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UNDERSTANDING INNOVATIVE PEDAGOGIES: KEY THEMES TO ANALYSE NEW APPROACHES TO TEACHING AND LEARNING

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Amelia Peterson, Harvard University; Hanna Dumont, German Institute for International Educational Research; Marc Lafuente, Educational consultant; Nancy Law, University of Hong Kong

This working paper has been authorised by Andreas Schleicher, Director of the Directorate for Education and Skills, OECD.

Note: The chapters that appear in this working paper were commissioned by the OECD in the context of the Innovative Pedagogies for Powerful Learning project. These papers expounded on some underlying research themes which were paramount to create the project conceptual framework, named the "C's" framework. An abridged version of these chapters is included in the publication Teachers as Designers of Learning Environments: The Importance of Innovative Pedagogies.

Tracey Burns, Senior Analyst, Tracey.Burns@oecd.org
Alejandro Paniagua, Consultant, Alejandro.Paniagua@oecd.org

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ABSTRACT

Pedagogy is at the heart of teaching and learning. Preparing young people to meet new contemporary challenges means to review and update the pedagogies teachers use. However, despite the increased reporting of teachers and schools that are innovating, schools remain largely seen as very resistant places for innovation. To address the importance and challenges of implementing new pedagogies, this paper brings together leading experts to reflect on key areas of pedagogy. In particular, each chapter addresses a pedagogical dimension that together offers a conceptual framework for action. This framework moves beyond a fragmented focus on specific innovations. In doing so, it helps explain how innovative pedagogies may be developed, applied and scaled. Amelia Peterson's first contribution shows how fundamental purpose is to pedagogy, while Hanna Dumont's section explores adaptive teaching as a cross-cutting concept over a range of different pedagogical approaches. Then the paper moves to discuss the importance of understanding pedagogies as combinations, which Amelia Peterson defines as two layers: one combining discrete teaching practices and another that combines approaches to meet long-term educational goals. Marc Lafuente looks first at content domains (mathematics, non-native languages, and socio-emotional learning) and how they relate to pedagogies. He then contributes to the thinking on "new learners" and technology, as important context influencing pedagogical choices and implementation. The final section by Nancy Law is focused on change, through the particular prism of technology-enhanced pedagogical innovations. Her analysis moves towards a theory of change that takes account of the need for alignment at the different levels of the educational system.

RÉSUMÉ

La pédagogie est au cœur de l'enseignement et de l'apprentissage. Préparer les jeunes à affronter les nouveaux défis contemporains implique la revisite et la mise à jour des pédagogies utilisées par les enseignants. Néanmoins, malgré le nombre croissant d'enseignants et d'établissements scolaires investis dans l'innovation, l'école est encore largement perçue comme très résistante à l'innovation. Pour souligner l'importance et le défi de mettre en œuvre de nouvelles pédagogies, ce rapport réunit des experts reconnus pour réfléchir sur les domaines clés de la pédagogie. En particulier, chaque chapitre aborde une dimension pédagogique qui offre un cadre conceptuel pour la mise en pratique. Ce cadre va au-delà d'une vision fragmentée sur des innovations spécifiques. Ainsi, il contribue à expliquer comment les pédagogies innovantes peuvent être développées, appliquées et ajustées. Dans sa première contribution, Amélia Peterson

démontre l'importance fondamentale de l'objectif pour la pédagogie, alors que le chapitre d'Hanna Dumont explore l'enseignement adapté comme notion transversale pour un éventail d'approches pédagogiques différentes. Les propos du rapport se dirigent ensuite vers l'importance de comprendre les pédagogies en tant que combinaisons, qu'Amelia Peterson définit comme ayant deux niveaux : l'un combinant les pratiques pédagogiques discrètes et l'autre combinant des approches visant à répondre aux objectifs éducatifs à long terme. Marc Lafuente, quant à lui, se penche d'abord sur le contenu (les mathématiques, les langues autres que la langue maternelle, et l'apprentissage socio-émotionnel) et sa relation avec la pédagogie. Il contribue ensuite à la réflexion sur les 'nouveaux apprenants' et la technologie, en tant que contexte important influençant les choix pédagogiques et leur mise en œuvre. La partie finale, rédigée par Nancy Law, examine le changement à travers le prisme des innovations pédagogiques améliorées grâce aux technologies. Son analyse tend vers une théorie du changement prenant en considération les besoins d'harmonisation à différents niveaux du système éducatif.

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1.1. Introduction

Pedagogies provide frameworks for the multitude of decisions teachers have to make about how they teach. Innovation in pedagogy, like any kind of innovation, takes existing ideas, tools or practices and brings them together in new ways to solve problems when current practice is not adequately meeting needs. To now, the choice of pedagogy has often have been made *ad hoc* or based on whatever a teacher had encountered in their teacher education or their own schooling (Lortie, 2002). But where teachers are supported by high quality teacher education and strong professional infrastructures, they are enabled to make concerted decisions about pedagogy, acting as designers of learning by selecting approaches with a clear sense of their intended impact (Vieluf et al. [2012]; Jensen et al. [2015]).

Certain strands of education research are aimed at providing teachers with the evidence to make informed decisions about pedagogy (Hattie [2011]; Higgins et al. [2015]). But, developing and selecting pedagogies involves more than working out what is "effective" as indicated by impact on diverse measures of learning. Different pedagogies are based on different theories of learning, and these theories entail different views of psychology and philosophy regarding what is most important in learning. The full power of a pedagogy – and of pedagogical innovation – can only be evaluated in taking into account all the things the pedagogies are trying to achieve. This does not mean there needs to be agreement about the outcomes of schooling before we begin – desired outcomes will always be diverse and manifold. But it does mean that it is necessary to give attention to intentions when evaluating pedagogies rather than assume that all have the same purpose.

1.2. The functions of pedagogies

There is no single meaning of the term "pedagogy", and it has different connotations across cultures. For this chapter, pedagogy refers to repeated patterns or sets of teaching and learning practices that shape the interaction between teachers and learners. I refer to established but loosely-defined sets of teaching and learning practices (for example, inquiry-based learning) as a "pedagogical approach". The development and use of pedagogy and pedagogical approaches fulfil a number of functions, over and above what is achieved by single teaching practices. Pedagogical approaches allow the pursuit of multiple purposes simultaneously; they provide reliable ways of organising learning; and they offer ways of bundling practices.

1.3. Pedagogies aim at multiple purposes

The goal of teaching is more than just the transfer of content from one person to another. The way that people are taught affects how and what students learn. Particular pedagogical approaches have been developed and refined to promote a variety of

different kinds of learning: for example, learning of explicit content, learning of particular ways of doing things, or the learning of values and habits. This variety increases the decisions that teachers must make.

As an example: a Literature teacher knows that, according to the jurisdiction's curriculum, all students in the class need to learn by heart a 16th century poem during that year. In pursuing this goal, there are several ways (s)he may try to do this, depending on the other developmental goals the school has prioritised. If the priority is for students to develop fluency with valorised culture, the teacher might select a number of famous poems, and deploy "spaced learning" over the course of the year to maximise the chance that students commit them to long-term memory. If the priority is for the students to develop emotional connections with literature, the teacher might ask students to select from a wide range of poems one which is meaningful to them. If the priority is to develop communication skills, the teacher might choose to spend considerable class time practicing performance of the poem, working on elocution and oracy as well as memorisation. Or the teacher might decide that the memorisation task is not a priority for the class and encourage them to learn something last minute, re-allocating the time to other activities.

Each of these routes entails choices about what the outcomes the teacher/school is concerned with, besides the goal of memorising a poem. The choice on this one activity is unlikely to make much impact on these outcomes. If, however, consistent choices are made across several activities – and particularly if other teachers in his/her school are doing the same – we might expect to see an impact on the students' development. Thus, the teacher and colleagues together can choose to adopt a communal pedagogy in order to achieve both their discipline-centric teaching goals and other goals besides.

Frequently, teachers make choices about their pedagogy not based on their own preference but according to a local/national curriculum structure. Many curricula now include "core competencies", "transversal skills" or "general capabilities" which point towards certain kinds of pedagogy and provide alternative starting points for learning design (UNESCO, 2015). Some curricula are constructed to be "competency-based", with the idea that students should move through the development of different skills and knowledge levels at their own pace (Bristow and Patrick, 2014). Many of the so-called innovative pedagogies call for curricula where students take an active role in managing their learning; they are expected to develop the habits of metacognition in terms of knowing what one knows and what one needs to understand better. A curriculum may be more or less specified, so teachers may then have different scope in the extent to which they or their students have choice about what knowledge to focus on.

Table 1.1. Different approaches have different purposes

	We use this approach so that students can…	…with the intention of promoting…
Mastery-based	build knowledge and skills sequentially with practice	Fluency, Automaticity
Spaced learning	memorise core knowledge, practice recall	Fluency, Automaticity
Problem-based	apply skills or knowledge to a situation	Meaning-making, Skill transfer
Place-based	connect knowledge with their context	Meaning-making, Identity building
Discussion-based	practice articulation, take in other perspectives	Communication, Perspective-taking
Flipped learning	self-pace when meeting new content	Metacognition, self-management
Inquiry	make connections, make their own learning path	Metacognition, self-management
Product-oriented	be motivated, produce high quality work	Engagement, Perseverance

Beyond the factor of curriculum, choices about pedagogy may be determined by assumptions about the way different approaches produce certain outcomes. The table above makes explicit some of these assumptions. The pedagogical approaches in the table are not exhaustive nor does the table define terms: individual teachers, schools and systems often have their own language for describing their pedagogy. But it illustrates how established pedagogical approaches have developed in line with different kinds of intentions, and therefore why comparisons of approaches come down to more than just the question about which pedagogy is "most effective".

Each of the pedagogical approaches in the table takes a particular route to promoting the acquisition of knowledge and skills, in line with particular intentions. There is a paucity of research on some of the intended outcomes of approaches. Moreover, the way that approaches may be combined to achieve a full range of desired outcomes is a key area of need for innovation and research.

1.4. Pedagogies organise people and time

Teaching is a highly complex task. Over the course of each day, week and year, a teacher has to make thousands of decisions. On the one hand, there are choices about how to sequence and frame knowledge, and how to model and scaffold particular discipline-specific skills. To make these choices effectively teachers may draw on what is sometimes called pedagogical content knowledge. Then there are choices about how to initiate, organise and maintain momentum in periods of learning. This covers anything from choosing how to group large numbers of young children, to deciding how much time adolescents should spend in an internship.

Many popular pedagogical approaches have developed as ways to organise a teaching and learning process. As such, they support three key organisational tasks:

- choosing a focus for the learning;
- managing the learning process;
- determining the length and shape of an "arc of learning".

Different kinds of pedagogical approaches are more or less compatible with different lengths of learning arcs - an individual lesson, a series of tasks over some days, or a sequence or project stretching over weeks, months or more. Similarly, pedagogical approaches imply different decisions about how topics are chosen and scoped, and how the actual process of learning is managed. In other words, pedagogical approaches help to provide answers to three perennial decision points in teaching:

- What should students work on?

- How to ensure they keep working?
- When do we move on?

Different established pedagogical approaches have different ways of answering these questions, often based on slightly different theories of learning, or in response to different organisational constraints.

Different pedagogical approaches give rise to different kinds of teaching and learning processes, each with advantages or disadvantages depending on the purposes being pursued and on context. Some approaches are quite rigid in how they define a learning experience. Others, such as project-based learning (not featured here but often used as a catch-all term to describe product-oriented, place-based, and problem-based learning), have become so widely used that they have developed variants and lend themselves to different balance points of teacher and student choice and management (Vander Ark, 2016).

For an expert teacher, it may be desirable to adopt an approach which acts as a loose frame, and allows for a great deal of flexibility within it. A more novice teacher might prefer to have a thoroughly-researched and codified approach to use with confidence. In the case of any approach, however, it is important to bear in mind that the same labels can mean quite different things at the level of practice, in terms of how they organise learning.

Table 1.2. Different approaches promote different ways of organising learning

	…chooses focus		…manages learning process			…ends the learning arc		
	Teacher	Student	Teacher	Student	Groups	Assessment	Product	Time
Mastery-based	x		x	x		x		
Spaced learning	x			x				x
Problem-based	x			x	x	x		
Place-based	x	x			x		x	
Discussion	x		x					x
Flipped learning	x			x		x		x
Inquiry		x		x	x	x	x	
Product-oriented	x	x		x	x		x	

1.5. Pedagogies bundle practices

The final advantage to thinking in terms of established pedagogical approaches is that an approach typically groups together sets of discrete research-based practices. For example, inquiry-based learning may involve working with students on developing questions; developing self-regulated learning habits; and conducting assessment using portfolios and presentations of learning. A teacher who begins using an inquiry-based approach can find a range of high-quality supports for each of these practices, such as the Right Question Institute on constructing questions, or the Exploratorium's Institute for Inquiry on formative assessment in science inquiry. The pedagogy can act as a cornerstone that brings together a professional community and knowledge management efforts, all geared towards developing and refining practice.

An advantage in thinking about approaches as bundles of discrete practices is to aid communication across contexts, where different labels may well be attached to similar bundles of practices. For example, support for project-based learning within teacher

education is impeded by the plethora of different notions of what "PBL" entails. By focusing on specific practices, teachers can move beyond the buzz words to really understand the how and the why of a particular pedagogical approach. Breaking down approaches into practices with specific aims – or even into the mechanisms which explain how a practice achieves its effect (Peterson, 2016) – may be an important precursor to understanding the potential of new innovations in pedagogy.

In breaking down pedagogical approaches in this way, however, it is important not to be too mechanistic in delineating what teachers should do and why. While evidence-based practices are a valuable starting point, they are only the building blocks of impactful teaching and learning. If the "science" of pedagogy is in identifying the mechanisms and potential impacts of different approaches, the "art" is employing and combining pedagogies effectively to achieve the desired effect in context.

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2. Adaptive teaching: Students' differences and productive learning (Hanna Dumont, German Institute for International Educational Research)

2.1. Introduction

School systems around the world are faced with the challenge of how to organise learning for large numbers of students, while at the same time responding to the diverse needs of each one of them. This is not only about ensuring that each student receives an optimal learning experience; it is also about tackling well-documented inequalities in education and providing students with equal opportunities to learn in ways independent of their background. This chapter discusses the concept of "adaptive teaching" as a way to meet the challenge of student heterogeneity in the classroom and discusses its effectiveness in terms of increasing student performance and equality of opportunity.

Students enter school with a vast range of differences on a number of dimensions, which together determine how well and how fast they will learn at school (Helmke and Weinert, 1997). First and foremost, students differ with regard to general cognitive capacities and more subject-specific cognitive competencies they have acquired in the years before school. For instance, whereas some students just entering school already know how to read and to write in the main language of instruction, others may not yet speak it. Some students have already learned how to add and subtract, others cannot yet count to ten. Some students may have cognitive or physical impairments. Students also differ in their approaches to learning: some are eager and hungry to learn, others dread going to school. Students differ in their motivations, interests, competence beliefs and emotions. They differ in their personalities and their social behaviour: for instance, some students cannot wait to meet new people and make new friends; others do not feel comfortable speaking in front of their classmates (see Quintilian as quoted in Randi and Corno, 2005). Obviously, such differences between students not only exist at the beginning of school; in any given grade, teachers are confronted with the individual differences of the students in their classroom.

In addition to those student characteristics, which immediately affect their school and learning experience, there is a wide range of other individual characteristics that constitute identity: the students' gender, their family and socio-economic background, their ethnic and cultural background, their native language, their religious beliefs - to name only the most obvious ones. Taken together, each student brings a unique configuration of these dimensions into the classroom, which is also constantly subject to change as students develop and learn (Scholz, 2012).

Such student differences have long been perceived as "obstacles to be surmounted" (Good and Brophy, 2003) during teaching. Accordingly, school systems around the world have tried to reduce student differences by creating more homogeneous groups of students through practices such as tracking, streaming or ability grouping. In more recent years, there have been calls to deal with student differences in more productive ways by creating heterogeneous groups of students and capitalising on student differences when

teaching (Randi and Corno, 2005; Reusser, Stebler, and Mandel, 2015; Sliwka, 2012; Trautmann and Wischer, 2011). That is, instead of directing instruction towards the most typical or average student in a classroom, teachers should adapt their instruction to individuals (Randi and Corno, 2005).

2.2. Adaptive teaching as a general pedagogical approach

2.2.1. The roots of adaptive teaching

The idea of adapting classroom instruction to individual students has been traced back to antiquity (see Corno, 2008). In more recent history, at the beginning of the 20th century, education scholars involved in progressive education movements (for an overview, see Graumann, 2002), and psychologists influenced by the newly-developed psychometric intelligence and achievement tests, emphasised that educators should pay closer attention to student differences (Washburne, 1925). Interest in the topic then peaked again in the 1970s with the so-called aptitude-treatment-interaction (ATI) research in educational psychology (Cronbach and Snow, 1977). This line of research was based on the assumption that instructional methods (treatments) would be more or less effective depending on the specific characteristics of the learner (aptitudes). During this time, the terms “adaptive education” (Glaser, 1977) and “adaptive instruction” (Cronbach, 1967) were coined and a number of formalised adaptive educational programmes were developed (Wang, 1992; Wang and Lindvall, 1984; Waxman et al., 1985). The aim was to find the best instructional method for each student or groups of students with similar characteristics so that teachers could tailor their instruction to best fit those characteristics.

The key finding to emerge was that students’ general cognitive abilities interacted with the level of structure provided by the teacher. In high-structure treatments - direct instruction or teacher-controlled classroom settings - teachers maintain a high level of control over learning activities, lessons are broken down into small units, frequent feedback is provided and the contents of learning are made explicit. ATI research has shown that students who score lower on measures of general ability do better in these types of learning environments than in low-structure instructional settings. The contrary holds for students with higher general ability, who benefit from less structure - so-called discovery learning approaches or learner-centred learning environments (Cronbach and Snow, 1977; Snow, 1989).

However, aside from this finding, the field soon realised that because students differ on so many dimensions and instructional methods function so differently depending on the context, it is extremely difficult to guide instruction through generalisations about which treatments best serve which learners. The concept of “adaptive teaching” (Corno, 2008; Corno and Snow, 1986) can be seen as a response to this realisation: instead of teachers following a formalised adaptive programme based on observed aptitude-treatment interactions, the teachers themselves are seen as best able to make moment-to-moment decisions about what works for each of their students.

2.2.2. The concept of “adaptive teaching”

The concept of adaptive teaching has been mainly developed by Lyn Corno (Corno, 2008; Corno and Snow, 1986) - a former student of one of the founding fathers of ATI research, Richard Snow - and was defined by her as follows:

> *"Adaptive teaching is teaching that arranges environmental conditions to fit learner individual differences. As learners gain in aptitude through experience with respect to the instructional goals at hand, such teaching adapts by becoming less intrusive. Less intrusion, less teacher or instructional mediation, increases the learner's information processing and/or behavioural burdens, and with this the need for more learner self-regulation. As the learner adapts, so also must the teacher." (Corno and Snow, 1986: 621)*

The finding from ATI research regarding the level of structure and support provided by the teachers thus lies at the heart of the concept of teaching: adaptive teachers provide support for less able students and withdraw support when students are capable of working alone. The goal is that each learner, regardless of whether they are beginning or advanced, will be equally challenged by the instruction. This not only applies to differences between students, it also applies to differences within students; that is, adaptive teaching takes into account that students develop capabilities over time, making a continuous adaptation of instruction necessary as students become more competent learners.

