i>	References	κ^*	95% CI**
Dynamic	Non-static, Changing, Evolving, Transformational	System adapts to changes continuously with time	15	Bal et al., 2014; Bal et al., 2016; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.33	-0.17-0.84
Inter-dependent	Interactions, Inter-connected, Relationships between agents, Interplay, Interwoven, Symbiotic	Interactions among elements or agents in the system that are reliant on each other	15	Bal et al., 2014; Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.77	0.33-1.00

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 3. (continued)

Term	Related term(s) [¶]	Definition	<i>n</i>	References	κ^*	95% CI**
Agents	Actors, Elements	Actors or elements within a system. They can be made up of individuals, groups, networks, environments and/or sub-systems	13	Bal et al., 2014; Bal et al., 2016; Bartelink et al., 2019b; Bisset & Potvin, 2007; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.12	-0.06-0.30
Contextual	Relevant, Unique	Elements or agents and their properties and behaviors that are unique to the system and cannot be generalised to other systems	12	Bal et al., 2014; Bal et al., 2016; Bartelink et al., 2019a; Bartelink et al., 2019b; Daly-Smith et al., 2020; Keshavarz et al., 2010; Mason, 2008; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.41	0.07-0.76
Emergence	N/A	New properties and behaviors that emerge from a complex system	10	Bal et al., 2014; Bisset & Potvin, 2017; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017	0.40	-0.03-0.80

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 3. (continued)

Term	Related term(s) [¶]	Definition	<i>n</i>	References	κ^*	95% CI ^{**}
Non-linear	N/A	Relationships within a system that do not follow a simple cause and effect line	10	Bartelink et al., 2019a; Bartelink et al., 2019b; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Mason, 2008; Minnema et al., 2006; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.43	0.09-0.77
Networks	N/A	A network of actors from multiple sectors working across many levels and are inter-connected to each other	9	Bal et al., 2014; Bal et al., 2016; Bisset & Potvin, 2007; Butler et al., 2010; Keshavarz et al., 2010; Laferrière et al., 2012; Mason, 2008; Murphy et al., 2018; Rosas, 2017	0.74	0.41-1.00
Complexity	Complex	A theory that concerns itself with the study of whole systems and the large numbers of elements or agents that are connected and interacting with each other in various ways which leads to the emergence of new properties and behaviors	9	Bal et al., 2014; Bal et al., 2016; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Mason, 2008; Minnema et al., 2006; Murphy et al., 2018; Thomas & Cronje, 2007	0.63	0.27-0.98

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 3. (continued)

Term	Related term(s) [†]	Definition	<i>n</i>	References	κ^*	95% CI**
Nested	N/A	A system that is made up of diverse agents that can be considered as separate systems on their own. Each system is part of a larger system	9	Bartelink et al., 2019a; Bartelink et al., 2019b; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Mason, 2008; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.46	0.07-0.84
Self-organisation	N/A	Self-reinforcement or self-sustaining nature of a system that follows a lock-in path generated from the inertial mass of the system	9	Bartelink et al., 2019a; Bisset & Potvin, 2007; Keshavarz et al., 2010; Daly-Smith et al., 2020; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Murphy et al., 2018; Rosas, 2017	0.10	-0.09-0.29
Perturbance	Disruption, Stress, Tension	Event in the system that produces system chaos or disequilibrium	8	Bal et al., 2014; Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2017; Mason, 2008; Murphy et al., 2018; Rosas, 2017; Thomas & Cronje, 2007	0.13	-0.11-0.36
Open boundaries	Permeable boundaries, “Fuzzy” boundaries	A non-rigid boundary that allows elements or agents from a system to associate and interact with other elements or agents from many other systems simultaneously	7	Bartelink et al., 2019a; Bisset & Potvin, 2007; Keshavarz et al., 2010; Magalhães de Barros et al., 2017; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017	0.16	-0.13-0.45

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 3. (continued)