In addition to this dynamic nature of adaptation, there are several key features of the concept of adaptive teaching as proposed by Corno (2008):

- *Student differences*: The concept of adaptive teaching acknowledges that students differ not only with regard to their cognitive abilities and their prior knowledge, but also with regard to their interests, motivations, personality and a number of other characteristics. Therefore, instruction needs to be adapted taking all these dimensions into account, viewing each learner as a complex individual. Moreover, in adaptive teaching, student differences are seen as opportunities and not as obstacles for teaching and learning.
- *Self-regulated learning*: Adaptive teaching and self-regulated learning are viewed as two sides of the same coin and thus intrinsically tied together. That is, while teachers adapt their instruction to students, they also foster self-regulated learning in students. The more capable and competent a student becomes, the less instruction the teacher needs to give and the more the student is able to regulate his or her own learning. In other words, not only does instruction adapt to the learner, the learner is also expected to adapt to the instruction. This is an ongoing, reciprocal process with the ultimate goal of increasing the number of learners who are capable of working independently within the classroom context.
- *Macro- and micro-adaptations*: Two levels can be distinguished: teaching adaptations at the macro and at the micro level. Adaptations at the macro level refer to instructional programmes or longer-term instructional adjustments for certain groups of students based on formal assessments. Adaptations at the micro level refer to short-term, moment-to-moment adjustments teachers make in immediate response to individual student differences based on informal assessments. These can take place while working with groups of students or through individual student-teacher interactions. Whereas macro-adaptations may sometimes occur, micro-adaptations lie at the heart of the adaptive teaching concept.
- *Group context*: Even though teachers adapt their instruction to individual students or groups of students with similar profiles, the group context of a classroom and thus the social nature of learning is never left aside. The goal of adaptive teaching is that all students can fully participate in classroom learning opportunities. This

can be achieved by capitalising on the strengths of each student, making use of students' self-regulated learning competencies and forms of collaborative learning in which students learn from each other.

2.2.3. Related concepts

There are a number of concepts with similarities and differences to adaptive teaching. For many of these concepts, however, there is no uniform definition and terms are often used inconsistently (in particular, across different languages and national contexts), sometimes even interchangeably (Waxman, Alford and Brown, 2013). The discussion of these concepts is thus based on a selection from the literature with no assumption that the treatment is universally valid.

Differentiation

The concept of "differentiation" or "differentiated instruction" (e.g. Constas and Sternberg, 2006; McTighe and Brown, 2005) refers to the idea of providing different groups of students with different instruction. It is a didactic concept that is particularly prominent in the German-speaking pedagogical literature, where the distinction is typically made between external and internal differentiation (Bönsch, 2004; Klafki and Stöcker, 1976). "External differentiation" refers to the provision of different instruction to students grouped together on a long-term basis based on their competencies, and is thus another way to refer to practices such as tracking, streaming and ability grouping. "Internal differentiation", on the other hand, refers to the provision of different instruction within a group of students or based on flexible student groupings. This form of differentiation is typically what the term "differentiating instruction" is taken to mean. Given the didactic origins of the concept, the literature on differentiation mainly focuses on in-depth descriptions and concrete examples for how to vary the instructional method, learning materials, the level of difficulty of a task, the time given to work on a task, and the learning content (Bräu and Schwerdt, 2005; Brüning and Saum, 2010).

The concept of (internal) differentiation clearly relates to adaptive teaching to the extent that both concepts involve the provision of different instruction to students with different needs. However, the aspect of adaptation as previously described is not inherent in the concept of differentiation; the instructional variations described above may not automatically be adaptive (Hertel, 2014; Wischer, 2007). On the other hand, discussions of adaptive teaching are generally not as explicit when it comes to describing how teachers can adapt and differentiate their instruction, making work on the concept of differentiation a useful complement to studies of adaptive teaching.

Individualised instruction

The concept of "individualised instruction" - also referred to as "individualisation", "individually-tailored instruction" and "individualised learning" (e.g. Bohl, Batzel, and Richey, 2011; Courtis, 1938; Waxman, Alford, and Brown, 2013) - refers to the idea that each student learns differently and that teachers should provide different instruction for each learner. It is less a coherent theoretical concept and more an umbrella term for classroom learning settings in which individual learners receive different instruction (Breidenstein, 2014; Wellenreuther, 2008). Individualised instruction is sometimes also used interchangeably with differentiated instruction; however, most authors consider individualised instruction as an extreme form of differentiated instruction because different instruction is not only provided to different groups of students but also to

individual students (Bohl et al., 2011; Bönsch, 2004). In the German context, a related term has become widespread over the past 15 years, "Individuelle Förderung", which may best be translated as "individualised support" (Klieme and Warwas, 2011). It also describes the idea that teachers' instruction should be responsive to the individual needs of students. However, no clear definition exists and this newer term is more used presently in discussions of policy and practice than in research.

Given that in adaptive teaching, teachers adapt their instruction to the specific needs of each student, one may be tempted to think that it is identical with individualised instruction. However, there is a fundamental difference between these two concepts: and that is, the emphasis on the group context. Whereas in individualised instruction students may be working mainly or entirely on their own (e.g. at a computer), the goal of adaptive teaching is to use the classroom as the group context from which students learn as much as possible. Corno (2008) explicitly distinguishes adaptive teaching from individualised instruction, noting that in adaptive teaching, teachers never adapt to individual students in a social vacuum.

Personalised learning

Similar to individualised instruction, "personalised learning" and "personalisation" (Burton, 2007; Campbell et al., 2007; Clarke, 2013; Diack, 2004; Johnson, 2004) also refer to the general idea of providing tailored instruction or education for individual students. However, these terms are used quite differently in the literature. For instance, whereas Diack (2004) and Campbell et al. (2007) use personalisation more as an umbrella term describing any kind of "tailored education", Clarke (2013) argues that it should only be applied when students also take responsibility for their own learning. Moreover, in recent years, the term has been mostly used in the educational policy context (Johnson, 2004) and with regard to corporate learning technology (Roberts-Mahoney, Means and Garrison, 2016), and may thus be considered more a political term than a pedagogical concept. In fact, it has even been argued that accounts of personalised learning minimise the role of teachers in the sense that technology will make pedagogical decisions for them (Roberts-Mahoney, Means and Garrison, 2016). This stands in stark contrast to the concept of adaptive teaching in which teachers play a crucial role in guiding student learning.

Open instruction

"Open instruction" is a concept embedded in the German pedagogy reform movement ("Offener Unterricht"). It describes instruction where students receive a lot of autonomy, choice and participatory opportunities in the classroom (Bohl and Kucharz, 2010). The "opening" of the instruction can happen along four different dimensions: (1) more flexibility in the temporal and spatial organisation of learning, (2) students can use different learning methods, (3) students can choose the learning content themselves, and (4) students can participate in shaping their learning environment. The concept is not to be confused with the terms "open learning" and "open education" in the English-speaking context, which mainly refers to the institutional opening of learning processes (Lewis, 1986). A related concept is "discovery learning", in which students receive minimal guidance from teachers and have a good measure of freedom in exploring and discovering the learning material and content on their own (Mayer, 2004).

The reason why open instruction or discovery learning are often mentioned in relation to adaptive teaching is because adaptive teaching cannot be realised with pure direct

instruction or in an entirely teacher-controlled classroom setting. However, it is a fallacy to think that adaptive teaching refers to classrooms that are characterised simply by open instruction or discovery learning. The concept of adaptive teaching posits that different instructional methods are needed for different students; for some students - in particular those who have already grasped the subject matter and have learned how to self-regulate their own learning process - discovery learning methods may be appropriate (e.g. Connor, Morrison, and Petrella, 2004).

Formative assessment

The concept of "formative assessment", sometimes referred to as "assessment for learning", describes an ongoing assessment of students' progress during the learning process in order to modify and adapt instruction to meet students' individual needs (Andrade and Cizek, 2009; Black and Wiliam, 1998, 2009; Kingston and Nash, 2011; Sadler, 1989). It is typically contrasted with "summative assessment", which refers to an evaluation of students' competencies at the end of a learning process. Formative assessment is a theoretically and empirically well-established concept in educational research and can be viewed as "the bridge between teaching and learning" (Wiliam, 2010: 137). It is thus an integral part of the micro-adaptations of adaptive teaching (Mandinach and Lash, 2015), though the term itself is not used by Corno (2008) when she describes the necessity for teachers to make informal assessments in micro-adaptations. However, formative assessment does not necessarily imply that teachers will adapt their instruction.

Self-regulated learning

"Self-regulated learning" is a prominent concept from educational psychology that views students as active learners and describes how students can initiate, organise and monitor their own learning process (Boekaerts, 1999; Boekaerts, Pintrich, and Zeidner, 2000; Winne, 2005; Zimmerman and Schunk, 1989). Notwithstanding the different models of self-regulated learning with differing emphases, all models deal with the interplay between the cognitive, meta-cognitive and motivational competencies of learners and assume that cognitive and motivational learning are intertwined (Zimmerman, 1990). Research on self-regulated learning has also focused on how it can be promoted in the classroom (see Boekaerts and Corno, 2005; Corno and Mandinach, 1983; Paris and Paris, 2001).

Two different approaches can be distinguished: on the one hand, some suggest that self-regulation competencies can and should be taught explicitly; on the other hand, others argue that self-regulated learning should be promoted as a way to develop cognitive competencies, so that all students learn how to learn. It is the latter conceptualisation, in which the teacher slowly withdraws support to give students more responsibility for their learning as they gain in competence, which is inherent in the concept of adaptive teaching. However, Corno (2008) calls into question whether most researchers studying self-regulated learning view it as the "natural outgrowth of adaptive teaching" as most research on self-regulated learning has been conducted in classrooms in which teachers do not adapt their instruction.

2.2.4. Adaptive teaching: An overarching pedagogical approach

In describing adaptive teaching and discussing how it relates to similar concepts, it becomes clear that adaptive teaching is an overarching pedagogical approach into which the other concepts can be integrated. It views student differences as opportunities for

teaching and learning, and therefore stands in stark contrast to pedagogical approaches in which instruction is directed at the most typical or average student in a class, which remains the norm in many schools around the world (Dumont and Istance, 2010). Adaptive teaching does not favour a specific pedagogy or instructional method; in fact, it incorporates all sorts of pedagogies such as direct instruction, specific interventions, motivational enhancements, cooperative learning, modelling guided practice, peer tutoring, independent study, and discovery learning (Randi and Corno, 2005). Which of those pedagogies should best come into play will depend on the specific characteristics and needs of each learner.

2.3. Empirical evidence on the effectiveness of adaptive teaching

2.3.1. Lack of evidence

The call to deal with student heterogeneity by adapting to individual differences within a heterogeneous classroom typically is made on the assumption that this should lead to increased student performance and deeper learning. While there are in-depth theoretical accounts of adaptive teaching (Corno and Snow, 1986; Corno, 2008) and examples of how adaptive teaching can look in practice (Allen, Matthews, and Parsons, 2013; Parsons, 2012; Randi and Corno, 2005), there is little empirical evidence on those micro-adaptations by teachers that constitute the core of the concept (but see Duffy et al., 2008; Krammer, 2009; van de Pol et al., 2015 for studies on teacher behaviours that are similar to micro-adaptations, such as scaffolding or contingent support).

Moreover, there is even less direct empirical evidence on the effectiveness of adaptive teaching as regards its promotion of student learning. In a synthesis of 38 studies on adaptive educational programmes from over 30 years ago, Waxman et al. (1985) came to the conclusion that adaptive instruction substantially affects student outcomes. However, the authors provided little information on the studies included in their synthesis, making it hard to evaluate the methodological quality of these studies or to apply today’s methodological standards. Furthermore, Waxman et al. (1985) analysed programmes of adaptive education, which cannot directly be transferred to the concept of adaptive teaching.

We can speculate about the scarcity of empirical evidence on adaptive teaching, which may be explained by the fact that adaptive teaching is still not very widespread. This makes it difficult to observe and study, especially within random and representative samples which are considered important typically for thorough educational effectiveness research. Alternatively, teachers who do adaptive teaching use different strategies and methods to accomplish this, so adaptive teaching can and perhaps should look different between classrooms. This means that adaptive teaching must be studied on a classroom basis, with commonalities observed and catalogued across them, and sorted to determine which aspects can be considered most important in supporting its effectiveness (see Randi, 2017). In addition, to analyse the effectiveness of adaptive teaching independent of the concrete teaching methods employed, one would first have to operationalise and measure the degree of adaptation within a given classroom.

2.3.2. Empirical evidence from research relevant to adaptive teaching

Leaving these cautionary notes aside, lines of research related to adaptive teaching may be used as indirect evidence for drawing inferences about its effectiveness.

Evidence on heterogeneous grouping, within-class grouping and differentiation

Given that adaptive teaching is typically conducted in heterogeneous classrooms, it is worthwhile to consider findings from studies that have investigated whether the practice of grouping students has an effect on student performance. This has been a prominent line of educational research for several decades. Studies comparing homogeneous with heterogeneous ability groupings come to the conclusion that grouping practices by themselves have no or only very small effects on student performance (Burris, Heubert, and Levin, 2006; Hattie, 2009; Kulik and Kulik, 1982; Lou et al., 1996; Mulkey et al., 2005; Schofield, 2010; Slavin, 1987, 1990). Effects were found to be larger for within-class grouping practices that are accompanied by differentiation of the instruction and frequent assessment of student competencies (Gutierrez and Slavin, 1992; Lou et al., 1996; Slavin, 1987). Hence, what matters seems to be the instruction and not so much the grouping of students, but disentangling grouping per se from matters of instruction and assessment is difficult. A German study has also found that a heterogeneous classroom does not automatically elicit differentiation practices or teacher adaptations to individual students (Warwas, Hertel, and Labuhn, 2011).

Evidence on individualised instruction

Research on individualised instruction flourished between the 1960s and 1980s. Meta-analyses synthesising findings from these older studies have found only small effects of individualised instruction on student performance (Bangert, Kulik, and Kulik, 1983; Horak, 1981). These findings are also in line with Hattie’s (2009) second-order meta-analysis in which he reports only small effects of individualised instruction. Hess and Lipowsky (2017) suggest that the low effectiveness of individualised instruction may be due to the fact that teachers who use it tend to focus more on how to organise individualised instruction than on the quality of the content they teach.

This is in line with recent studies from German-speaking countries. In Swiss secondary school mathematics classrooms, Krammer (2009) observed that teachers did not engage in cognitively challenging interactions with their students during individualised learning phases. Lotz (2015), observing first grade classrooms in Germany, also reported that the interactions between teachers and students during individualised instruction were rather superficial and did not deal with the learning content in depth. In an ethnographic study on four schools that practice individualised instruction, Breidenstein and Rademacher (2017) came to the conclusion that teachers were more concerned with organising the learning activities of individual students than with engaging in meaningful interactions with students about the learning content. Moreover, they described instruction in these schools as being “decentralised”, meaning with hardly any interactions occurring in the classroom group context.

Individualising instruction may insert a level of complexity into designing and implementing effective classroom practices for teachers, which can result in neglecting the learning content. Evidence that individualised instruction can be implemented in an effective way comes from Connor et al. (2009). In an intervention study, these authors trained teachers to provide computer-assisted individualised reading instruction and were able to show that carefully planned instruction responsive to each student’s changing skills and needs was associated with stronger reading development than instruction without individualisation.

Evidence on discovery learning and the provision of guidance by teachers

The amount of guidance teachers need to provide during instruction has been the subject of considerable empirical research and scientific discussion (Kirschner, Sweller, and Clark, 2006; Sweller, Kirschner, and Clark, 2007). The empirical evidence is now strong in showing that minimal teacher guidance as in discovery learning is ineffective for most student learning (Alfieri, Brooks and Aldrich, 2011; Mayer, 2004). Cognitive load theory suggests that having too much freedom to explore complex learning material results in cognitive overload for many students and prevents them from engaging with the learning content in depth (Kirschner et al., 2006; Mayer, 2004). However, guided or assisted discovery learning, in which teachers provide feedback, assist learners and elicit explanations, has shown to be effective for larger numbers of students (Alfieri et al., 2011; Hardy, 2006).

The challenge in guided discovery is for teachers to know how much and what kinds of guidance to provide. This is where the key finding from ATI research mentioned above comes into play: students with lower cognitive abilities will benefit from more guidance from teachers than advanced students. This finding has been confirmed by more recent studies. Focusing on language arts instruction, Connor, Morrison and Petrella (2004) find that children with below-average reading comprehension skills benefited more from teacher-explicit instruction, whereas children with above-average skills showed higher levels of growth in reading in child-managed instruction. An intervention study on inquiry-based science education in German primary schools compared standard instruction to the same instructional unit but enriched with guidance through scaffolding instructional discourse, formative assessment, and peer-assisted learning. It revealed that low performing students particularly benefited from more teacher guidance through scaffolding and formative assessment (Decristan, 2015). Taken together, every student needs guidance from teachers, but especially students with lower average cognitive ability levels.

Evidence on instructional quality and teaching effectiveness

Following Gage (1977), this line of research has been mainly based on observations of so-called “direct instruction”, where the teacher leads the class in a lesson presented with a sequence of structured material, followed by soliciting questions, and reacting feedback. However, research on the general principles of good teaching and instructional quality can provide valuable insights for understanding the circumstances under which adaptive teaching may be effective. This line of research has shown that the effectiveness of teaching is not determined by the “surface level”, i.e. teaching methods or classroom organisation, but rather by the “deep level” of instruction, i.e. the quality of interactions between teachers and students around meaningful content and the quality of explanations provided by teachers in class and in response to students work samples and expressions of thinking (Clarke, Resnick and Rosé, 2015; Kunter and Trautwein, 2013; Patrick, Mantzicopoulos, and Sears, 2012; Roehrig et al., 2012).

By now, a large empirical body of knowledge exists on what constitutes high quality instruction at the deep level (Helmke, 2009; Seidel and Shavelson, 2007). In German educational research, three basic dimensions of instructional quality have been proposed and empirically established, namely classroom management, supportive climate and cognitive activation (Fauth et al., 2014; Klieme and Rakoczy, 2008). “Classroom management” refers to different behaviours teachers use to keep students organised, attentive and focused so that the learning time in the classroom is used efficiently.

"Supportive climate" refers to the student-teacher relationship and is high when teachers give contingent, constructive feedback and have a positive approach towards students' errors. "Cognitive activation" refers to instruction that fosters students' cognitive engagement with the subject matter by providing meaningful and challenging tasks, and by discussing ideas and concepts in depth. These three dimensions are very similar to the international systematisation of instructional quality into organisational, emotional, and instructional support by teachers, which underlie the widely used CLASS observation measure (Pianta and Hamre, 2009).

Evidence from the learning sciences

In addition to research conducted in classrooms by studying actual teaching behaviours or instructional methods noted above, there is also micro-level research from the learning sciences on understanding how students learn (Sawyer, 2015). This line of research has resulted in a powerful knowledge base that can be used to draw conclusions about effective instruction (Bransford, Brown, and Cocking, 2000; Dumont, Istance, and Benavides, 2010). According to current socio-constructivist learning theories, learning is an active and idiosyncratic process that happens through the interaction of individuals with their social environment and depends on the specific context in which this interaction is embedded (Brown, Collins and Duguid, 1989; Corno et al., 2002; De Corte, 2010; Greeno, 1998; Schneider and Stern, 2010; Schnotz, 2016).

More specifically, each learner needs to make sense of the learning content by connecting it to their prior knowledge and building and developing a coherent and organised mental representation of that content. Both the general cognitive capabilities and the content-specific prior knowledge of a learner will determine how well and how fast the content is learned. Put simply, when learning content is too advanced or too complex for a given learner, there is a risk of cognitive overload and limited learning. If the learning content is too easy and the learner is not challenged, new knowledge can be likewise limited by a lack of motivation or interest in performing. The role of the teacher is thus to guide the learner by providing just the right amount of instructional support so that each learner will be in a "zone of proximal development" (Vygotsky, 1963)—a process which is also known as "scaffolding" (van de Pol, Volman and Beishuizen, 2010; Wood, Bruner and Ross, 1976)

Conclusions regarding the effectiveness of adaptive teaching

Even though there is presently little direct evidence to support the effectiveness of adaptive teaching as an overarching pedagogical approach, related research makes a strong case for its potential to increase student performance. The general idea of adapting teaching to students based on a continuous assessment of students' already-existing competencies is well aligned with what we know from the learning sciences about how students learn.

Research on individualised instruction and instructional quality shows that differentiation and individualisation practices, which are often applied in adaptive teaching, are only effective when students engage with the learning content in depth and are stimulated cognitively. Such cognitive engagement by students needs to be elicited and supported by teachers through structuring the learning content, asking thought-provoking questions or by providing the conditions for meaningful peer interactions (Corno and Mandinach, 1983). The fact that teachers always need to guide students, even throughout instructional phases when students have more freedom and responsibility for their own learning

activities, is also supported by research on (guided) discovery learning. This active and guiding role of teachers during instruction may not always be visible, but is essential for adaptive teaching to be effective, and is addressed in the theory of adaptive teaching proposed by Corno (2008). Taken together, despite the evident potential of adaptive teaching as an overarching pedagogical approach in contrast to teaching approaches aimed at the typical student, its implementation by teachers is highly challenging, so that studying its effectiveness is imperative.

2.4. Adaptive teaching and equality of opportunity

Not only is the idea of adapting teaching to individual differences associated with the aim of raising student performance, it has also been expected "to ensure equal and quality educational opportunities for each and every school-aged child and young adult" (Wang and Lindvall, 1984: 207; see also Fischer, 2014; Glaser, 1977; Klippert, 2010 for similar assumptions). In fact, Corno (2008) argues through micro-adaptions, teachers create a "middle ground" in the social context of the classroom, which brings students of different levels closer together. However, there is even less empirical evidence about the relationship between adaptive and equality of opportunity than on the effectiveness of adaptive teaching. Nevertheless, given that low-achieving students are disproportionately from disadvantaged backgrounds, the finding reported above that low-achieving students benefit from more structured environments for learning in school is important in addressing equality of opportunity.

In addition to these general conclusions, two well-evaluated U.S school reform programmes that were specifically designed for disadvantaged students - *Success for All* created by Robert Slavin and colleagues, and the *University of Chicago Charter School* founded by Anthony Bryk, Stephen Raudenbush and others - have shown that high quality instruction can reduce inequalities (Borman et al., 2007; McGhee Hassrick, Raudenbush, and Rosen, 2017). Even though the instruction of those programmes is not called adaptive teaching, one key element common to both is that teachers "skilfully 'assess and instruct' moment by moment" (McGhee Hassrick et al., 2017: 11); this evidently mirrors the micro-adaptations at the heart of adaptive teaching. In a similar vein, Yeh (2017) also suggested that achievement gaps can be closed through what he calls "rapid performance feedback": an individualised and structured model of instruction, in which each student is presented with tasks that are challenging but not too difficult, so that they have a high likelihood of receiving positive performance feedback on a daily basis.

When considering adaptive teaching and equality of opportunity, it is necessary to specify what equality of opportunity means and what goal should be achieved (Lipowsky and Lotz, 2015). Is the goal to reduce the size of the achievement gap between advantaged and disadvantaged students, thus the equality of outcomes? Or should the amount of learning progress be equal, regardless of where students are located on the achievement ladder? Maybe the provision of equal instruction is the focus? And if so, is this achieved by providing the same or different instruction to students? Or is it about each student reaching their full potential? Or is it about ensuring that all students acquire competencies above a certain threshold suggesting a focus on compensating deficits?

The answers given to these questions have different implications regarding equality of opportunity. For instance, it may well be that when every student is challenged optimally through adaptive teaching, then high-achieving students make more progress than low-achieving students (also known as the "Matthew effect"), resulting in a wider

achievement gap. It could also be that adaptive teachers spend more time with low achieving students because they need more structure, which would be an unequal treatment of students. In adaptive teaching, teachers also need to decide whether they will set the same learning goals for all students or have different goals for different students. These are normative questions that need to be addressed prior to empirical analysis.

2.5. Conclusions and ways forward

As awareness grows that the creation of homogenous groups through practices of tracking and classroom instruction aimed at a typical student is not the ideal way to deal with student differences, there is a clear need for pedagogies that can productively address heterogeneity in the classroom and student differences. The present chapter argues that adaptive teaching is a promising pedagogical approach to meet this challenge. However, the positive connotation of the concept should not obscure the fact that we do not yet know enough about its effectiveness in terms of increasing student performance and equality of opportunity. Therefore, there is a clear need to advance our knowledge about how adaptive teaching can actually be carried out in practice and under what conditions it is effective.

The main challenge for an empirical investigation of adaptive teaching as an overarching pedagogical approach lies in studying classroom instruction in a more holistic way than is typically done. More specifically, instead of analysing the effectiveness of specific teaching methods, we need to further identify and study the underlying principle of adaptive teaching, namely the degree of adaptivity within and across classroom. While this goal is certainly challenging, the good news is that there are already schools around the world that teach micro-adaptively (OECD, 2013). Interestingly, these schools are often located in areas with a particularly diverse student body or have even increased the level of student heterogeneity in classrooms by creating mixed-aged groups or by including students with special needs. These schools may be seen as ahead of the current debate in policy and research. Perhaps the time has come to cross the bridge between research and practice from the other side - by translating practice into research: that is, to make use of the knowledge gained by adaptive teachers and learn from them (see Randi, 2017), in order to study the effectiveness of adaptive teaching.

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3. Combinations of pedagogies, innovative and established (Amelia Peterson, Harvard University)

3.1. Introduction

This chapter builds on this to explain how combinations of approaches have developed to fulfil the multiple purposes of education. To the extent that education has multiple goals, the design of learning will always require drawing on a variety of practices and pedagogical approaches. As we have seen, in some cases a pedagogical approach can act as a frame that combines sets of compatible practices within an overarching sequence such as a student inquiry or project. Other approaches may involve adopting several discrete practices and using them in sequence. At a school level, we find teachers using a variety of approaches appropriate to different developmental stages and subjects, and thinking about how these might combine to achieve broader, more complex educational goals over time.

There are therefore two layers at which we can think about combinations, one in terms of discrete practices within a framing pedagogical approach, and one about how combinations of established approaches can meet long-term educational goals. Where schools are thinking carefully about their learning design, they tend to anchor that design in a small number of approaches which are defined by the different ways they arrange time and agency. There are benefits in having a limited set of framing approaches which students can become familiar with - for example, project- or inquiry-based learning – which provide a framework for activities, addressing dilemmas of organisation and allowing students to get used to sequences of more self-directed learning within an overall teacher-managed arc. Then each one of these frames involves more discrete pedagogies to achieve more specific teaching and learning goals within the sequence. It may be difficult to meet all learning outcomes within just one of these framing approaches and a small number of frames may be sufficient to achieve the full set of their goals.

The study of pedagogical combinations offers a fruitful way to understand how established pedagogical approaches can be brought together to create effective learning designs. This focus takes us beyond the study of learning environments to consider school models, and long trajectories of student learning and development.

The first part of this chapter introduces a key factor driving the adoption of different pedagogies, namely the shift in focus towards developing higher-level personal and social competences throughout education. This shift has led to a greater emphasis on 'student-centric' pedagogies which aim to promote student agency and abilities for independent action and social interaction. This in turn creates a challenge for teachers in balancing this focus with adequate attention to student acquisition of a necessary breadth and depth of knowledge, promoted by more discipline-centric pedagogies. The second part illustrates how combinations of practices and approaches can meet this challenge with some

examples of how individual school networks are balancing learning goals across different pedagogies.

3.2. The evidence base

This chapter is based on three types of sources: academic literature on the learning sciences, pedagogy and youth development; international visits to schools deemed ‘innovative’ and schools engaged in teacher-led inquiry and practice development; and an online scan of school networks with distinct pedagogical models (see Annex 3.A).

The learning sciences and the science of youth development provide a foundation for understanding the range of outcomes which pedagogies seek to achieve (Dumont, Istance and Benavides, 2010; Nagaoka et al., 2015). The long traditions of pedagogical theory provide a basis for defining certain approaches and their contribution to outcomes. The ability to describe teaching and its impacts accurately has advanced through large-scale studies of teaching, including video studies and international surveys (Tomáš and Seidel, 2009; Vieluf et al., 2012). One such sequence of studies, carried out predominantly in Germany, concludes that impactful teachers are those who consistently achieve three central tasks: classroom management (structure); classroom climate (support); and cognitive activation (engagement and challenge) (Klieme, Pauli and Reusser, 2009). This framework is supported by a great variety of other research into teaching, as well as by the science of learning, which highlights the importance of both the social and emotional conditions created by interaction with teachers and peers, and the cognitive demand of tasks (Bransford et al., 2000; National Research Council, 2003). Different pedagogies have developed different ways of balancing these three tasks, and some give greater emphasis to one or other. To achieve these three components, teachers are likely draw on a combination of pedagogical approaches, but there is further work to be done to understand the contribution different pedagogies can make.

Definitive knowledge on the relationships between pedagogical combinations and a variety of educational outcomes is limited. The majority of research on teaching practices takes an evaluative frame and seeks to establish the ‘effect’ of a practice, using causal inference methods which require focusing on an individual pedagogy rather than on pedagogical combinations. And there is no guarantee that practices which are studied in isolation have the same effect once combined (and ideally, any combination should equate to more than the sum of its parts). Systematic studies of the impacts of combining pedagogies may be found in studies of ‘deeper learning’ schools (Zeiser et al., 2014) or of the international baccalaureate programmes (Saavedra, 2014), which tend to involve combinations of more discipline-centric and more inquiry or project-based pedagogies. Research into these models has not been carried out with the aim of studying combinations, however, and the extent to which either model entails consistent combinations is open to question.

The lack of knowledge on the impacts of combining certain pedagogies is in part due to the struggle to measure many of the outcomes that pedagogies aim at (Duckworth and Yeager, 2015). Factors such as mind-sets, motivation and identify which some pedagogies seek to effect remain difficult to study systematically - although work is developing in that direction (Stecher and Hamilton 2014; Haynes et al., 2016). Researchers thus have much more access to data from assessments of content recall and basic skill demonstration (‘first-order’ outcomes of learning), than assessments of some of the more complex or ‘higher-order’ outcomes of learning, such as general capabilities, dispositions or identity. Incorporating qualitative research, we are still developing ways to

recognise let alone assess these higher-order outcomes. Studies which look at more long-range impacts of school networks and curricula, such as those referenced above, offer hope of developing our knowledge of how particular pedagogies relate to the outcomes.

For the most part, therefore, pedagogical combinations await further research, and one intention of this chapter is to provide common language and frameworks for studying the impact of pedagogical combinations in relation to their intentions.

3.3. The context of combinations - expanded goals for education

Everywhere around the world, the goals of education are multiple. Schools are expected to fulfil a number of important functions at once, including to prepare young people as future citizens, as well as to help them develop core knowledge and skills to be successful in work and life. Additionally, individual systems, leadership teams, teachers or students may have more specific goals which they seek to fulfil through schooling.

The purposes of education are typically inscribed in curriculum documents, whether school curricula or national curriculum frameworks. The goals in these documents can be divided into academic and long-term aims. Academic aims cover the discrete, concrete knowledge and skills children are expected to master. We might see these laid out as bullet points or 'standards', usually arranged by discipline, for example, that nine-year-olds should have a mastery of multiplying numbers up to twelve in their heads. Long-term aims are more general and abstract, and might be thought of as the headline aspirations of a curriculum, for example, that children become confident learners or healthy citizens.

The relationship between these two types of goals is contested. Some believe that if teachers teach and children meet all of the academic aims, this should lead to the natural emergence of desired long-term outcomes (thus we might think of these as 'first-order' and 'higher-order' goals). For others, personal, social and emotional competencies need to be developed concertedly. This has led to the development of different pedagogical traditions.

On the one hand, educators have made great progress in developing discipline-centric pedagogies which offer improved ways to teach specific concepts or develop specific skills relevant to a domain of knowledge. These developments build on advances in cognitive science and in our understanding of conceptual learning. For example, the study of the misconceptions people hold about the natural world has led to the development of new methods for teaching physics and chemistry, using carefully targeted questions and graphical representations to advance student understanding past common pitfalls.

In another tradition, educators have worked on developing more student-centred pedagogies targeted towards developing students' personal competence as part of content learning. One strand of this tradition has emphasised the importance of experiential learning, believing that young people learn how to hold a discussion, how to speak in front of an audience, or how to manage an experiment by doing it. Another has focused on promoting self-regulated learning, developing theories and methods designed to support students to manage their own learning, in order that they become more competent at learning independently.

Yet we cannot draw a concrete line between knowledge-centred and student-centred methods. Teachers working to support self-regulated learning, for example, would always want to be mindful of whether students have the relevant knowledge for the task at hand,

and be prepared to use an effective approach to supplement that knowledge where necessary. This is because of the central role of working memory in learning: the theory of 'cognitive load' has developed based on findings that learners can only handle a certain amount of new material at once. Teaching has to take this into account to ensure that learners, even when they are working independently, have the necessary background knowledge or scaffolding to carry out a task (Kirschner, Sweller and Clark, 2006). Moreover, developing competences and skills should not be conflated with experiential learning. Studies of developing expertise find that 'deliberate practice' is key (Ericcson and Charnass, 1994): in learning a sport, for example, it can be more effective to practice specific moves and techniques rather than endlessly playing full games. Despite these acknowledgements, however, the place of student-centred learning has continued to grow. Why is this the case?

3.3.1. New purposes, new pedagogies

If education were all about imparting content knowledge, developing and evaluating pedagogy would be all about establishing the best methods to promote memorisation and understanding of knowledge and concepts. And indeed, this forms the foundation of any education; content-less learning is quite literally meaningless. But discipline-centric pedagogies cover only part of what a teacher, school or system might want to develop in students. Schools have always been designed to teach students certain behaviours and dispositions as well as to impart knowledge. When Benjamin Bloom and colleagues sat down to create a 'Taxonomy of Educational Objectives' in 1956, they described learning as applying to cognitive, affective and psychomotor dimensions (Bloom and Krathwohl, 1956). Different traditions of pedagogical theory have developed which place different emphasis on each of these dimensions.

Sixty years later, while our terminology has changed, there is still find debate about different dimensions of learning, and concerns about striking the right balance. In particular, we are witnessing a shift in focus from the 'cognitive' to other dimensions of learning. What exactly these dimensions are remains under-specified. The term 'non-cognitive skills' derives from identifying these factors in terms of outcomes that go unexplained by cognitive achievement tests (Heckman and Rubinstein, 2001). The term has achieved widespread use (e.g. Farrington et al., 2012; Roberts, Martin and Olaru, 2015), though many psychologists and educationalists tend to refer to 'social and emotional skills' OECD (2015), or 'interpersonal' and 'intrapersonal' factors (Stecher and Hamilton, 2014). Others have referred to 'super-cognitives', to emphasise the fact that these factors rely on and emerge from particular (cognitive) thoughts, ideas and developed meanings (Intrator and Siegel, 2014).

There is considerably overlap with these factors and what educationalists have called '21st Century Skills', which cover skills for improved personal management and interpersonal interaction (Pellegrino and Hilton, 2012). Whatever exactly these 'skills' are, in many contexts there has been a concerted shift towards pedagogies which aim to develop higher-level personal and social competence. There are at least four factors driving this shift.

Firstly, there has been recognition that developing students' personal and social competences are a foundation for higher learning (Farrington et al., 2012). The more students understand themselves and others, the more they can engage in complex learning activities; incorporate multiple perspectives; and reflect on and develop their own knowledge, beliefs and abilities. Moreover, without a sense of identity as a learner and

supportive peer relations, students may not be receptive to teaching and learning opportunities. As is often pointed out, the ‘non-cognitives’ are extremely poorly named. The contemporary learning sciences (Meltzoff et al., 2009) establish the interdependence of affective, cognitive and physical processes, highlighting, for example, the role of emotions in cognitive activation (Immordino-Yang and Damasio, 2007), or the place of embodied cognition as part of memory (Claxton, 2015). Attention to students’ emotional and motivational state and development therefore becomes part of any pedagogical design.

Secondly, societies and industries founded on digital technologies require people to be practiced in managing and using a more complex array of information, and increase the value of social skills. One conclusion sometimes drawn from technological change is that new technologies lower the requirement to master knowledge and skills, as holding information and many basic tasks may be ‘outsourced’ to devices. This position goes too far in neglecting the importance of learned knowledge and skills as foundations for more complex abilities, but it must be acknowledged that the ready availability of information changes our learning needs.

A third factor in this shift is the way that societal changes have increased the complexity of choices and tasks young people face as they transition from adolescence to adulthood. Without wishing to over-simplify the past, up until the mid-point of the previously century most people in industrial societies faced a relatively limited array of options when it came to where they would live, what job they would do, whether they would marry, and whom. Liberalisation has produced huge benefits in terms of expanding our opportunities for agency, and to live meaningful and successful lives. But it also demands new levels of personal and social competence to thrive in more diverse and complex societies.

Finally, we must place this shift in the context of other institutional changes in education. More explicit attention to ‘super-cognitive’ factors might be seen as a pushback against the intensified focus on standardised assessments of cognitive skills as part of hard and soft accountability regimes. Educators are concerned that efforts to optimise test scores have crowded out other activities which develop students along other dimensions. Additionally - and paradoxically - those seeking to maximise test scores have realised that intrapersonal factors such as mind-sets and motivations are an important step in opening up students to learning and achievement.

In understanding where this drive comes from, we can come closer to establishing what it hopes to achieve. On the one hand, developing pedagogies to promote super-cognitives may enhance individual achievement and success. This is primarily a focus on intrapersonal skills, and we might call it ‘instrumental’. On the other hand, the changing nature of work and societies demands new competencies, in particular interpersonal competencies but also different intrapersonal ones. We might call this the intrinsic value of super-cognitives.

It is important to hold these goals separate in order to avoid all learning dimensions becoming subservient to the ‘cognitive’. ‘Affective’ learning goals – such as developing emotional stability – must still be seen as educational ends in and of themselves, not just a means to higher test scores.

3.3.2. Pedagogies for life-long learning

The shift in focus towards learner-centred pedagogies is part of a larger change in the way we think about the goals of learning, who can learn and how. The science of learning has

changed how we think about human potential and skill development. We see an increase in 'mastery-based' approaches to education which are intended to allow everyone to learn to a high level – a stark difference from the systems of a century ago.

The shift in the balance of educational purposes from imparting an established body of knowledge to preparing life-long learners has considerably implications for pedagogy. Teachers have developed pedagogies to promote learning skills and strategies even from young ages (Cervone and Kushman, 2012); Swann et al., 2012), building the 'developmental attributes' such as 'academic mind-sets and dispositions; self-regulated learning skills; and academic behaviours' (Haynes et al., 2016). These skills describe what the OECD has called 'learning to learn': the strategies, practices and motivations associated with high performance (OECD, 2010).

In many contexts, new pedagogies are shaped around the notion of 'self-regulated learning': approaches that intend to develop people's ability to manage and progress learning without the direct instruction of a teacher. The 'three-layer model' of self-regulated learning (Boekaerts, Pintrich, and Zeidner, 2000) is one framework which captures the different kinds of mind-sets, dispositions and skills which need to be developed in order for students to be able to learn productively on their own. The inner layer of cognitive regulation encompasses the practices a student needs to master to carry out information processing. The middle layer of metacognitive regulation describes the students' knowledge and skills that allow them to make effective choices about what they study and how. The outer layer of motivational regulation represents the "self", the learner's own goals, needs and expectancies. Teachers have the ability to influence each of these layers, and so designing pedagogy becomes a more complex – but potentially more rewarding – task.

3.4. The importance of pedagogical combinations

The intention of the above account is to broaden our picture of the purposes pedagogies might aim at. This is vitally important so that we can evaluate and appraise pedagogies from an authentic position, rather than trying to pretend that all pedagogies aim at the same goals. The above account also established that both discipline-centric and student-centric pedagogies are fundamental to achieving the purposes of education: the study of how expertise develops and of 'cognitive load' highlights that explicit teaching of knowledge and skills is a vital part of education. But once we recognise that motivation and emotion are 'the gatekeepers of learning' (Dumont, Istance and Benavides, 2010) any line between discipline-centric and student-centric pedagogies becomes more blurred: engaging with students as individuals is just the other side of the coin of teaching concepts and skills effectively. One definition of 'deeper learning' describes teaching for deeper learning as a 'spiral' of mastery, creativity and identity (Mehta and Fine, 2015): students master new knowledge and skills, practice putting them to work in new ways, and in doing so create meaning that helps them to define their identity. Thus, the depth of outcomes - and the complexity of pedagogies a teacher can use - grows as learners develop more of that fluency and background knowledge.

In sum, the two traditions cannot survive in opposition: teaching to develop personal competence cannot be achieved effectively without some teaching for knowledge acquisition, while teaching knowledge alone is futile if students do not have the personal and social competence to put it to use. To this extent, it is only useful to talk about 'discipline-centric' and 'student-centric' pedagogies for the purpose of clarity about intentions. The need to separate pedagogies into different approaches arises not only from

our tendency to dichotomise but also from the needs of research: in order to study accurately whether a set of practices is having a desired impact, it is helpful if we can codify it and examine it in relation to specific outcomes. In this way, we can advance the science of teaching. For all purposes beyond clarity in research and evaluation, however, it may be best to steer clear of dichotomising labels. In actual teaching, teachers find they need to bring these different pedagogies back together to meet the multiple dimensions of learning. Teaching is therefore all about combinations.