Term	Related term(s) [†]	Definition	<i>n</i>	References	κ^*	95% CI**
Bottom-up	Downstream	Collective action amongst agents in the system that results in change coming from the grassroots level of the system	6	Bal et al., 2016; Bartelink et al., 2019a; Bartelink et al., 2019b; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Minnema et al., 2006	0.67	0.27-1.00
Co-evolution	N/A	Elements or agents in the system learn and change together	6	Bisset & Potvin, 2007; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Murphy et al., 2018; Rosas, 2017	0.39	-0.03-0.80
Edge of chaos	Tipping point	The point where system stress or perturbation that produces a continuous state of chaos or disequilibrium triggers change in the system	6	Bartelink et al., 2019b; Keshavarz et al., 2010; Magalhães de Barros et al., 2017; Mason, 2008; Rosas, 2017; Thomas & Cronje, 2007	0.26	-0.17-0.68
Feedback loops	N/A	Information that returns to the original transmitter which enhance the transmitter's actions which is then shared to other agents in the system in a continuous and cyclic manner	6	Bartelink et al., 2019a; Bartelink et al., 2019b; Keshavarz et al., 2010; Mason, 2008; Murphy et al., 2018; Thomas & Cronje, 2007	0.64	0.29-0.98

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 3. (continued)

Term	Related term(s) [¶]	Definition	<i>n</i>	References	κ^*	95% CI ^{**}
Holism	Non-reductionist	The system is greater than the sum of its parts with emergent properties and behaviors that are not contained or predicted from its compositional elements or agents	6	Keshavarz et al., 2010; Daly-Smith et al., 2020; Magalhães de Barros et al., 2017; Mason, 2008; Preiser et al., 2014; Rosas ,2017	0.71	0.36-1.00
De-centralised	Distributed control, Non-hierarchal	Power is shared between agents in the system which exhibit autonomous behaviors where system outcomes do not emerge from a controlled, designed and standardized central body	5	Keshavarz et al., 2010; Magalhães de Barros et al., 2017; Murphy et al., 2018; Preiser et al., 2014; Thomas & Cronje, 2007	0.20	-0.15-0.55
Random	Unpredictable	Inputs do not lead to predictable results	5	Bartelink et al., 2019a; Keshavarz et al., 2010; Mason, 2008; Rosas, 2017; Thomas & Cronje, 2007	1.00	1.00-1.00

Note. [¶] N/A = Not Applicable. *Kappa coefficient <0 = No agreement, 0.00 to 0.20 = Slight agreement, 0.21-0.40 = Fair agreement,

0.41-0.60 = Moderate agreement, 0.61-0.80 = Substantial agreement, 0.81-1.00 = Almost perfect agreement (McHugh, 2012).

**95% Confidence Interval.

SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 4

Rationale for using the Complex Adaptive Systems approach to sustain improvement initiatives in schools (n=16)

Article	Rationale given by author(s)		
	Changing dynamics of schools	Contextual implementation of initiative	Limitations of the whole-school approach
Bal et al., 2014		X	
Bal et al., 2016	X	X	
Bartelink et al., 2019a		X	X
Bartelink et al., 2019b	X	X	X
Bisset & Potvin, 2007		X	
Butler et al., 2010	X	X	
Daly-Smith et al., 2020	X	X	X
Keshavarz et al., 2010	X		X
Laferrière, Law & Montane, 2012	X		
Magalhães de Barros et al., 2017	X		
Mason, 2008	X		
Minnema et al., 2006	X		

(continued)

SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 4. (continued)

Article	Rationale given by author(s)		
	Changing dynamics of schools	Contextual implementation of initiative	Limitations of the whole-school approach
Murphy et al., 2018		X	X
Preiser et al, 2014	X		X
Rosas, 2017	X		
Thomas & Cronje, 2007	X	X	

SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5*Components of sustainability of improvement initiatives in schools as Complex Adaptive Systems (n=16)*

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Finances and resources	<ul style="list-style-type: none"> • School has access to sufficient current funding • Plans are in place for long-term funding • School partnered with external agencies to increase access to resources and funding opportunities • School has access to expert advice • School has access to resources such as toolkits, equipment and space to implement the initiative 	15	Bal et al., 2014; Bal et al., 2016; Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.45	-0.15-0.78
Engagement and involvement	<ul style="list-style-type: none"> • Engaging stakeholders to be involved in the initiative • Active involvement of multiple stakeholders internal and external to school • Engaging and involving the social ‘movers and shakers’/champions 	15	Bal et al., 2014; Bal et al., 2016; Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.63	0.27-0.98

(continued)

SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Adaptability and flexibility	<ul style="list-style-type: none"> • Ability to adapt to the changing needs of the school community following implementation of initiative • Schools continuously making adaptive changes to day to day practice in response to new information and conditions • Teachers able to adapt their teaching and learning practices to include changes due to initiative 	14	Bal et al., 2014; Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Murphy et al., 2010; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.45	-0.15-0.98
Collaboration and partnerships	<ul style="list-style-type: none"> • Collaborative efforts between internal and external stakeholders to ensure continuity of the initiative • Collaboration within and between schools that move towards co-configuration aimed towards production of resources and services that adapt to the changing needs in schools 	14	Bal et al., 2014; Bal et al., 2016; Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Laferrière et al., 2012; Minnema et al., 2006; Magalhães de Barros et al., 2017; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.46	0.07-0.84

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Policies	<ul style="list-style-type: none"> • School policies • External stakeholder's policies (e.g., education and health policies, local government's policies) 	14	Bal et al., 2014; Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Mason, 2008; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.46	0.07-0.84
Evaluation data	<ul style="list-style-type: none"> • Collection and analysis of data to evaluate process, outcome and sustainability of initiative • Data is available for stakeholders to make decisions concerning the direction or evolution of the initiative 	13	Bal et al., 2014; Bal et al., 2016; Bartelink et al., 2019a; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.31	-0.05-0.67
Culture	<ul style="list-style-type: none"> • School culture or norm • School fostering a culture of learning • A culture of innovation exists in the school 	12	Bal et al., 2014; Bal et al., 2016; Bartelink et al., 2019a; Bisset & Potvin, 2007; Butler et al., 2010; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017	0.43	0.09-0.77

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Building knowledge and skills	<ul style="list-style-type: none"> • Production and continual development of ideas • Collective acquisition of new knowledge and skills 	12	Bal et al., 2014; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Magalhães de Barros et al., 2017; Mason, 2008; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.86	0.60-1.00
Feedback	<ul style="list-style-type: none"> • Feedback concerning the initiative is available and communicated to stakeholders involved in the initiative • Feedback from stakeholders inform decisions concerning the initiative • Providing continuous feedback to stakeholders 	11	Bal et al., 2014; Bartelink et al., 2019a; Bartelink et al., 2019b; Keshavarz et al., 2010; Magalhães de Barros et al., 2017; Mason, 2008; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.87	0.63-1.00

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Team and network building	<ul style="list-style-type: none"> • Development of a multi-disciplinary team • Building a cohesive team • Avoid working in isolation • Development of a network of stakeholders that co-evolves 	11	Bal et al., 2014; Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Keshavarz et al., 2010; Laferrière et al., 2012; Mason, 2008; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017	0.43	0.09-0.77
Planning and coordination	<ul style="list-style-type: none"> • Clear goals, implementation plan, evaluation plan and sustainability plan are placed in writing • Co-planning that involves all stakeholders • Sufficient coordination of implementation and feedback 	11	Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017; Thomas & Cronje, 2007	0.75	0.44-1.00

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Adequate time	<ul style="list-style-type: none"> • Giving the initiative time to be embedded into school • Sufficient time for professional education • Adequate time to develop trust and build relationships between stakeholders • Enough time to collect and analyse data from the implementation of the initiative 	10	Bal et al., 2014; Bal et al., 2016; Bartelink et al., 2019a; Bartelink et al., 2019b; Butler et al., 2010; Keshavarz et al., 2010; Laferrière et al., 2012; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014	0.75	0.45-1.00
Ethos, values and beliefs	<ul style="list-style-type: none"> • School ethos, values and beliefs Teachers' and other stakeholders' (e.g., parents) values and beliefs 	10	Bal et al., 2014; Bartelink et al., 2019a; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Mason ,2008; Rosas, 2017; Thomas & Cronje, 2007	0.88	0.64-1.00
Building relationships	<ul style="list-style-type: none"> • Building and sustaining interpersonal relationships between stakeholders • Building trust and cooperation between stakeholders 	9	Bal et al., 2014; Bal et al., 2016; Butler et al., 2010; Keshavarz et al., 2010; Laferrière et al., 2012 2012; Magalhães de Barros et al., 2017; Murphy et al., 2018; Preiser et al., 2014; Rosas ,2017	0.75	0.44-1.00

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Building capacity	<ul style="list-style-type: none"> • Building organisational capacity to integrate programs into everyday school operations • Building community capacity to adapt to changes in school • Develop research capacity to generate evidence and support for initiative 	9	Bal et al., 2014; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Magalhães de Barros et al., 2017; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017	0.74	0.41-1.00
Staff, community and external support	<ul style="list-style-type: none"> • Staff are supportive of the initiative • Community and external stakeholders support the initiative 	9	Bartelink et al., 2019a; Bartelink et al., 2019b; Bisset & Potvin, 2007; Butler et al., 2010; Daly-Smith et al., 2020; Laferrière et al., 2012; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017	0.41	0.07-0.76