3.4.1. Achieving balance

What are the ways in which combinations occur? The sections that follow describe factors which appear to shape the creation of combinations at the classroom and school level. In combining pedagogies, the central question is one of balance. How teachers organise their own time and that of their students has implications for the range of opportunities students have to develop competence, and the depth and breadth of knowledge they acquire. A central question of balance is of course about 'the what of education' (Fadel, Trilling and Bialik, 2015): how to create adequate depth and breadth of focus, taking into account the many different domains of knowledge and skills. A mandated curriculum may or may not leave many choices to be made. But if we are concerned with the development of students' personal and social competences, an equally important question is about how students experience their day-to-day learning. Who are they working with? What control do they have over what they are doing? How are they receiving feedback? What do they think it is all for?

In chapter 1, it was proposed that an important function of pedagogy is to organise learning. The table below illustrates again how different established pedagogies tend to lead to different kinds of learning experiences.

Table 3.1. Different approaches create different learning experiences

		What makes students keep working?				
		Teacher instruction	**Self-managed**	**Group dynamics**		
What do students work on?	**Teacher choice**	Lecture	'Personalised'	Collaborative	**Time-based**	**When do we move on?**
	Co-constructed	Mastery-based	Blended	Discussion	**Continuous assessment**	
	Student choice	Scaffolded Inquiry	Independent Inquiry	Project-based	**Final product**	

Each type of pedagogy comes with trade-offs related to the advantages and disadvantages of different set-ups. Educators might therefore choose to combine certain pedagogies to achieve a balance of types of learning experiences. For example, a teacher working on developing both student agency and self-regulation might choose pedagogies that allow students to select the focus of learning and to manage their own time, such as inquiry. If, however, the teacher is also concerned that student knowledge is lacking on certain topics and they need to maximise the efficient use of time, they might opt for combining that with periods of 'personalised' (often computer based) learning, which can be deployed within a specific time allotment.

3.4.2. Trade-offs in combining pedagogies: variety vs familiarity

If we were seeking to maximise the different kinds of learning experiences student have, we might think this is best achieved by combining as many pedagogies as possible. There are trade-offs, however, in the number of pedagogies a teacher tries to use. For each approach, there will be a learning curve. Recalling the earlier example of the Literature teacher: we may not want to always emphasise personal connection, or always give more time to oracy skills, but we also want to develop some consistency of emphasis over time so that it has a chance of real impact.

We saw already that we can also think about pedagogies as bundles of discrete practices. Combining pedagogies which share common practices can help reduce the trade-offs of using too many pedagogies. For example, in a school where students are practiced in inquiry-based learning, teachers might feel more confident in combining their approach with challenges or complex projects, knowing that students are competent at managing their own learning. Likewise, systems might create more effective professional development or teacher education opportunities by looking for coherence between pedagogies at the level of practices. By focusing on the core knowledge and skills that are common across many pedagogies, opportunities could develop these while still allowing teachers and schools to make their own decisions about they combine specific approaches.

Studying common combinations of pedagogies can help to identity those practices which are common to several pedagogies, such as presentations of learning, or student self-assessment. Building both teacher and student familiarity with these practices could make it easier to support a greater diversity of pedagogical combinations across a school or system.

3.4.3. Combining pedagogies into a school design

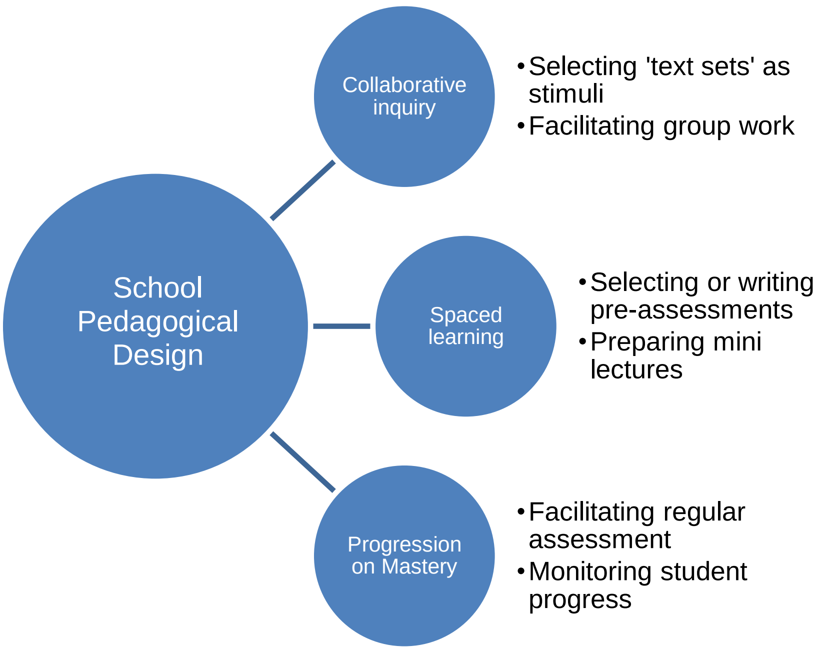
When a school has a robust and overarching pedagogical design, it has made a collective decision about the way it will combine several pedagogies to meet multiple educational goals as a community. The advantage of making this decision at the school level is that the power of each pedagogy is strengthened considerably. When teachers are working with the same pedagogical approach, individual teacher planning can be reinforced at the organisational level and teachers can collaborate together more easily, sharing ideas and improving each other’s practice. Students in such schools can transfer the learning approaches they develop in one year or subject area to another. Moreover, the promotion of long-term outcomes is likely to be more successful when carried out across a whole school.

It is still relatively rare for schools to operate with this level of coherence, particularly at the secondary level. There are limits to the extent a pedagogical approach can and should be shared across different disciplines and domains: some pedagogies have been developed specifically to teach the particular core knowledge and skills of different disciplines and these may shape the bulk of teaching and learning practices. In order to promote personal and social competences, however, some attention to school-wide coherence and developmental pathways seems necessary. To the extent that children and young people move between schools, there is also reason to think about the need for some pedagogical coherence at a local or even jurisdiction level: for key skills such as oracy and project management, just as with numeracy and literacy, it might be desirable for teachers across a jurisdictions to be able to share common continua and language related

to a particular pedagogy, which they would then need to be able to integrate into their individual pedagogical design.

Overall, from the perspective of school pedagogical designs, there are two levels at which we can think about combinations of pedagogies. On the one hand, any given pedagogical approach entails a set of practices which can be refined and improved upon the more they are used. At a more general level, established pedagogical approaches are combined to make up an overarching pedagogical design at the school level, which provides coherence and ensures a balance of discipline-centric and student-centred learning goals.

Figure 3.1. Practices combine within approaches, which combine in a school-level pedagogical design



3.5. Examples of combinations

Conceptual models can help to clarify how pedagogical combinations are formed and why. These models are derived in part from looking at what expert practitioners do, and we can learn more from looking at the details. This section features three illustrative examples of how a sample of school networks have combined distinct approaches and practices to generate the experience, learning and outcomes they want for young people.

This section draws on a wider scan of how schools and school networks describe their pedagogical models. A fuller list of examples is included in Appendix 3.A. The cases may be familiar to many educators, but are selected to provide relatively explicit examples of pedagogical combinations, and to show that pedagogical designs can emerge ‘bottom up’ through informal networks and innovation, as well as being cascaded ‘top down’ through the concerted efforts of a school chain or network. A series of conclusions and outstanding questions follows the examples.

3.5.1. High Tech High, San Diego, California

The High Tech High (HTH) schools (www.hightechhigh.org/) began with the founding of one high school in San Diego in 2000. There are now 13 schools in the network, all based in the San Diego area and including elementary, middle and high schools.

The central pedagogy at High Tech High schools is learning through projects. Projects are designed primarily by pairs of teachers who represent two or more disciplines, meaning that they are multi-disciplinary, but focus on core subject content. A project arc will be designed so that periods of time when students are working on their own in groups are interspersed with teacher-led sessions that provide key content or introduce necessary skills. Through projects, HTH seeks to fulfil its four founding 'design principles': personalisation, adult world connection, and common intellectual mission, teacher as designer.

The cornerstone of the project-based approach at HTH is public exhibitions: at the end of each project students present or display their work at an event for parents, other students and teachers, and members of the community. These events are well attended by the community, and act as an important form of motivation and accountability: HTH teachers observe that the level of freedom given to students in how they manage their time and group work across a project is only possible because all students know they have to have something to show for it at the end.

Teachers develop their skills in project based learning through a network-specific initiation (the 'Odyssey'), as well as ongoing school-based professional development. The network has its own Graduate School of Education which provides teacher education oriented specifically towards the HTH pedagogical design. HTH teachers have recognised that not all the necessary learning students need comes naturally through projects or interspersed teacher-led sessions. Portions of the school week are therefore given over to more intensive skills building. For Mathematics, some teachers have adopted an individualising pedagogy called 'Judo Math', originally developed by HTH teacher Dan Theone. Students earn 'belts' as they progress through different mathematics topics and skills and demonstrate mastery.

While High Tech High as an organisation has resisted spreading geographically, there are a number of HTH-inspired schools around the world. School 21, in London UK has developed a model of project-based learning with support from High Tech High teachers, and combines it with a number of different components to achieve their desired curriculum goals. For example, alongside the emphasis on exhibitions, School 21 promotes the development of communication skills through a unique 'oracy' curriculum and drama-based pedagogy. Additionally, amidst longer project lessons, students spend time each day in short, intensive skill-building sessions focused on numeracy and literacy, which adopt a more didactic pedagogy.

3.5.2. Lumiar Schools, Sao Paulo, Brazil

The first Lumiar school (http://lumiar.org.br/) was founded in 2003 in Sao Paulo by entrepreneur Ricardo Semler. The Lumiar Institute, established in 2009, now oversees three schools in the region. The Lumiar pedagogical model is underpinned by a defined view of learning and education. Eduardo Chaves, former President of the Lumiar Institute, described (https://lumiarschool.wordpress.com/2007/10/19/lumiars-pedagogical-proposition/) how they see education "as a process of human development", the end goal of which is to become "a competent and autonomous adult". According to

this view of education as human development, education occurs throughout the life course and through all interactions, but the role of "schools, as formal learning environments" is central, as long as schools and their pedagogies are organised to incorporate and engage with the wider process of development. Consequently, the "learning methodology" of Lumiar schools is based on a picture of what learning looks like in wider life, that "the best way to learn is by acting, doing, transforming projects into reality". Chaves describes this as an "active methodology".

The central approach of Lumiar schools is project-based learning, but of a particular kind. Students undertake projects either individually or in small groups, formed around interests. Every two months teachers provide students with a wide range of choices of problems to work on, and shape projects around the student choices. Student suggestions are taken very seriously, and the goal is that as students advance in their education their projects will become increasingly self-determined and important to them. In contrast to some other PBL models, therefore, projects are more likely to track local or current concerns than the mandatory curriculum, although curriculum content will be incorporated. The high level of student choice is enabled by the notion of the 'mosaic curriculum': that curriculum should be viewed as a patchwork which students complete in any order they like, as opposed to a mandatory sequence. The core curriculum is built from a 'matrix of competencies' which (to the extent to two can be separated) prioritise skills over standardised knowledge.

To provide opportunities for learning knowledge and skills not fully developed through projects, there are two other key components of the Lumiar pedagogical design: workshops and learning modules. Workshops focus on specific content and operate with a studio or apprenticeship pedagogy, where students see skills modelled and have time to practice. Workshops are the method through which students develop necessary skills that are applied in projects.

Learning modules operate with either a didactic or dialogic pedagogy, where teachers are leading a sequence of learning on a specific topic. One learning module all students take is 'World Reading', focussed on engaging with international affairs through reading and discussing current newspapers. The topics of learning modules are chosen by the teachers, to ensure students are being exposed to breadth as well as depth of content.

At Lumiar, the teaching role is divided between leaders of projects who are not full-time staff, but supply expertise knowledge and motivation, and the full-time tutors who monitor and guide student learning and progress. Embodying these different skill sets in different staff also gives rise to different pedagogical combinations and variety.

3.5.3. Growing Innovation in Rural Schools, British Columbia, Canada

Rural schools in British Columbia are networked in an overlapping set of official programmes and informal relationships between educators and researchers working in the province and beyond. Over recent years, the sharing of practices has allowed these schools to develop a cohesive set of pedagogies which are highly complementary and aligned with goals to promote social and environmental sustainability and awareness of place. The development of pedagogical practices has been particularly encouraged by the 'Growing Innovation'(www.ruralteachers.com/growing-innovation-2011) projects in rural schools, funded by the Ministry of Education and facilitated by faculty from the University of British Columbia.

The first and most distinct of these approaches is outdoor or place-based learning. Schools have developed projects and learning sequences specific to their environments, which serve the dual purpose of engaging students in authentic learning and connecting them to the knowledge that is most valuable in their context. A number of sequences have revolved around the development of community gardens or farms, which have subsequently given rise to food technology and cooking programmes, and related enterprises. The type of learning experiences and content students have been able to engage with therefore naturally has become more complex as an outdoor learning space grows.

Another variant of outdoor learning focuses on developing students' capabilities to engage with uncharted terrain such as mountains or forests, which lends itself to content learning in key areas of science and geography but is also used as inspiration for writing exercises, as well as opportunity to develop students' persistence, self-reflection and social and emotional stability.

These forms of powerful learning experiences lend themselves well to combination with inquiry-based approaches, where outdoor learning provides an initiating point or culmination for periods of inquiry. For example, students planning a hike to a location of particular geological significance are charged with working out where they needed to go, how to get there and what supplies to bring, applying core literacy, numeracy and research skills in the process. In schools where students work on more personal inquiries, an outdoor experience might provide the basis for students to develop new wonderings to pursue, relevant to their context and place.

Alongside inquiry and place-based approaches, the rural education networks have also facilitated the sharing of practices to improve students' reading, writing, questioning and number work, which are all core skills for carrying out inquiries. 'Daily 5s' are a popular method at the elementary level to engage students in practicing these skills, where students chose from one of five activities geared either towards maths or reading and writing. A method found across North America and beyond, it is particularly compatible with inquiry-based learning as it promotes students' self-management.

Another practice which scaffolds inquiry skills is the use of text sets, where teachers put together a selection of books and/or other media resources on a topic from which students select to conduct their research. This practice allows teachers to define the bounds of relevant content for an inquiry, ensures that students are engaging with high quality written material. A parallel activity is possible through the curation of online content, and educators in the network share tips on the use of sites such as National Geographic for Kids (http://kids.nationalgeographic.com/) or Kiddle (www.kiddle.co/) (a child-friendly version of google, still undergoing improvements). These new practices around the use of open online resources may emerge as discrete approaches which could be combined with other approaches besides inquiry.

3.6. Creating strong combinations

How and why do approaches and practices combine – and how can existing combinations inform further innovation? This section extrapolates from the examples above to offer three hypotheses on what can be learned from viewing teaching and learning through the lens of pedagogical combinations. These are proposals to test through the broader project. This concluding section also includes further questions for research and practice.

3.6.1. Emergent hypotheses

Depth and balance

Each of the networks has developed a pedagogical design where teachers draw on a limited number of pedagogical approaches. Successful models seem to be those which balance approaches that maximise opportunities for students' personal and social development, with those which prioritise the development of core skills and knowledge. This finding suggests that the entrenched positions of student-centric and discipline-centric advocates can be overcome: expert educators are drawing on both of these traditions to promote learning that is both rich in new concepts and skills and personally engaging.

A strong core

Each model has a single central approach which typically cuts across different subject areas or disciplines, such as project-based learning in the case of High Tech High or inquiry learning in the B.C. rural schools. Teachers view this as a 'core pedagogy' which provides a rhythm to the school day, week and year, for example, the duration of a project leading up to an exhibition, or a cycle of inquiry. This rhythm means that students have a sense of momentum in their work, and learning is shaped meaningfully as opposed to by arbitrary bells and schedules. Both within this structure and in separately allotted times, teachers also adopt subject-specific pedagogies to propel learning in particular domains. The combinations ensure that knowledge and skill development do not lose out amidst the focus on the core pedagogy.

Network-specific variations

In most cases, the examples illustrate a distinct version of a more general pedagogical approach, for example, within project-based pedagogies, High Tech High teachers design whole class projects around subject-based inspirations, while the Lumiar approach to projects is more about student choice and a focus on tackling problems. In each case, the network in question provides for teachers a particular 'anchor' or framework for the approach, so that teachers within a school have the same starting point and language. In the best networks, teachers become expert at designing around that frame or anchor.

3.6.2. Outstanding questions for research and practice

Balance – across what arc of learning?

Some schools or networks are in a position to create a pedagogical design that covers the whole duration of formal schooling (or even beyond). Balance discipline-centric and student-centric goals may look different depending on whether one is planning for development over the course of one year, or over a young person's entire school career. Both researchers and practitioners cannot seek to establish general principles of balance and combination without taking into account the situation of students. How to construct that balance is likely to look different depending on the developmental stage of students, and their background experience. Further work on how combinations are created at each stage of education could help inform this question.

Optimising – for what?

This question addresses the tension between different kinds of learning goals. In seeking to identify innovative combinations of pedagogies, it is necessary to have some way of evaluating what makes one combination better than another. But the combinations of pedagogies likely to lead to optimal knowledge outcomes may not be the same as that which leads to optimal personal and social development. For example, project-based approaches geared towards collaboration and student agency requires some sacrifice of time that might be spent on content coverage. The study of combinations may be a key opportunity to highlight how higher-order personal and social competences can be produced without sacrificing discipline-centric learning. But this will remain difficult while assessment is primarily geared towards subjects and a few key skills. External evaluators will need to look to long-term student outcomes, or proxies thereof, as well as impacts on test scores. It is also important to acknowledge that final appraisals of pedagogical choices are value judgments to be made at a class, school or system level.

Less is more, or more is better?

With the proliferation of network-specific versions of many pedagogical approaches, it is an open question whether it would be desirable to try to combine several of these together – for example, for a model to emphasise both real world challenges and exhibitions, along with best questioning practices, use of rotations, personalised learning plans etc. It might be more desirable for a network to focus on building the best possible capacity around fewer anchors and frames, to create their own 'core pedagogy'. This question could be explored further through cases of how networks have reached decisions about which practices to make central to their model.

Annex 3.A. Appendix: Networks with innovate pedagogical designs

This Appendix provides examples of how schools and school networks describe their pedagogical designs, drawing especially on extracts from network publications, sourced from an initial search. It is far from illustrative of the full range of pedagogical combinations or innovative models in operation today. In line with the emphasis given elsewhere in this report, the search focused only on school networks, which often have greater capacity (and need) to codify their pedagogical design as it is being applied across organisational sites. It complements examples given in earlier chapters of this report

AltSchool www.altschool.com/education#our-approach

All students have a personalised learning plan, based on their current knowledge across all academic areas, individual goals, and interests. Through technology, educators curate relevant individual and group activities that support each student's goals and needs. Educators assess student progress on an ongoing basis to keep students challenged. Because social-emotional skills are seen as just as important as academics, the educators track them with the same rigour. Students of different ages are grouped in the same classes to experience being leaders, learners, and teammates together.

In addition to building skills for how to learn, the students build competency across core academic domains. Educators assess student work and progress against each student's individual learning objectives and nationally-recognised standards. To build a strong academic foundation, students advance when they have demonstrated competency in an area, not because the class has advanced.

Real-world inquiry brings learning to life. Through projects, students put foundational skills directly into practice in an interdisciplinary way. They have opportunities to investigate topics through field trips, individual and group research, and visits with partners from AltSchool's Expert Network. As a culmination of a particular arc, students plan, produce and present a project of their own.

Aspire Public Schools https://aspirepublicschools.org/discover_aspire/instructional-approach/

Educators at Aspire use a variety of strategies in their teaching practice, depending on how students learn best, and are trained to adapt these strategies to each child. The major strategies used include: explicit instruction, academic discourse, group and individualised, problem-solving, inquiry, project-based instruction, and apprenticeship. To establish a foundation for success, there are three main areas of focus:

1. *Basic Skills*: Master at least grade-level competency in the four core subjects: mathematics, science, social studies, and language arts (including reading, writing, listening and speaking).

2. *Thinking Skills*: Be able to apply classroom learning to their real-world experiences in a relevant and valuable way, using higher-order thinking skills. These include critical thinking, creativity, decision-making, problem-solving, reasoning, and knowing how to learn.
3. *Life Skills*: Develop personal qualities of individual responsibility, intellectual curiosity, sociability, self-management, confidence and integrity.

Aspire has developed a blended learning approach, working to convert existing schools to an integrated model that focuses on enhancing student achievement and supporting teacher effectiveness within current facilities, using small group learning.

Big Picture Learning www.bigpicture.org/

Each student at a Big Picture Learning school is part of a small learning community of 15 students called an advisory. Each advisory is supported and led by an advisor, a teacher that works closely with the group of students and forms personalised relationships with each advisee. Each student works closely with his or her advisor to identify interests and personalise learning, engages and is challenged, and the learning is authentic and relevant.

Each student has an internship where (s)he works closely with a mentor, learning in a real-world setting. Parents and families are actively involved in the learning process, helping to shape the student's learning plan and are enrolled as resources to the school community. The result is a student-centred learning design, where students are actively invested in their learning and are challenged to pursue their interests by a supportive community of educators, professionals and family members.

"Advisory structure" and "learning through interests and internships" are two of the ten "Distinguishers" which unite Big Picture schools around the world. The remaining eight are: one student at a time (personalisation); parent and family engagement; school culture (student voice and leadership); authentic assessment; school organisation (culture of collaboration); leadership (democratic community); post-secondary planning; and professional development (in-house coaching). These exist as a comprehensive whole: they are interrelated and inform one another and the integration of reflection-based action with the "distinguishers" lying behind the power of the Big Picture Learning design.

Carioca Experimental Gymnasium Network www.innoveedu.org/en/carioca-experimental-gymnasium-network

The Carioca Experimental Gymnasium programme operates in grades 7-9 in public municipal schools in Rio de Janeiro, beginning in 2011 in ten schools, and now in nearly 30. It is designed to re-engage students and promote agency and autonomous learning. Alongside the components of directed study, Youth leadership and Elective subjects, a central element of the model is the "life project".

All students participate in Life Project activities, aiming to develop students' human sides and potential. The course is weekly, with reflection on values and the promotion of attitudes, such as relationships with others, in sport and in life. Students also engage in collaborative activities, which are monitored by their tutor who also provides personalised guidance. The teachers collaborate in planning the classes and use new technology and didactic subjects structured by handouts and exercises. Educators and

students use the *Educopedia* platform of digital classes, which supports the teachers by providing class plans, pedagogical games and videos.

Dream School http://adhyayan.asia/site/the-dream-school-in-kauniainen-finland/

The Dream School model, created by the local school authority in Kauniainen, Finland, is an initiative to re-think the purpose and experience of the school in order to prepare students for "jobs that don't yet exist in this fast-changing world". The project began in 2011 and has spread to 30 primary and secondary schools. They are now working to "open-source" the model by codifying the work for debate and development with others.

The student-centric pedagogy strives to recognise and harness real-world knowledge brought by the students. The curriculum can incorporate the knowledge students themselves have to share. This necessitates re-mapping of the learning environment, the role of the educator and the teacher-student relationship, and the school itself; supporting this is an open-source technology model.

Envision Schools www.envisionschools.org/our-approach/

Envision Education is a charter management organisation in the United States, operating three schools in the San Francisco Bay area of California. It was founded in 2002 and over several years developed a project-based learning and portfolio assessment approach. In 2010, it founded a consultancy division, Envision Learning Partners, which works with schools and teachers across the U.S. to spread their pedagogical approach.

Know, do, reflect: Envision Schools help students not only to master academic content, but also to apply that knowledge to other situations. The curriculum and model are organised around the "know, do, reflect" approach to promote the 21st century skills: thinking critically, collaborating productively, communicating clearly and managing projects effectively, and the core competencies (research, inquiry, analysis, and creative expression).

Portfolio Assessment: In addition to traditional forms of testing, assessment emphasises the deep understanding of academic disciplines. Students assemble a portfolio of their best work, which they must "defend", dissertation-style, in front of an audience of educators, peers and community members. Students present a defence of their work at the end of 10th grade, and, for seniors, passing the college success portfolio defence is a requirement to graduate.

Real-world projects: Project-based Learning aims at getting students to apply academic knowledge to new situations, in which students put their knowledge to work solving real-world problems and challenges. Envision teachers embed academic content in projects that speak to students' life experiences with relevance and application in the real world. Teachers share their expertise by creating new projects and posting them to the Project Exchange, an open source for rigorous and relevant curriculum.

Workplace Learning Experience: community-based projects and internships at partner organisations and businesses through the workplace learning experience. During part of their 11th grade year, all Envision students go to work at an internship site where they learn from an employer mentor and complete a project with measurable outcomes.

Eos Education http://eoseducation.com/

Eos Education is a teaching school alliance and professional development provider in England, with a focus on immersive and learner-centred pedagogies. It was founded in 2014 at Hartsholme Academy in Lincoln, and now works with teachers and schools around the country. The core elements of the pedagogical approach include: Immersive classrooms; Exhibitions; and Behaviours for Learning.

Other aspects of the Eos pedagogical approach are presented in the form of principles:

- Place the learner at the centre of all activities, continuously reflecting on how effectively actions are impacting on the outcomes of each individual.
- Ensure that curriculum content is relevant to the lives of learners and that outcomes are authentic and have an impact on the real world.
- Provide learners with the necessary tools and environments to enable them to be flexible, choosing how, where and with whom they work
- Ensure learners are engaged in collaborative, self-directed learning with the teachers acting as facilitators.
- Staff members are treated as professionals, with emphasis on professional dialogue and time to plan, design and teach in teams.
- Respect and promote the work/life balance of employees through workplace systems and schedules. Policies and protocols should be regularly reviewed and evaluated to measure their relevance and effectiveness and to ensure that bureaucracy is kept to a minimum.
- Provide opportunities to network and collaborate across the whole EOS network and with the wider community, sharing information freely.
- Value research and the development of new pedagogies and tools to liberate learning and connect learners in powerful ways.
- Expeditionary Learning http://eleducation.org/about/our-approach.

Expeditionary Learning, now called EL Education, formed in 1991 as a collaboration between *Outward Bound* and the *Harvard Graduate School of Education*, funded by the *New American Schools initiative* from the U.S. federal government. There are now over 150 schools in the Expeditionary Learning network. In 2013, EL received a major grant to scale up its practice, and now supports many more schools through professional development and curriculum materials.

The EL model is based on '10 building blocks': 1. The Primacy of Self-Discovery; 2. The Having of Wonderful Ideas; 3. The Responsibility for Learning; 4. Empathy and Caring; 5. Success and Failure; 6. Collaboration and Competition; 7. Diversity and Inclusion; 8. The Natural World; 9. Solitude and Reflection; 10. Service and Compassion.

Central to the EL model are expeditions – long-term projects through fieldwork and the creation of complex, authentic work, involving higher-order thinking, multiple perspectives, and transfer of understanding. The emphasis on high quality work and the requirement for students to demonstrate craftsmanship means that students produce work through multiple drafts. Student might produce five or six revisions of the same piece of work, building core skills as they practice and refine their efforts, and learn to critique and improve each other's work (http://modelsofexcellence.eleducation.org/).

Fab Labs http://innoveedu.org/en/fab-education

Fab Lab is the educational outreach component of Massachusetts Institute of Technology's Centre for Bits and Atoms (CBA), an extension of its research into digital fabrication and computation. A Fab Lab is a technical prototyping platform for innovation and invention, providing stimulus for local entrepreneurship; it is a platform for learning and innovation - a place to play, create, learn, mentor and invent. It means connecting to a global community of learners, educators, technologists, researchers, makers and innovators, spanning 30 countries and sharing common tools and processes.

FabEd is a network collaboration to provide support and professional learning opportunities for schools and teachers. FabEd is a collaboration between The Fab Foundation and TIES, the Teaching Institute for Excellence in STEM. FabEd over time is looking to codify the pedagogical approaches suited to STEM learning in the context of a Fab Lab.

International Baccalaureate www.ibo.org/programmes

The International Baccalaureate Organisation (IBO) supports and authorises schools to provide its primary years programme (ages 3-12), middle years programme (ages 11-16), diploma programme and careers programme (both ages 16-19). Each is essentially a curriculum and an approach to assessment, but the curricula are designed to work with certain ways of teaching. Schools aiming to become IB go through particular professional development, meaning that IB curricula are taught with an emphasis on particular pedagogies. For example, the primary years programme is presented in the form of the written curriculum which explains what primary years programme (PYP) students will learn, the taught curriculum which sets out how educators will teach it, and the assessed curriculum which gives the principles and practice of the effective assessment of the PYP.

The central element of the pedagogical approach in the PYP is structured, purposeful inquiry which engages students actively in their own learning. The programme supports students' efforts to construct meaning from the world around them by:

- drawing on their prior knowledge;
- providing provocation through new experiences; and
- providing opportunities for reflection and consolidation.

This approach respects students' developing ideas about how the world works. It encourages them to question, consider and refine their understanding of the social and natural world.

The middle years programme (MYP) adds additional pedagogies. Students demonstrate interdisciplinary understanding when they bring together concepts, methods, or forms of communication from two or more disciplines or areas of expertise. They are expected to do this so that they can explain a phenomenon, solve a problem, create a product or raise a new question in ways that would have been unlikely through a single discipline. In each year of the programme, MYP schools are responsible for engaging students in at least one collaboratively planned interdisciplinary unit involving at least two subject groups. Time for collaborative planning must be managed systematically and effectively, and it must involve all teachers.

Long-term project: Students who complete the MYP in Year 3 or Year 4 complete the community project. All students who complete the MYP in Year 5 complete the personal project. The community project provides an important opportunity for students aged 13-14 to collaborate and pursue service learning. Schools register all MYP Year 5 students for external moderation of the personal project, promoting a global standard of quality. MYP projects are student-centred and age-appropriate, and they enable students to engage in practical explorations through a cycle of inquiry, action and reflection.

Teaching and learning in context: Students are seen to learn best when their learning experiences have context and are connected to their lives and their experience of the world that they have experienced. Using global contexts, MYP students develop an understanding of their common humanity and shared guardianship of the planet through developmentally appropriate explorations of: identities and relationships; personal and cultural identity; orientations in space and time; scientific and technical innovation; fairness and development; and globalisation and sustainability.

Conceptual understanding: MYP students use concepts as a vehicle to inquire into issues and ideas of personal, local and global significance and examine knowledge holistically. The MYP prescribes sixteen key interdisciplinary concepts along with related concepts for each discipline.

Approaches to learning (ATL) are a unifying thread throughout all MYP subject groups and provide the foundation for independent learning and encourage the application of their knowledge and skills in unfamiliar contexts. Developing and applying these social, thinking, research, communication and self-management skills help students learn how to learn.

Action and service have always been shared values of the International Baccalaureate (IB) community. Students take action when they apply what they are learning in the classroom and beyond. IB learners strive to be caring members of the community who demonstrate a commitment to service - making a positive difference to the lives of others and to the environment. Service as action is an integral part of the programme, especially in the middle years community project.

NAF Academies http://naf.org/about

NAF, originally the National Academy Foundation, is a U.S. organisation that brings together schools and businesses to create STEM-infused industry-specific curricula and work-based learning experiences. NAF partners with high schools to create small learning communities known as NAF academies within existing schools (sometimes more than one in a school). Each academy is structured around a growing industry, such as finance, hospitality and tourism, information technology, engineering, or health sciences. Almost 89,000 students now attend one of 716 NAF academies, located in 482 different high schools, across 36 U.S. states.

The NAF Educational Design involves four essential elements of practice: the Academy Development and Structure (small, focused learning communities), Curriculum and Instruction (career-themed curriculum and project based instruction), Advisory Board (providing a bridge between schools and the work place), and Work-Based Learning. The NAF curricula are created in partnership with industry professionals and designed around projects that help students develop workplace skills and longer-term career options.

NAF's approach to work-based learning is based on a continuum of work-based learning experiences beginning with career awareness, then career exploration activities, and then career preparation activities, including internships. Businesspeople guest speak in classrooms, host college and career skills workshops, and take part in mock interviews. Students tour worksites and network with and shadow business professionals. Work-based learning culminates in an internship.

New Tech Network http://newtechnetwork.org/

New Tech Network (NTN) is a non-profit organisation that supports schools to move towards project-based learning and other deeper learning pedagogies. It operates across the U.S. and partners with both individual charter schools and school districts.

Project-based learning (PBL) is at the heart of the instructional approach, in which learning is contextual, creative and shared. Students collaborate on meaningful projects that require critical thinking, creativity, and communication to answer challenging questions or solve complex problems. Students aren't just assessed on their understanding of academic content, but on their ability to successfully apply that content when solving authentic problems, thereby also developing real-life skills.

NTN schools also use problem-based learning - inquiry-based instruction used primarily in mathematics based on a series of smaller problems rather than the single large project. They share similar aspects such as Entry Events, the Need-to-Know (NTK) process, and student-centred scaffolding.

Individual Assessments of Knowledge and Thinking: assessments that call for students to demonstrate authentic skills are frequently referred to as "performance assessments" and project-based learning depends on these sorts of assessments. There is special attention to the design of disciplinary-strong individual performance tasks called Individual Assessments of Knowledge and Thinking (IAKTs) as a curriculum embedded element of strong PBL.

College Readiness Assessments (CRAs) are curriculum-embedded performance assessments used to assess students' mastery of Knowledge and Thinking and Written Communication outcomes. The Knowledge and Thinking rubrics are specific to each core discipline and assess the key knowledge and skills necessary for college readiness in a particular content area against an externally validated standard. CRAs allow teachers to integrate individual tasks aligned to external standards for quality into larger, authentic projects. NTN CRAs are derived from a performance assessment process developed by Envision schools and the Stanford Centre for Assessment, Learning and Equity (SCALE), and are aligned with the Common Core State Standards, and NTN has collaborated with Envision and SCALE to adapt their processes and rubrics.

All classrooms have a one-to-one computing ratio and use technology for students to become self-directed learners, not relying on teachers or textbooks. There is an online learning management system (Echo) that helps students, teachers, and parents connect to each other, and to student projects across the country.

Quest to Learn www.q2l.org/about/

Quest to Learn, in New York City, and Quest to Learn Chicago are schools developed by the Institute of Play, which practice game-based learning; games are carefully designed, student-driven systems that are narrative-based, structured, interactive and immersive.

Main components of this approach are:

- Games assume collaboration with others and promote learn by doing.
- They signal success and failure and encourage iterations after a failure; failure is a necessary and integral part of the “game”.
- Learning experiences in games feel like play.

At Quest to Learn, learning happens by doing. Game-based learning takes a variety of forms at Quest to Learn. For instance, in 9th grade Biology, students spend the year as workers in a fictional bio-tech company, and their job is to clone dinosaurs and create stable ecosystems for them. By inhabiting the role of biotech scientists, the students learn about genetics, biology and ecology. Educational games are at the core of Quest’s curriculum. These games not only engage students in the learning process, but also allow teachers to assess students in real time and provide feedback on learning experiences immediately.

Game-based learning at Quest is supported by a learning platform called PupilPath. The Institute of Play provides “design packs” on Systems Thinking, Games and Learning, Curriculum Design, and School Design which articulate broader aspects of their model. The Chicago Quest School also emphasises connected learning, a pedagogical approach that has been promoted by the MacArthur Foundation. It leverages the potential of social and digital media to integrate young people's interests, peer culture, and academics. The Chicago Quest School uses these principles to connect students to real-world contexts. Game-based learning and connected learning are combined into one pedagogical model in examples such as the ‘boss level’ at Quest to Learn NYC, where students spend two weeks working on particular challenges to be presented to the community: http://connectedlearning.tv/

Reggio Emilia/Reggio-inspired schools www.aneverydaystory.com/beginners-guide-to-reggio-emilia/main-principles/

The individuality of the child and the importance of the community are central to the Reggio approach, and no set of practices looks the same but there are “Fundamental Principles”:

- Children are capable of constructing their own learning and are driven by their interests to understand and know more.
- Children form an understanding of themselves and their place in the world through their interactions with others. There is a strong focus on social collaboration, working in groups, where each child is an equal participant, having their thoughts and questions valued. The adult is not the giver of knowledge. Children search out the knowledge through their own investigations.
- Children are communicators, and communication is a way of discovering things, asking questions, and using language as play, and children are listened to with respect.
- The environment is the third teacher; it is filled with natural light, order and beauty. The space encourages collaboration, communication and exploration and is cared for by the children and the adults.
- The adult is a mentor and guide and adults observe the children, listen to their questions and their stories, find what interests them and then provide them with opportunities to explore these interests further.

- There is an emphasis on displaying and documenting children's thoughts and progression of thinking; making their thoughts visible in different ways: photographs, transcripts of children's explanations, visual representations (drawings, sculptures etc.).

The Hundred Languages of Children is the belief that children use many different ways to show their understanding and express their thoughts and creativity. Each of these Hundred Languages must be valued and nurtured.

Steve JobsSchools http://stevejobsschool.world/

Steve JobsSchools is a small chain of private primary schools in the Netherlands, founded in 2014. A Steve JobsSchool has flexible school hours. It does not have classes of children in the same age group, but core groups of approximately 25 children with a maximum age difference of 4 years, in which the older children help the younger ones. The children start their day in their core group. The first half hour is on social emotional development, usually by a group discussion of recent events or of the children's preoccupations. The core group meets again for half an hour at the end of each school day.

Just as in secondary school, the child is taught by subject professionals instead of a single teacher. There is a permanent coach for the junior years and another one for the senior years. This coach is the permanent contact person and counsellor, keeps track of performance and evaluates this every 6 weeks, with the student and parent using the Individual Development Plan. Normally, 10.30-12pm is given to 'instruction', in the Language studio, the Math studio and the World studio, at their own level and speed. In the afternoons children may choose from a number of workshops and activities and they practise learning materials independently on the Quiet plaza.

String Theory Schools http://stringtheoryschools.com/our-model/

String Theory is a U.S. charter management organisation with four campuses in Philadelphia, all with a focus on performing arts, which together form a K-12 continuum. One of those schools was 'entrusted' to String Theory Schools as part of the School District of Philadelphia's Renaissance Schools initiative. They have the goal to rapidly expand the network on the basis of their technology-based model. Key components of the pedagogical model include:

Creation - The Imagination at Work: The vision is to provide the opportunity for students to explore their interests in the arts, language, science and /or technology that will prepare them for postsecondary studies or for a faster entry into related occupations through a proven model of excellence. The balance between artistic development and academic preparation is fundamental.

iTunes U: Instead of the textbook they use iTunes U - teachers are course designers, creative problem solvers, researchers, collaborative team members, and authorities about instructional strategies and best practices for delivering content as it relates to curriculum standards and student needs. The iTunes U course becomes a collection of resources that students use to retrieve all of their materials. Collectively, students and teachers determine workflows using applications for writing, reading, creating, solving and so forth. Students do not rely on information from a single textbook: teachers guide instruction and ask students to research, analyse, evaluate and draw conclusions and the

students become content curators, resource creators, and designers with a better understanding through collaboration.

Majors (High school level): Students deepen their knowledge and expertise within their Major, as one block per day devoted to the content and practices in that Major. The art-infused curriculum places a premium on both academic and performance excellence. As students develop within their Majors, internships and other opportunities allow them to work with professionals in their chosen fields.

Success Academies www.successacademies.org/our-approach/

Success Academies is a charter management organisation operating primarily elementary and middle schools (and one high school) in New York City. Learning through doing is seen as being at the core of learning so that scholars receive only 80 minutes of direct instruction every day. The rest of the day is devoted to small group instruction and hands-on learning. Beginning in kindergarten, scholars receive hands-on, inquiry-based science five days a week with a dedicated science teacher. Project Based Learning means an intensive, multidisciplinary study of one topic – exploring a topic in such depth brings history to life and allows scholars to develop their own deep insights. Through frequent field studies, scholars discover New York City; recent field studies have included the American Museum of Natural History, Alvin Ailey American Dance Theater, Queens County Farm Museum, and the Big Apple Circus. Not all field studies take place outside the schools.