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SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Agency and motivation	<ul style="list-style-type: none"> • Agents' motivation to facilitate or adopt, adapt and maintain change in schools • Individual's motivation to establish and engage in relationships and interactions that sustains the initiative • Agency demonstrated through co-learning and co-production of resources 	8	Bal et al., 2014; Butler et al., 2010; Daly-Smith et al., 2020; Keshavarz et al., 2010; Laferrière et al., 2012; Mason, 2008; Minnema et al., 2006; Rosas, 2017	1.00	1.00-1.00
Professional development	<ul style="list-style-type: none"> • Professional development opportunities are available for staff and other stakeholders involved in the initiative 	8	Bal et al., 2014; Butler et al., 2010; Daly-Smith et al., 2020; Laferrière et al., 2012; Minnema et al., 2006; Murphy et al., 2018; Rosas, 2017; Thomas & Cronje, 2007	0.52	0.17-0.88
Sharing information or information exchange	<ul style="list-style-type: none"> • Stakeholders share information that can help implementation and continual adaptation or adoption of the initiative 	7	Butler et al., 2010; Keshavarz et al., 2010; Laferrière et al., 2012; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014; Rosas, 2017	0.48	0.02-0.93

(continued)

SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Leadership and administration	<ul style="list-style-type: none"> • Leaders and administration support the initiative • Leaders provide support in the day to day implementation of the initiative • Leaders communicate the vision of the initiative 	7	Bal et al., 2016; Daly-Smith et al., 2020; Laferrière et al., 2012; Mason, 2008; Minnema et al., 2006; Murphy et al., 2018; Rosas, 2017	0.85	0.56-1.00
Prioritisation	<ul style="list-style-type: none"> • Initiative prioritised over other initiatives • Initiative meets the agenda of the school and its related systems 	6	Bal et al., 2014; Butler et al., 2010; Keshavarz et al., 2010; Minnema et al., 2006; Murphy et al., 2018; Preiser et al., 2014	0.26	-0.17-0.69
Commitment and ownership	<ul style="list-style-type: none"> • Individual's time, effort and resource commitment to the implementation of the initiative • Stakeholders' long-term commitment to the change process which involves mutual adaptation to suit the needs, interests, and opportunities of the school 	5	Bal et al., 2014; Butler et al., 2010; Laferrière et al., 2012; Preiser et al., 2014; Thomas & Cronje, 2007	0.50	0.13-0.87

(continued)

SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Reflection and refinement	<ul style="list-style-type: none"> Stakeholders reflect on the process of implementation, personal practices, values and beliefs to aid in the refinement and adaptation of initiative 	5	Bal et al., 2014; Bal et al., 2016; Butler et al., 2010; Daly-Smith et al., 2020; Rosas ,2017	0.26	-0.17-0.69
Adequate staffing	<ul style="list-style-type: none"> Having adequate staff to implement initiative Plans are in place for long-term staffing Having a balance of staff, volunteer and students to implement the initiative 	4	Bartelink et al., 2019a; Bartelink et al., 2019b; Butler et., al 2010; Laferrière et al., 2012	1.00	1.00-1.00
Program selection	<ul style="list-style-type: none"> Initiative was selected to meet the needs of the school Initiative is supported by evidence and/or data 	2	Laferrière et al., 2012; Rosas 2017	1.00	1.00-1.00

(continued)

SUSTAINABLE SCHOOL-IMPROVEMENT

TABLE 5. (continued)

Components	Example conditions	<i>n</i>	References	κ^*	95% CI**
Resilience	<ul style="list-style-type: none"> Stakeholders able to achieve initiative goals despite change in policy or priority in school Stakeholders able to bounce back despite setbacks 	1	Laferrière et al., 2012	1.00	1.00-1.00

Note. *Kappa coefficient <0 = No agreement, 0.00 to 0.20 = Slight agreement, 0.21-0.40 = Fair agreement, 0.41-0.60 = Moderate agreement, 0.61-0.80 = Substantial agreement, 0.81-1.00 = Almost perfect agreement (McHugh, 2012). **95% Confidence Interval.