Reading and Writing - THINK Literacy through which scholars are introduced to great literature, emphasising critical thinking and the thoughtful discussion of ideas. This prepares scholars for different reading and writing challenges they will encounter throughout their education. Math - activity-based investigations blends conceptual understanding with a push for precision and accuracy. The math programme is centred on activity-based investigations, which encourage scholars to work cooperatively and think creatively and develop their own approaches to problem-solving. Chess is compulsory for all students from kindergarten up, as is computer science from the middle school level.

Summit Public Schools www.summitps.org/approach

Summit Public Schools are a charter management organisation which now operates 11 schools on West Coast USA. Summit is currently partnering with Facebook to 'scale personalised learning' by making its Personalised Learning Plan Platform (PLP) freely available to schools across the USA. Teachers play a three-pronged role - as teacher, leader and mentor. They support individual needs, facilitate deeper learning, and encourage students in their development of cognitive skills and Habits of Success. Teachers use data - quantitative and qualitative - to diagnose student needs, and use professional skills and knowledge of best practices to personalise learning. Through the mentor-mentee relationship teachers meet the student several times each week in small-group settings and one-on-one. Mentors get to know their mentees' families and out-of-school life. As leaders, teachers take on a variety of leadership roles, understand the value of collaboration and of a common language and expectations. They share best practices across the network, observe one another's practice, and work as a team.

Project Time: Students develop deeper thinking and life skills through project-based learning. They have Project Time for all of their core courses in English, History, Math, Science, and Spanish (in high school). Summit projects resemble real-world work

experiences, and students use problem-solving, critical thinking, and communication skills to tackle challenging problems. They regularly present their analysis, recommendations and projects because public speaking is a key life skill. Many projects require teamwork and students are graded on their ability to work well with others, listen and participate.

Summit Reads: Every student reads every day for at least 30 minutes. Depending on their individual needs, students will read in groups, independently or with a teacher.

Personalised Learning Time: Students learn the content knowledge they need for all of their courses. They learn through a combination of online playlists, peer-to-peer coaching, and one-on-one tutoring from their teachers, and move at their own pace. Every student has an online Personalised Learning Plan (PLP). Which students use to set goals, access learning resources, submit work, and track their progress.

Summit Solves: Students practice math problems for at least 30 minutes a day and practice on Khan Academy.

Mentor Time: Each student is assigned a teacher mentor who is the student's coach, college counsellor and advocate, and supports them to excel both inside and outside the classroom. Mentors meet weekly with their mentees. Students lead these check-in's, reflecting on the week, and discussing their goals and plans for the coming week. The mentor and family work together to support a student's goals and academic success.

Community Time: Every student at Summit is assigned a mentor and community group. Every student spends at least 1 hour per week with their Community Group and Summit high schools end each day with their group.

Expeditions: For four 2-week sessions throughout the school year, students take a break from their core courses and immerse themselves in electives in which students explore and develop their passions. They may be in the Arts, STEM, Physical and Emotional Well-Being, Leadership and Society, and College and Career Readiness. Students gain real-life experiences and High school students can intern in different fields.

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4. Pedagogies and domains focusing on mathematics, non-native languages, and socio-emotional learning (Marc Lafuente, Educational consultant)

4.1. Introduction

In this chapter, I analyse the affinity of pedagogies with domains which are key for reform endeavours. Are pedagogical innovations equally effective across domains? Or are particular pedagogies especially relevant for particular domains? To what extent are pedagogies sensitive to the specifics of domains and learning goals? This chapter focuses on three specific areas, each with its own priority in education's contemporary agenda:

- Mathematics is a core to curricula everywhere and is fundamental in promoting logical thinking, and to work on science, engineering, and technology-related disciplines (Mevarech and Kramarski, 2014). Attention to pedagogy is needed, given the common pattern of student low engagement and understanding of the subject.
- Non-native language learning is especially important in today's context of increased mobility, communication, and migration - and yet often students struggle with them in school. They are important for cultural understanding (Della et al., 2012).
- Socio-emotional learning is fundamental in achieving personal development and social well-being, as is increasingly recognised in policy (OECD, 2015). How this kind of learning can best be promoted through teaching is thus an important question.

The next sections discuss the sensitivity of pedagogies to domains, the issues arising in working on different learning goals at the same time and what this demands of pedagogies. The main challenges and responses with teaching innovation in the three domains are discussed, using the seven principles of powerful learning from earlier OECD innovation work (Dumont, Istance and Benavides, 2010).

4.2. Pedagogies – domain-neutral?

How independent are pedagogies from domains? Might a pedagogy be equally effective across domains or are specific pedagogies needed for particular domains and learning goals? I understand "domains" as particular fields of study or practice like mathematics, sports or literature, that require specific knowledge, skills and attitudes to practice them. Broadly, there is the "generalist" school of thought proposing that pedagogies can be similarly applied to whatever the subject/domain, and there is the "specialised" approach that considers pedagogies to be domain-specific and hence problematic to transfer across domains.

Behind the generalist school lies the assumption that human development is the acquisition of general human capacities such as understanding or speech. On this view, teaching should primarily contribute to individual development by consolidating domain-

transcending competences like critical thinking and self-regulation. The process and content of teaching/learning are seen as independent: cognition and cognised objects are separable such that learners master the “process” (e.g. critical thinking), and then apply it to whatever contents they have to learn. The teacher’s task is to “pedagogise” subject matter to make it learnable by students (Segall, 2004). Knowledge, skills and attitudes are regarded as easily transferable by students from one domain to another.

The specialised school of thought considers human development to depend on the acquisition and accumulation of knowledge within different domains. Competences do not develop in a vacuum but rather originate through specific knowledge and experiences (e.g. Carey, 1985), and teaching aims at promoting domain-specific knowledge (Deng, 2015). This view is commonly associated with knowledge-centric school curricula. The specialised approach considers that process and content are inextricable and cognition and emotion are always shaped by their object. Pedagogy is inseparable from what is being taught (Segall, 2004): teachers must identify the pedagogical nature of such materials, and work with and around them. In order for transfer to happen, instruction must promote it through explicit and transfer-inducing practices, often working on contextualised and concrete scenarios (Dochy, 1992).

I suggest resolution through a middle position which we may call a “domain-sensitive” approach. In this, pedagogies are seen as shaped by domain specificities, but they also work towards shared underlying aims like enhancing learner engagement, or social interaction and collaboration. Pedagogical innovation is concretised according to what is being taught and learned, but is usually underpinned by common fundamentals of human learning. This position builds on the following ideas:

- Human development needs both knowledge acquisition and skills development and they are mutually interactive.
- Knowledge, skills and attitudes can be domain-specific or domain-transcending.
- All domains have their own specific knowledge, skills and attitudes and differ in the level and mix of these needed for mastery in the domain. But, mastery also needs domain-transcending knowledge, skills and attitudes.
- Learning requires both domain-specific and domain-transcending processes: for instance, learning geometry requires domain-specific concepts and skills, but also general elements like self-regulation skills and persistence.
- Learning transfer does not easily happen across domains but students can achieve reasonable transfer, especially with appropriate teaching. If there was no learning transfer, it would be difficult to explain how learners deal with new situations and information (Alexander and Judy, 1988).

The literature often emphasises teacher’s knowledge of the subject and how to teach it – pedagogical content knowledge (PCK) (Shulman, 1986) - as underpinning different subject pedagogies. However, many other factors contribute to those differences:

- Each domain has its own fundamental epistemic structure and nature which pose their own requirements for pedagogy. A domain’s specific knowledge, skills and attitudes reflect the original human activity through which they were produced, as well as the function they serve (Bosch and Gascón, 2006).
- Teaching in a domain reflects historical traditions in which a subject has been taught in a particular fashion for a long period of time, sustained by such factors as policies, teacher education, popular beliefs about how a subject should be

taught, and low diffusion of domain advances and pedagogical innovation (Silver and Herbst, 2007).

- At the level of school organisation and practice, subjects are filters for teacher practice and through them teachers plan their work, create associations, respond to policy initiatives, and interact with students (Grossman and Stodolsky, 1994). Teachers tend to form sub-cultures with their own beliefs, norms and teaching practices (Drake, Spillane and Hufferd-Ackles, 2001). These are often reinforced institutionally through, for instance, school departments (Grossman and Stodolsky, 1995; Siskin, 1994).
- Teachers' knowledge, beliefs and emotions about their subject define the context in which they teach, making some pedagogies more or less acceptable as consonant with their views (Depaepe et al., 2013; Gess-Newsome, 1999). These beliefs often have their roots in teachers' own experiences as school students and harden early in their teaching careers; later accumulated professional expertise and knowledge may (but often don't) modify such beliefs.

The domain-sensitive approach seeks a middle way between affirming an unambiguous relation between pedagogies and domains and aiming at the innovative pedagogy that will enhance learning across all subjects and domains.

4.3. Competences, domains, learning goals and pedagogical priorities

Learning goals play a decisive role in shaping pedagogies and goals commonly revolve around competences, a competence seen as the capacity to mobilise and use knowledge, skills, and attitudes to meet complex demands or solve complex tasks (Ananiadou and Claro, 2009). Competences, as opposed to content, orients pedagogies towards knowledge integration, interrelating knowledge, skills and attitudes, and towards increasing learning functionality and transfer to specific contexts. Acquiring competences involves mastering typical patterns of using knowledge, skills and attitudes to solve particular kinds of tasks.

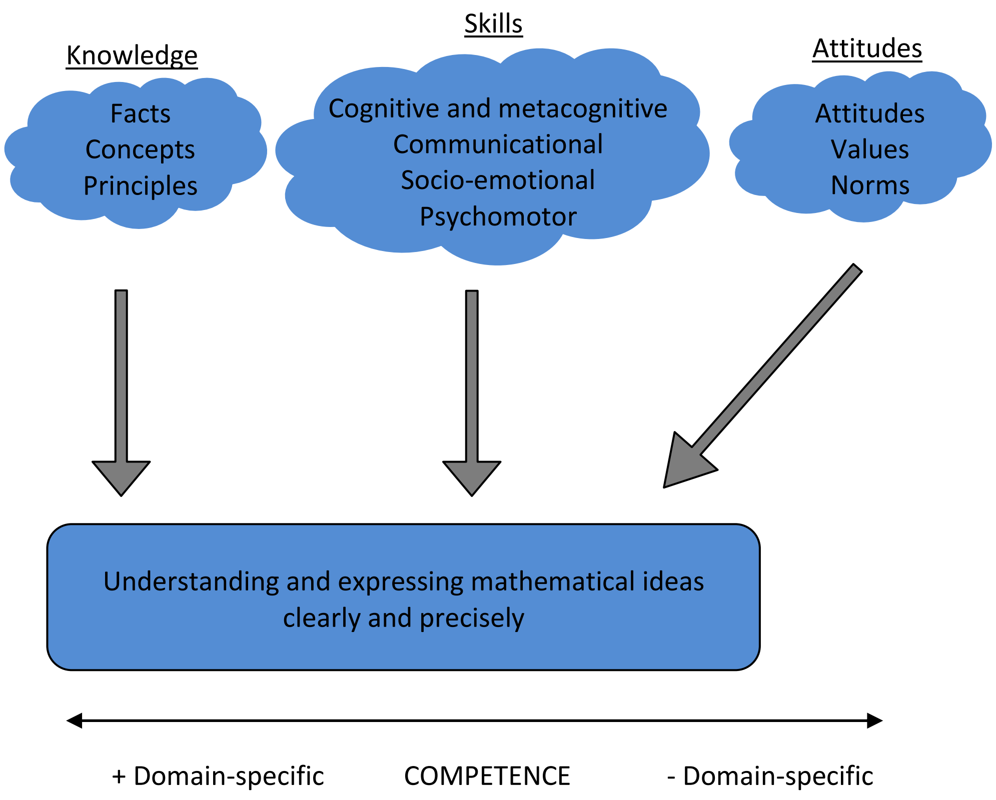
- Knowledge includes facts, concepts and principles that are highly domain-specific in nature like the concept of square root, or the Big Bang theory; however, knowledge also includes domain-transcending elements such as the concept of truth (Dochy and Alexander, 1995).
- Skills embrace the cognitive and metacognitive, communicational, socio-emotional, and psychomotor, as well as domain-transcending procedures like setting one's goals in a certain activity (metacognitive skill). Skills can also be highly domain-specific like visualising and using geometrical models for problem-solving.
- Attitudes are sometimes defined as domain-specific (e.g. the ethical principles of science) but most are applicable across domains such as perseverance in the face of difficulties.

Although knowledge, skills and attitudes present both domain-specific and domain-transcending elements, they vary in the mix: knowledge tends to be more domain-specific than skills, especially when skills rely on heuristic procedures like note-taking or concept-mapping (Pozo and Postigo, 2000), while skills tend to be more domain-specific than attitudes. The domain-specificity of competences can be conceived of as a continuum and the product of two vectors:

- The emphasis placed on knowledge, skills and attitudes; where knowledge acts as an attractor of domain-specificity, and attitudes draw domain-generality.
- The domain-specificity of those components; in which the more domain-related is each of those elements, the more domain-specific will be the competence.

Mathematics is a subject that typically involves domain-specific competences as in such curriculum statements as ‘expressing mathematical ideas clearly and precisely using mathematical language, and understanding others’ ideas’. This competence relies on a large body of mathematical knowledge, including the meaning of particular operations and concepts of algebraic calculations, geometric shapes, etc. The student also requires a large set of often domain-specific skills like performing function representation or using mathematical symbols to represent relations. The emphasis on domain-specific knowledge and skills typically results in highly domain-specific competences (see Figure 4.1).

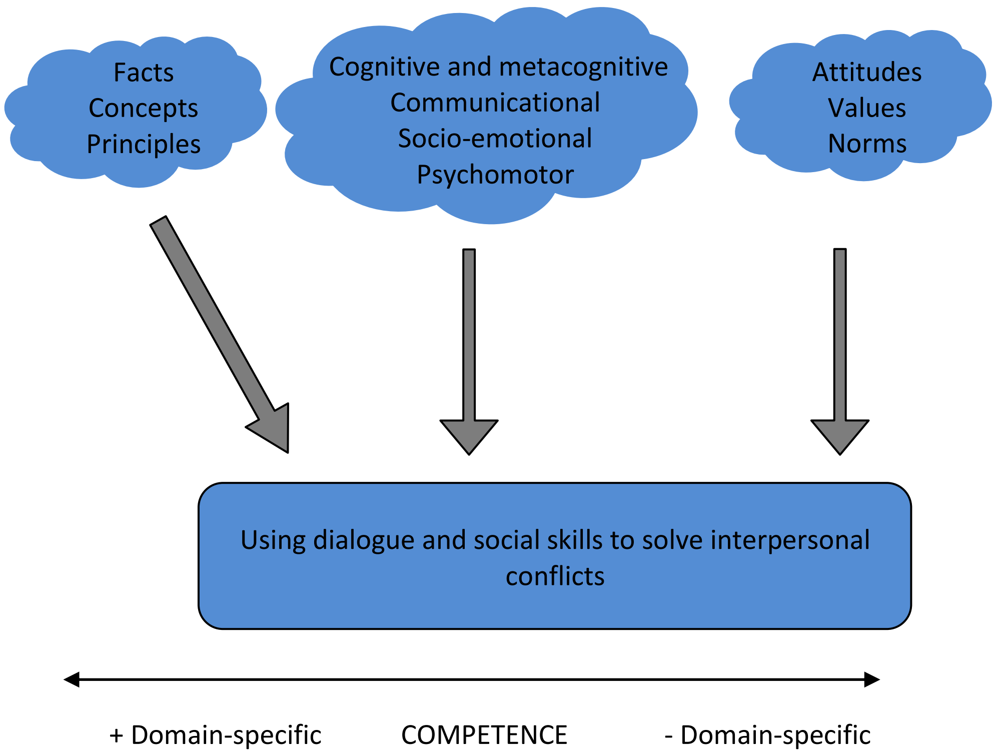
Figure 4.1. A highly domain-specific competence



Socio-emotional education, on the other hand, typically promotes domain-transcending competences, such as in the curriculum statement ‘using dialogue and social skills to solve interpersonal conflicts and promote a peace culture’. The student requires attitudes relevant across many learning tasks and contexts, like accepting plurality and difference or identifying and solving conflicts, and norms such as the rejection of violence. The student also needs skills that can be applied in different contexts and tasks; for example, regulating one’s emotions during discussions or expressing one’s opinions assertively. Although knowledge plays a role, the prominence of transversal attitudes and skills turns

many of the competences into highly domain-transcending (see Figure 4.2) and can be learned and applied in different school subjects.

Figure 4.2. A highly domain-transcending competence



4.3.1. Implications for pedagogy

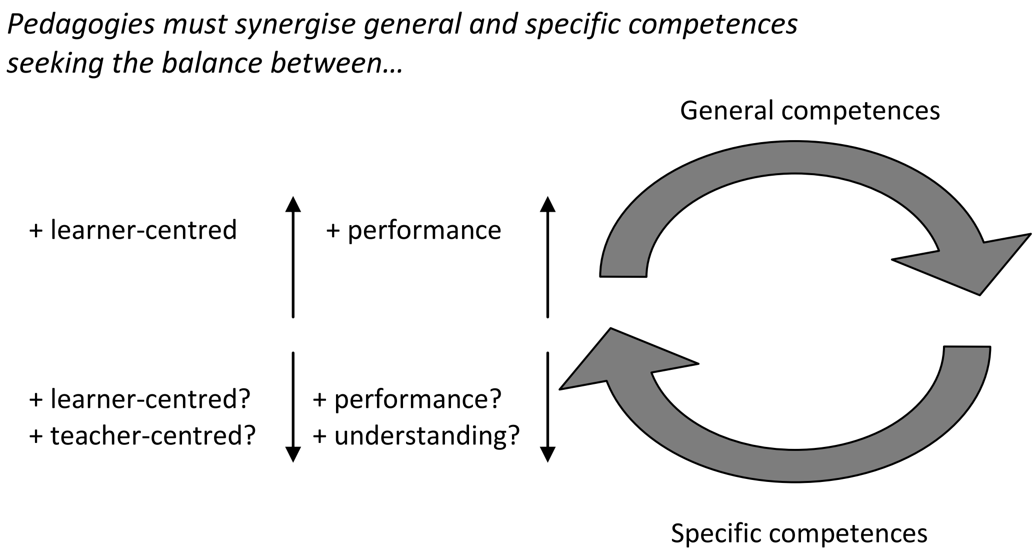
When domain-specific competences are being promoted, pedagogies must be responsive to peculiarities of the subject knowledge and skills, and the nature of the tasks or problems to be solved. Promoting specific competences requires teaching approaches often very different from each other. For instance, in non-native language teaching, fostering understanding oral texts from the academic and daily life will rely mostly on teacher-centred approaches and the promotion of knowledge understanding. The teacher tends to be the most important source of oral language and is best placed to respond to the complexity of student speech. But quite different is a goal such as successfully applying techniques and tactics of different sports. Once basic rules have been grasped, the competence largely relies on performing in real-life situations. It is learner-centred such that student practice leads to the acquisition of disciplines-related techniques and their strategic application. The variability of pedagogical priorities in teaching domain-specific competences is the rationale of the “domain-sensitive approach”.

General competences demand a strong focus on student’s performance, as the student must learn to apply general attitudes and skills to succeed. Learner-centred pedagogies are particularly suitable, such as inquiry-based learning or collaborative learning, as they give the learner an active role and promote the application of key skills and attitudes. Assessment of such competences similarly demands a strong focus on student performance and the use of complex and authentic tasks, rather than being excessively focused on discrete knowledge. This is not to exclude explicit guidance such as teacher

modelling and demonstrations, or the presentation of information, but their use should be framed within a setting where the ultimate objective is to promote student's performance and the adoption of an active role in solving tasks.

General competences like managing and solving conflicts, learning to learn, collaborating, or critical-thinking, transcend domains and there has been a growing policy interest in such competences, especially those described as "21st century competences" (Voogt and Roblin, 2012). This has sometimes led to instructional practices "apart from" or regardless of school subjects and domains whereas fostering them within domains is essential so that students know how to use them in different contexts; indeed, this should be a main objective of instruction (Partnership for 21st Century Skills, 2009). Students should learn the benefits and subtleties of applying those competences in particular domain-related situations; for instance, collaborating in an art project or in solving a mathematical problem may be quite different (UNESCO, 2015). Instruction should accommodate general competences to the pedagogical particularities of the subject and vice versa. This is complex because general competences impose their own pedagogical requirements which then need to be integrated within the pedagogical particularities of domain-related competences.

Figure 4.3. Pedagogies for synergising specific and general competences



Thus, integrating general competences into specific ones is about finding appropriate formulas to sequence and combine pedagogies, in order to promote both kinds of competences at the same time and in ways to boost the learning of each. These formulas should take account not only of the learning goals and the competences to be promoted, but also key aspects of the instructional context. For instance, students' existing level of mastery should strongly influence whether to use teacher- or learner-centred pedagogies in a specific situation: in general, the less able they are to provide internal regulation the more they need explicit guidance (Kalyuga, 2007). Fostering general and specific competences at the same time means adopting sequences and combinations of pedagogies, that find a balance between both teacher-centred and learner-centred approaches, and between focusing on students' understanding and their performance (see Figure 4.3).

4.4. Challenges for pedagogy in mathematics, non-native language and socio-emotional education

This section focuses on teaching challenges in mathematics, non-native language and socio-emotional instruction, identifying what is distinctive in each to which innovation can offer solutions.

4.4.1. Mathematics

Despite mathematics being a policy priority, many challenges of mathematics learning remain unsolved: results are seen as poor and far too many learners (especially female students) feel disengaged (Sriraman and English, 2010). In PISA 2012, for example, fewer than 1 in 100 students performed at the highest level in mathematics and about a third (32%) did not reach the baseline level (Schleicher, 2014).

Mathematics is a domain with a clear internal structure that relies heavily on specific notations to promote the development of logic and abstract thinking skills. Mathematics can cover entirely abstract concepts and relations, and it can also be applied for practical purposes in fields like natural sciences, social sciences or engineering. Traditional teaching has tended to emphasise pure mathematics and more modern approaches have tended towards applied mathematics. Mathematics pedagogies should seek an optimal balance between abstraction and the application of knowledge. Over-emphasis on abstraction can induce loss of interest while over-emphasis on application can induce loss of understanding.

Whereas the nature of mathematics may give some students a positive sense of clearly delineated work and control over contents, too often it is perceived negatively with students feeling a lack of confidence as well as learning anxiety. There are generally adverse motivations and emotions towards mathematics learning compared with other subjects (Punaro and Reeve, 2012; Wigfield and Eccles, 1992, 1994). Research also suggests that students' self-efficacy in mathematics is more tied to their perceived personal ability to do the tasks, compared with other subjects (Stodolsky, Salk and Glaessner, 1991). Negative attitudes towards mathematics learning are often formed early in primary school (Larkin and Jorgensen, 2016). Blatchford (1997) suggests that early differences in student perceptions, such as of higher ability for language learning compared with mathematics, tend to remain throughout the primary and secondary cycles. Perceived high difficulty and lack of confidence (especially for female students) helps to explain student disengagement from mathematics (Brown, Brown, and Bibby, 2008; Köğce et al., 2009; McLeod, 1992).

Some research suggests that mathematics teachers believe that their subject must be more accurately sequenced than other subjects, with more clearly defined content boundaries, and that contents change little over time (Stodolsky and Grossman, 1995). Such "closed" conceptions are associated with pedagogies that draw on isolated, mechanical and routine tasks as often mathematics instruction is more structured and less engaging than other subjects such as social studies (Stodolsky, 1988). Perceptions of the nature of the mathematics can instil a sense of "obviousness" about mathematical concepts and calculations (following clear steps to an evident result). That sense of obviousness clearly reveals and exposes students' mistakes which, if not treated appropriately, may reinforce some students' insecurity and anxiety.

Hence, innovation needs to address the challenge of increasing student engagement and learning outcomes. Often meaning deploying pedagogies using more open, complex and

authentic tasks, such as problem-based, project-based, and inquiry-based learning (Atkinson and Mayo, 2010; Lesh and Zawojewski, 2007; Ruthven, 2011; Savelsbergh et al., 2016). Effective pedagogies need to focus on student's mathematical reasoning and sense-making (Boaler, 2012), fostering a conceptual discourse instead of a calculational one (Cobb and Jackson, 2011). Pedagogies may also promote visualisation and the manipulation of materials to enhance understanding of mathematical relationships (NCTM, 2014; Carbonneau and Marley, 2012). Mathematics teaching may address meta-cognition to improve students' abilities to control mathematics learning (Mevarech and Kramarski, 2014); it may draw on collaborative settings to improve engagement and learning outcomes (e.g. Slavin and Lake, 2008). Some research also suggests that using technology as a complementary support of teacher instruction (e.g. video gaming, computer-assisted instruction) can yield positive results (Steenbergen-Hu and Cooper, 2013). Pedagogies should treat learners' mistakes as a way to promote, not impede, learning (Borasi, 1994; Gresalfi et al., 2009). Some research highlights the value of enhancing growth mind-sets for increasing self-efficacy beliefs and reducing anxiety (Boaler, 2011; Rattan, Good and Dweck, 2012).

4.4.2. Non-native language education

All human languages have an obvious communication function and they also have an internal structure with rules about how to combine phrases, words and morphemes (i.e. grammar). Acquiring a language from birth is a process that is based on the communicative use of such language, and the implicit learning of its grammatical rules. Non-native language acquisition requires something other than implicit or "natural" learning of grammar, and teaching has often responded by (over)emphasising the importance of the explicit learning of grammatical rules at the expense of communication. But this has led to the typical situation in many systems that, after years of non-native language school instruction, the average student still struggles to hold even a basic conversation. The challenge is thus to find pedagogies which make optimal use of instruction time and which yield better results.

As fluency and accuracy are both necessary (Dalili, 2011), the challenge of combining communication and grammar gives a clear direction for innovating with pedagogy. Pedagogy should provide both input to the learner and the opportunity to create output (Wong, 2013). It should ensure that the learning of grammatical form and communication are interconnected, and that they are embedded in meaningful and authentic contexts (Dalili, 2011). Common pedagogies to respond to these challenges are task-based learning (Ellis, 2003), and project-based learning (Chang and Tung, 2009).

Responding to these challenges may mean extending language teaching by connecting it to other contexts - within the school, the meso-system, and the wider world. Examples include using non-native language as an instruction medium in other school subjects, as in bilingual or school immersion (Cummins, 2009); through place-based approaches that lead to study abroad (Collentine, 2009); and using technology to connect learners to communities of practice where they have the chance to interact with native speakers (Black, 2009).

4.4.3. Socio-emotional learning

Socio-emotional education has emerged strongly on educational policy and research agendas. Since socio-emotional education encompasses key transversal competences like collaboration and decision-making, it is increasingly regarded as important for the so-

called 21st century competences. Socio-emotional education may enhance subject-related learning outcomes (Durlak et al., 2011) and it can have a positive impact on students' well-being and the school climate (Djambazova-Popordanoska, 2016). It may in general contribute to social progress and prosperity (OECD, 2015). Socio-emotional education could thus aspire to be a basic and transversal foundation of schooling. Since, however, it is usually not included in formal student assessments or figure in teacher and school accountability (OECD, 2015), this may well weaken the incentives to promote it.

Socio-emotional competences can be learned and applied in many ways so that the challenge for innovation is to promote them across curricular areas and learning contexts. They tend to be addressed through specific subjects (e.g. civic and citizenship education, physical and health education), and/or transversally across many curricular subjects (OECD, 2015), suggesting the value of incentivising interdisciplinary instructional initiatives including appropriate professional development. There is need to integrate socio-emotional learning goals across curricular areas (UNESCO, 2015), using opportunities for meaningful and authentic learning. Likewise, socio-emotional pedagogies need to adopt a communitarian perspective, and mobilise different agents of the student's meso-system (Cohen et al., 2015; Elias, 2014; Thapa et al., 2013). Instruction is especially effective when it is embedded in change addressing the whole school climate.

The socio-emotional domain refers to the conjunction of the emotional and the social. It embraces both competences referred to the "self" (and, especially to the emotions and feelings produced by oneself), and to the sphere of social relationships (CASEL, 2005). Self-related competences include, for example, self-awareness and self-management. Social competences include for instance social awareness and relationship skills. Therefore, socio-emotional pedagogies should aim at the appropriate integration of working with the learners' personal feelings and thoughts, and acting on their social relationships.

Pedagogical innovations in the socio-emotional domain include, for instance, active and performance-based pedagogies that work on students' personal feelings and their relationships like role-playing, collaborative-based pedagogies, gaming, case study work, and social problem-solving (Durlak et al., 2011; Durlak, Weissberg and Pachan, 2010; Rimm-Kaufman and Hulleman, 2015). A strong focus on learner-centred pedagogies and the performance-based is consistent with the finding that social studies teachers overall tend to conceive of their subject as less defined, less sequential, and more dynamic than other subjects (Stodolsky and Grossman, 1995), and they use less structured approaches, and a wider range of tasks to engage students (Stodolsky, 1988). Collaborative approaches like small group learning, and socially interactive pedagogies involving discussion are especially important for promoting communication and emotional skills, as well as pro-social attitudes (Sprung et al., 2015; Yoder, 2014; Zins and Elias, 2007). Mindfulness, where students focus on their current emotions and experiences, has gained in prominence and some research supports its implementation (Frank, Jennings and Greenberg, 2013; Zoogman et al., 2015).

4.5. Domains and the OECD/ILE learning principles

4.5.1. Pedagogies for learner engagement

The first principle of powerful learning establishes that "the learning environment recognises the learners as its core participants, encourages their active engagement and

develops in them an understanding of their own activity as learners" (Dumont, Istance and Benavides, 2010: 14).

Increased engagement, in mathematics and other domains, often means adoption of problem-solving, project-based, and inquiry-based approaches (Atkinson and Mayo, 2010; English and Sriraman, 2010; Ruthven, 2011; Savelsbergh et al., 2016). Problem-solving usually revolves around a central problem or task that the student must solve (and sometimes pose); project-based approaches involve planning and managing more complex and longitudinal tasks to create artefacts or give responses to mathematical challenges; inquiry approaches involve students devising research questions and methods, collecting and analysing data, and interpreting the results. These pedagogies face important challenges like:

- coupling learning of problem-solving skills with understanding knowledge of mathematics;
- implementing effective scaffolding strategies to sustain learning;
- resistance to abandoning routine and decontextualised tasks as the main means of learning.

These are challenges for approaches that rely on real-life, complex, non-routine tasks that invite students to create artefacts and interpret situations, allowing them flexibly to use mathematical procedures and domain-transcending skills (NCTM, 2014).

Pedagogies based on metacognition have been used for increasing student's engagement and improving their capacity for self-regulation (e.g. Mevarech and Kramarski, 2014), with teachers scaffolding by posing certain questions and helping students find answers for promoting comprehension and strategic thinking. Other strategies to enhance engagement include promoting visualisation of mathematical relationships to deepen understanding, using diverse representations like diagrams, graphical displays and symbols (Flores et al., 2015). Pedagogies may foster students' physical interaction with objects to learn specific contents – manipulative-based pedagogies (Carbonneau and Marley, 2012), such as using play money to teach arithmetic functions, or algebra tiles to teach multiplication and division skills. Meta-research studies show small to moderate effect sizes in favour of such approaches compared with instruction that only uses symbolic information (Carbonneau, Marley and Selig, 2013).

Encouraging reasoning and sense-making is key for students to feel more engaged with mathematics (Boaler, 2012); fostering understanding of tasks and contents increases agency over the mathematical domain and shows transfer into adulthood. Some research shows the benefits of engaging students through discussion-based approaches, explaining their own mathematical ideas and connecting these with other students' ideas (e.g. Ing et al., 2015). These pedagogies promote a conceptual discourse, with students explaining why they used certain mathematical procedures, instead of a calculational discourse in which students explain how they achieved the result (Cobb and Jackson, 2011; Webb et al., 2014). Some studies focus on students' identity as mathematics learners (Andersson, Valero and Meaney, 2015; Gresalfi and Cobb, 2011), and their "sense of belonging" to mathematics – student's feelings of membership in the mathematics domain (Good, Rattan and Dweck, 2012). This helps to understand engagement in mathematics learning, including female students' lower outcomes and desire to continue in maths in their futures, and suggests the value of working on student's self-definition as mathematics learners, as well as their past experiences and their expectations with the subject.

For non-native language teaching, pedagogies engage students when they foster both mental representation of that language, and the ability to use it functionally (Van Patten and Benati, 2010). Pedagogies should both structure well-designed input to the student and engage them in generating meaningful output (Wong, 2013). Mirroring certain of the examples in mathematics teaching, common pedagogical approaches include task-based (Ellis, 2003) and project-based learning (Chang and Tung, 2009). Tasks are not "exercises" but are based on real-life situations and emphasise meaning not linguistic structures. Such approaches provide opportunities to explore and experiment with non-native language through the authentic, meaningful and functional use of language. Comprehension and the analysis of grammar are also encouraged, but communicating remains the primary focus (Long, 1991; Nassaji and Fotos, 2010). Other examples in language teaching to increase student engagement include:

- Drama and movement-based teaching especially for young learners, where kinaesthetic activities help develop decoding skills, vocabulary, and fluency (Rieg and Paquette, 2009), though there is no firm evidence on its impact on learning (Belliveau and Kim, 2013).
- Storytelling, where students engage role-play or create a digital narrative around a particular plot and characters; there is some evidence of positive impact on learning outcomes, especially at the primary level (Moodie and Nam, 2016).
- Computer-Assisted Language Learning (CALL), where the technology supports vocabulary acquisition and pronunciation skills (Golonka et al., 2014; Presson, Davy and MacWhinney, 2013) using, for example, map tours, subtitled video, chat rooms and learning games. There is some evidence to support the enhancement of learner engagement (Golonka et al., 2014), especially as regards pronunciation training and chat.

Teaching for socio-emotional learning tends to emphasise active and performance-based pedagogies (Durlak et al., 2011; Reyes and Elias, 2011). Practice is necessary for the acquisition of socio-emotional competences and therefore student performance is essential. Role playing, gaming, collaborative-based pedagogies, discussion-based learning, case-study, (social) problem-based pedagogies, and service-learning have all featured in meta-studies as potentially effective pedagogies for socio-emotional learning (CASEL, 2013; Clarke et al., 2015; Durlak et al., 2011; Payton et al., 2008; Rimm-Kaufman and Hulleman, 2015; Sprung et al., 2015; Zins and Elias, 2007). These pedagogical approaches focus on students' personal feelings and relationships. Used with the teacher providing appropriate support through information, modelling and feedback, these pedagogies may foster the practise and acquisition of new behaviours.

A common feature of pedagogies to engage students in socio-emotional learning is inducing behaviour change through the student's own ability to self-regulate, creating situations in which students can be self-directive and activating meta-cognitive and meta-affective processes (Domitrovich, Cortes and Greenberg, 2007). Teachers help students to identify the consequences of particular actions while avoiding over-management of student behaviour (Yoder, 2014). Students may be given increased autonomy and responsibility, through ways such as, for instance, giving students structured and meaningful choices such as in helping to create classroom rules (Rimm-Kaufman and Hulleman, 2015).

4.5.2. Pedagogies for social learning

Powerful learning is based on the development of social activities that can sustain learning. According to Dumont, Istance and Benavides (2010: 15), "The learning environment is founded on the social nature of learning and actively encourages well-organised co-operative learning".

In mathematics instruction, strong effects are associated with cooperative-learning (Slavin and Lake, 2008; Slavin, Lake and Groff, 2009), with all in small groups contributing (Cobb and Jackson, 2011) and where teachers guide learners and resolve doubts only when necessary. Through discussion, students can raise productive cognitive conflicts arising from different interpretations, which can facilitate the reorganisation of their mathematical reasoning. Collaboration underpins much of technology's potential in mathematics instruction when technology complements the teacher – Supplemental Computer-Assisted Instruction - rather than just delivering instruction – Computer-Management Learning (Cheung and Slavin, 2013; Steenbergen-Hu and Cooper, 2013). Similarly, videogames work better when used by highly interactive teachers (Atkinson and Mayo, 2010) with great potential to promote collaboration.

Collaboration and social interaction obviously underpin non-native language teaching and learning. Developing instructional conversation is important for integrating communication and grammar, and teachers need to support learners using meaningful interaction in verbal exchanges while bringing out grammatical forms (Dalili, 2011). Language minority children can especially benefit from cooperative learning (Cheung and Slavin, 2012), and in particular with one-to-one tutoring and small group learning. Technology opens new avenues to change traditional teacher-centred instruction, for example, by facilitating communication with native speakers through social networking sites, or establishing communities through virtual worlds (e.g. Chen, 2016). Mobile devices especially can support language learning when they support different approaches based on a mix of pedagogies that includes social interaction, such as self-directed study and a collaborative learning task (Sung, Chang and Yang, 2015).

The value of social and collaborative settings for socio-emotional teaching and learning is obvious, because they represent both the means and the final purpose of such instruction. Collaborative approaches like small group learning and socially interactive ones like role-playing and social problem-solving are recurrent, commonly proposed for promoting socio-emotional competences. When socio-emotional education crosses subjects, there is common value in collaborative learning pedagogies, with students working towards collective goals, gaining communication and emotional skills as well as pro-social attitudes (Yoder, 2014; Zins and Elias, 2007). Other socially interactive pedagogies like social problem-solving engage students by inviting them to bring in their own viewpoints and feelings, and to engage in dialogue critically and respectfully. Teachers support the discussion, ensuring that everyone has sufficient to hold a meaningful dialogue.

Pedagogies addressing socio-emotional learning may indeed have a recursive positive effect on outcomes across subjects through addressing social dimensions of learning (Durlak et al., 2011). The teaching can build on social factors that sustain powerful learning such as improved student-teacher and peer-to-peer interactions, or enhanced classroom and school climate (Zins and Elias, 2007). Teaching for socio-emotional learning can help combat dropping out of school by improving relations with peers or teachers and reducing the sense of feeling left out. This is especially true for virtual educational settings, where socio-emotional connections are key to keeping students engaged (Delahunty, Verenikina and Jones, 2014).

4.5.3. Pedagogies sensitive to motivations and emotions

Emotions, affect and motivation are key aspects of powerful learning: "The learning professionals within the learning environment are highly attuned to the learners' motivations and the key role of emotions in achievement" (Dumont, Istance and Benavides, 2010: 15).

Regarding mathematics, innovation in relation to emotions addresses at least two interrelated barriers to learning: fixed mind-sets about mathematics talent and maths anxiety. Pedagogies should be founded on growth mind-set messages because they have a large positive impact on student's attainment (Boaler, 2013; Rattan, Good and Dweck, 2012). Conversely, pedagogies that rely on fixed ability thinking, such as rigidly grouping students by their prior competences and outcomes, risk the opposite. There is also the issue of mathematics anxiety (Dowker, Sarkar and Looi, 2016). Some studies distinguish between anxiety as a state, felt when facing certain mathematical tasks, and anxiety as trait – the stable attitude of feeling anxiety towards the mathematical domain (Buckley et al., 2016). There is thus a double challenge: preventing the immediate anxiety in the short term, and increasing engagement over the longer term.

Three ingredients emerge for innovation through pedagogies to promote growth mind-sets and prevent mathematics anxiety:

- Encouraging learning progress and awareness, encouraging every student to advance and fostering self-awareness of progress.
- Treating mistakes productively, enhancing mathematics learning while preserving self-esteem and self-efficacy. Pedagogies should treat mistakes as opportunities for learning (Ingram, Pitt and Baldry, 2015), providing conceptual and procedural tools to address errors.
- Emphasising mathematical processes instead of final results, avoiding over-emphasis of "right answers and right methods", and developing reasoning and doing mathematics (Philipp, 2007). Learning assessment shifts from appraising "the final answer" to evaluating student's comprehension (Näslund-Hadley, Cabrol and Ibarraran, 2009).

Experiences around assessment for learning suggest that when students are assessed and given feedback throughout their learning, their mathematics anxiety is lower (Núñez-Peña, Bono and Suárez-Pellicioni, 2015), becoming more aware of their advances and difficulties and empowered to further learning.

Innovation in non-native language instruction has also focused on preventing language anxiety (Hashemi and Abbasi, 2013), which is more prevalent in listening and speaking tasks (Horwitz and Young, 1991). The goal should be to find ways to help students overcome their anxiety. Common sources of language anxiety are: excessively demanding expectations by teachers; very formal classroom settings; giving presentations in front of others; and fear of making mistakes and of losing positive image in front of teachers and peers.

Research supports (Hashemi and Abbasi, 2013):

- Treating linguistic mistakes naturally, providing constructive feedback but not interrupting the communication flow.
- Discussing emotions overtly, making clear that feelings of insecurity and uneasiness are very common while speaking a non-native language.

- Encouraging all students to participate in collective activities, not just those who regularly speak up, reassuring and positively reinforcing their performance.
- Setting high but realistic expectations for every student and avoiding the perfectionism of perfect pronunciation or faultless grammar.
- Making the classroom environment more informal, like using gaming or drama-based pedagogy.

"Integrativeness" is key for promoting student's motivation (Gardner, 2006) - promoting positive attitudes towards the non-native language community and interest in acquiring their language. This may mean promoting student interaction with native speakers and knowledge about their community, such as study abroad, discussion and collaborative pedagogies through technology.

With socio-emotional learning, student emotions are both the medium and the final goal. Education for socio-emotional development generally yields positive outcomes regarding self-perception and attachment to school, and less distress and disruptive behaviour (Payton et al., 2008; Rimm-Kaufman and Hulleman, 2015), which in turn are likely to have a positive impact on other learning outcomes (Durlak et al., 2011). Emotion and cognition are more integrated than previously thought (D'Mello and Graesser, 2012; Immordino-Yang and Damasio, 2007), so there is good reason to seek emotional improvement not only for its own sake but as part of the cognitive.

One approach that has gained attention in recent years is mindfulness, which focuses on experience and emotions to enhance well-being (Baer, 2003). It may target either the teacher or the students. With teachers, it aims to both increase the teacher's well-being, and indirectly to improve classroom climate and student academic outcomes (Jennings et al., 2011; Roeser et al., 2013). When addressed to students, mindfulness aims to promote emotions regulation, stress control, and the identification of somatic symptoms (Zoogman et al., 2015), and is compatible with diverse approaches such as discussion-based learning or role-playing. Socio-emotional programmes have also been used for addressing school violence (e.g. Cedeno et al., 2010), by enhancing students' feelings of belonging to the school and coping skills, and improving school climate (Thapa et al., 2013). Such experiences suggest the value of targeting specific emotional processes: giving students a voice and involving them in school issues; using collaborative and social pedagogies; avoiding discrimination and counteracting stereotypes; and communicating high expectations and recognising student's efforts.

4.5.4. Pedagogies to recognise individual differences

Powerful pedagogies consider every student's learning needs and include every learner in the educational process: "The learning environment is acutely sensitive to the individual differences among the learners in it, including their prior knowledge" (Dumont, Istance and Benavides, 2010: 16).

Research and innovative mathematics pedagogies often acknowledge the need to reach all students and a multiplicity of student factors produce differences in how they learn mathematics. Two main variables have had most attention regarding mathematics learning: gender and socio-cultural background (Pais, 2012). On gender, there is an interaction between biological factors, students' personal beliefs and emotions (mathematics anxiety), the perceived future usefulness of maths, and teachers' differential treatment (Jacobs, 2010). Pedagogical design should take account of the cultural beliefs and stereotypes underlying these differences (Mendick, 2005; Gherasim, Butnaru and Mairean, 2013; Kaiser, 2010):

- Avoiding grouping or tracking measures can discriminate students according to their gender (Esmonde, 2009).
- Avoiding pedagogies that might favour boys such as favouring competitive approaches rather than collaborative and supportive ones.
- Using pedagogies that emphasise discussion - talking and writing about emotions and addressing not only cognitive aspects (e.g. Park, Ramírez and Beilock, 2014) may be beneficial for students less engaged with the domain.

Socio-economic and cultural background influences how students talk and reason about mathematics, and how they shape classroom norms and practices (Cobb and Hodge, 2002). Some propose contextualising learning tasks into the cultural contexts of students, including place-based learning experiences, as an opportunity to improve understanding of mathematical content (González, McIntyre and Rosebery, 2001). Similar proposals are to de-track grouping where tasks are appropriate for different levels (e.g. Boaler, 2008; Marks, 2014), so as to capitalise on student diversity as a resource for teaching instead of as problematic.

Educational neuroscience offers another avenue for analysing individual differences in mathematics learning. Research has identified how brain areas are activated differently for different learners on certain mathematical tasks, hence opening the way for better understanding the biological foundations of individual differences (Looi et al., 2016). Such research has not, however, produced practical outcomes to shape more effective pedagogies (Campbell, 2010).

With non-native language teaching, research on language acquisition has traditionally pointed to age as the key to predicting facility of language learning (Long, 1990): the younger the learner, the more they rely on natural communication to acquire language and will do it more quickly; the older the learner, the more they deliberately acquire knowledge, while meta-knowledge becoming more difficult to improve. This would suggest that pedagogies should be based on communication early on and from a certain age should be mixed with more formal approaches. There is, however, lack of evidence about clear maturational cut-off points associated critical periods for learning a non-native language (Muñoz and Singleton, 2011), and many variables other than age are involved such as similarity between native and non-native language and the learners' attitudes and motivations (Lindgren and Muñoz, 2013). Background and the conventions of the student's socio-cultural group have an impact (García et al., 2010), and emotions are not homogeneous across cultures with some displaying higher language anxiety levels than others (Woodrow and Chapman, 2002).

Language minority children, who start at a disadvantage, often catch up during primary school if appropriate measures are adopted (Chen, Geva and Schwartz, 2012). Some research supports bilingual school immersion, where the societal language is learned across subjects with a content-based pedagogy providing a language focus within subject matter activities (Dalton-Puffer, 2011). Nevertheless, a daily block of time may also be devoted to language learning itself (Saunders, Goldenberg and Marcelletti, 2013), though it may be best during this period to group students by language proficiency.

Teaching for socio-emotional learning is also developing understanding of the role of individual differences and how to respond to different student profiles, especially related to gender and socio-cultural background. Some suggest that girls' advantage in such competences are already visible by the early school years, with boys more aggressive and less pro-social (Keenan and Shaw, 1997; LaFreniere and Dumas, 1996), and less able to identify emotions (McClure, 2000). Similarly, children from disadvantaged socio-

economic backgrounds tend to show less socio-emotional competence visible from the early stages of their development (Campbell and Stauffenberg, 2008; Ryan, Fauth and Brooks-Gunn, 2006).

Denham et al. (2012) advocate a person-centred approach to socio-emotional education, given that not all have the same learning needs, and identified different socio-emotional profiles in early childhood learners:

- *At-risk*: those having trouble understanding emotions and regulating their behaviour, with aggressive patterns for problem-solving and the common display of negative emotions;
- *Competent-restraint*: those generally socio-emotional competent but with aggressive responses to problem-solving, and less social interaction;
- *Competent social-expressive*: commonly displaying good competence in all aspects.

Personalised approaches can benefit everyone, but especially those with an at-risk profile. Some studies suggest that socio-emotional education may contribute to student resilience, though the evidence base is not well developed (Ager, 2013). Socio-emotional programmes should be adapted to the student and provide learning objectives and tasks suitable for their socio-cultural background (Elias and Haynes, 2008).

4.5.5. Pedagogies to challenge students

Pedagogies are effective when they promote learning that pushes students with tasks that require effort: "The learning environment devises programmes that demand hard work and challenge from all without excessive overload" (Dumont, Istance and Benavides, 2010: 16).

In mathematics, the learning task difficulty should be adjustable to the learner, and should challenge them to reason through multiple resources like graphics or puzzles (Boaler, 2012). Overall, the sequence of learning tasks should present an increasing degree of difficulty, whereby the student reaches further understanding and performance (Cobb et al., 2011). The balance between challenge and support underlies concerns about learner-centred approaches (e.g. problem-solving, project-based learning and discovery learning), in mathematics as well as in other domains (Kirschner, Sweller and Clark, 2006). Problem-solving requires mastering complex and difficult skills like strategic thinking, meta-cognitive and social skills, as well as conceptual knowledge (English and Sriraman, 2010). Project-based learning requires that students develop worthwhile questions, plan and monitor complex tasks, and collaborate effectively (Atkinson and Mayo, 2010). It is unlikely that all these elements can be acquired by students exclusively working on their own. Therefore, learner-centred approaches should ensure that students have the necessary knowledge, skills and attitudes which means complementary teacher-centred strategies such as modelling or lecturing as necessary.

Appropriate scaffolding is also important to avoid disengagement from mathematics (Guifford, 2014). Some research shows that short, intensive one-on-one tutoring programmes can alleviate mathematics anxiety (Supekar et al., 2015). Others have suggested the value of problem-posing, a variant of problem-based learning, in which students are challenged to come up with their own problem formulations (Cai et al., 2015). Some emphasise creativity in mathematics learning (Mann, 2006), and of using open-ended tasks and critical thinking (Lev-Zamir and Leikin, 2011). Creativity is seen as

an essential component of mathematics learning enabling the elaboration of constructs and abstract ideas.

Making tasks progressively more demanding is important in non-native language teaching as well (Barcroft, 2012), with pedagogies that mean the learner is constantly challenged to understand more difficult input, and to produce more complex and correct output. For input, the student can be frequently presented with new words, expressions, grammatical forms, and text genres, whether through intentional learning, following designed sequences and materials, or through incidental learning such as acquiring new vocabulary through informal or unplanned messages (Sharples et al., 2015). For the output, students may be "pushed" to produce specific linguistic forms in the context of meaningful tasks (Dalili, 2011) in an increasingly fluent and correct fashion, whether through speaking or writing. Students are challenged to use new words and forms in a variety of contexts that go beyond the examples given and teaching aims to facilitate the production of ever-more complex and correct output (Barcroft, 2012). Providing scaffolding support at different stages of the student's output production is commonly identified by research as helpful (e.g. Schwieter, 2010). Ensuring that students have understood the task, and that they have the sufficient knowledge and skills to complete it, helps to relieve language anxiety (Hashemi and Abbasi, 2013). The early stages of non-native language learning are crucial and the pedagogical choices made should avoid learning tasks that bring early frustration and ensure that the student is progressing before moving forward to more difficult tasks.

Challenging students and providing supporting structures are also important in effective teaching for socio-emotional competence. It demands sufficient time and attention, using diverse learning tasks (Durlak, Weissberg and Pachan, 2010; Durlak et al., 2011). Students may be challenged to reflect on the different attitudes, skills and knowledge required to exercise different socio-emotional competences; teachers should ensure that students grasp them using challenging but not excessively demanding goals. Tasks are planned considering the developmental level of all students, looking to stretch it (Zins and Elias, 2007). Teachers should be aware of every student's individual emotional development and sociability, looking to push them further. Scaffolding helps, with the teaching providing support especially early on like introducing or modelling a certain competence, perhaps showing how to react in the face of conflict. Teachers provide less assistance over time, intervening when necessary and taking advantage of natural "teachable moments" (Domitrovich, Cortes and Greenberg, 2007). The aim is to make students more independent and socio-emotionally competent.

4.5.6. Pedagogies for formative assessment and feedback

Powerful pedagogies integrate assessment that enriches learning, when what is expected from students is clear, and when it provides information to help close the gap between current and expected performance: "The learning environment operates with clarity of expectations and deploys assessment strategies consistent with these expectations; there is strong emphasis on formative feedback to support learning" (Dumont, Istance and Benavides, 2010: 17).

Research and innovation experiences in mathematics education tend to de-emphasise occasional summative assessments at the end of lessons. They suggest clearly different approaches from traditional methods of correction in favour of generating continuous evidence about performance and understanding – formative assessment (NCTM, 2014). This better assesses student's progress and provides more accurate feedback, adjusting

instruction to further promote learning. Assessment practices should align with more open-ended, complex and authentic mathematics tasks (Jones and Inglis, 2015), coherently using such pedagogical approaches as problem-based assessment which are more revealing of the student's competence in the targeted problems than closed, mechanical tasks that assess discrete and de-contextualised knowledge and skills. It suggests greater focus on students' intentions and approaches to solving the task, using different assessment criteria as in rubrics assessment (Diefes-Dux et al., 2012). Feedback should be not only about the correctness of results ("corrective feedback"), but also about the student's performance and how to improve in the future ("elaborative feedback").

Formative assessment and feedback through complex and authentic tasks show a pathway to innovation in mathematics assessment, and technology has an important role to play. The use of digital tools such as video-games and virtual scenarios can mine data on the student's performance on complex situations (Dede, 2014; Fisch et al., 2011), in which information is continuously gathered on mathematical reasoning and skills. Feedback may be automatically provided to the student by the technology, or given by the teacher upon observing the student and analysing available data (or both). However used, it is valuable to have key information about performance to inform teaching.

Research and innovation programmes on non-native language teaching similar emphasise the use of formative assessment. The traditional use of standardised tests for summative purposes like promoting students to the next level has focused on measuring the student's proficiency, with little feedback to improve learning (Kunnan and Jang, 2009). There is need, therefore, to move towards classroom-based methods to assess the student progress, allowing tasks that are more coherent with previous learning, more adapted to local particularities, and more authentic and complex. Greater emphasis on teacher-constructed and teacher-assessed tasks and assessments can be beneficial (East and Scott, 2011). Authentic, complex and performance-based tasks assess not only input-related skills – reading and listening - but also output-related ones – writing and speaking. Some (e.g. Bachman and Palmer, 2010) claim that tasks should not be artificially separated by one skill such as a listening or speaking test, but should involve a mix as in real-life. Such assessment practices often involve open and meaningful output: for instance, digital stories where learners compile photo, video, audio and text materials to produce personal narratives (Rowinsky-Geurts, 2013); written essays/reports on certain topics; portfolios where students gather and reflect on evidence about their learning; performances such as role-plays, debates or discussions (face-to-face or through chats, virtual worlds or serious games). The use of automated CALL environments can make accurate diagnosis of specific skills like pronunciation or mastery of rules (Presson, Davy and MacWhinney, 2013). However, current environments have serious limitations to diagnose performance in complex tasks and so might be better used as a complement to other forms of assessment and feedback.

Assessment should go beyond appraising mastery to further improving it – assessment for learning. This means a shift from the static to the dynamic, with interaction whereby the assessor responds to the student's difficulties with appropriate support and feedback (Leung, 2007). When such feedback is based on knowledge of students and their progression, it can be tailored accordingly. Such approaches can also help to decrease students' language anxiety (Hashemi and Abbasi, 2013).

Research suggests that teaching related to socio-emotional learning is more effective when driven by clear learning objectives, which facilitates explicit communication with students and clarity about what is expected and the assessment standards (Durlak et al.,

2011). Students need to be aware of socio-emotional learning objectives and the consequences of their behaviour on assessment, which may be more difficult when socio-emotional education is infused across subjects. Some recommend using standardised tests for assessment purposes (Denham, Ji and Hamre, 2010; Haggerty, Elgin and Woolley, 2011), and arguably such tools are cost-effective, easy to administer, and possess measurement reliability and validity (Kendziora et al, 2011). However, their exclusive use promotes assessment of learning, instead of assessment for learning. Such tools are usually administered at the end of a programme, and are commonly disconnected from prior learning without specific feedback on how to improve. Formative assessment is likely to offer students greater insights through real-time feedback on their socio-emotional strengths and areas of need.

Performance-based tasks may be appropriate to promote socio-emotional learning, with teachers setting tasks that activate students' skills and attitudes such as collaboration, problem- or conflict-solving, debates, role-playing, etc. It may take advantage of situations that emerge naturally such as conflict between classmates or collective decision-making to assess students' competences. Teachers' observations may be necessary for gathering relevant data and keeping track of student progression, with clear assessment criteria and repeated observations to ensure reliable assessment. Some recommend using self-assessment procedures (Kendziora et al., 2011), guided and designed according to the student's developmental stage.

4.5.7. Pedagogies for horizontal connectedness

Powerful pedagogies will enrich learning by making connections: "The learning environment strongly promotes 'horizontal connectedness' across areas of knowledge and subjects as well as to the community and the wider world" (Dumont, Istance and Benavides, 2010: 17).

In mathematics, there is the challenge of innovating with pedagogies that overcome excessively closed, routine and highly de-contextualised tasks without any connection to other domains or real-life contexts. A common response has been problem-, inquiry-, and project-based approaches. With problem-solving and modelling, the learner may be presented with a problem and then create rules or artefacts to accomplish certain goals (Lesh and Zawojewski, 2007). There has been a longstanding interest in multidisciplinary problems with the aim of enhancing learning transfer. Such approaches are complex and assume that the student has the knowledge and skills to perform adequately, as well as having guidance to facilitate the transfer. Such approaches must be well-designed and demand high levels of coordination of the teaching from the different domains. Project-based learning and inquiry-based pedagogies often involve challenging real-world tasks that call for competences from different domains, as well as general abilities like self-regulation. Given that these two approaches facilitate interdisciplinary teaching, they have often been used to develop mathematics in science-related, STEM education (Näslund-Hadley and Bando, 2015; Ruthven, 2011).

Some pedagogical approaches may assume inter-disciplinarity. For instance, history-based mathematics uses historical contexts to frame mathematical contents (Fauvel and van Maanen, 2002): illustrating mathematical contents with historical facts; introducing historical problems to work on mathematical content; or establishing history as a frame to sequence mathematical contents chronologically (Jankvist, 2011). Some studies suggest that such approaches can improve maths outcomes (e.g. Lim and Chapman, 2015).

Context-based pedagogy and extra-curricular activities intend to engage learners including in maths (Savelsbergh, 2016). With context-based pedagogies, students develop tasks emphasising the relevance and applicability of mathematics in society and their personal lives. Extra-curricular activities are developed outside the classroom environment but they are connected to curricular activities (e.g. lab visits, guest lectures).

Interdisciplinary instruction is also seen as a means to improve language learning outcomes. In some cases, students are taught regular school subjects both in their native and in another non-native language – bilingual or school immersion (Cummins, 2009). Such approaches in general need:

- having well-planned instruction, where teaching in both languages is well organised and distributed across the subjects to achieve proficiency in the two languages;
- maintaining those programmes for long periods of time, for instance throughout primary school;
- giving sufficient priority to teaching through the non-native language, assigning it at least half the instructional time.

Although such programmes have tended to separate instruction in one language or the other – having two distinct monolingual teaching environments – some advocate using the native language to support the learning of the non-native language, and such an approach may work as well with language-minority students. Many conclude that language-minority children benefit more from bilingual education than from non-native language monolingual instruction (Cheung and Slavin, 2012; Cummins, 2012).

Connecting non-native language instruction to the student's wider world is also being explored in innovations. For instance, place-based learning may be used to improve language learning in study abroad experiences (Collentine, 2009), which are good opportunities to enhance fluency. Such experiences are effective when they are well-designed; prepare the student in advance with appropriate levels of grammar and vocabulary, as well as metacognitive strategies such as monitoring and self-correction; when school teaching and in-place teaching practices are coordinated; and when in-place instruction includes grammar to complement learning through communicative daily contexts. Language learning outcomes are closely related to exposure to the language in out-of-school contexts, for example, listening to music with lyrics, and especially watching subtitled audio-visuals (Lindgren and Muñoz, 2013). Studies on watching TV and films with same-language subtitles shows positive results (Vanderplank, 2016). Teaching that brings students to interact with captions as in freeze-framing subtitles, or identifying and defining unknown words, might be worthwhile.

Technology is a promising way to achieve synergies with out-of-school contexts through specific classroom tasks and projects. Learners can engage with real community players, and through chat or forums can interact with native speakers and learn common textual artefacts (Black, 2009). These approaches allow learners first to observe and then use real, popular and culturally-valid forms of communication (Fandiño, 2013). There may also be synergies with non-formal settings like the popular technological applications and platforms used for non-native language acquisition. Such applications include features to increase learners' motivation such as social collaboration, game-like features such as scoring, adaptive difficulty, and the lower emphasis on explicit grammar instruction (Kallioniemi et al., 2015).

Although socio-emotional education is implemented in some OECD countries as a curriculum subject, socio-emotional competences are especially suitable for transversal curricular teaching. When embedded in interdisciplinary programmes, socio-emotional competences can be learned as part of the standard curriculum. Socio-emotional programmes may be more effective when implemented by school staff rather than external professionals (Capsada, forthcoming). Integrating socio-emotional education into the existing curriculum involves coordinating learning goals, activities and assessment practices with those of other subjects (Durlak et al., 2011; Zins and Elias, 2007). Similarly, educators commonly use meaningful and authentic opportunities for students to generalise socio-emotional competences for their daily lives.

Socio-emotional programmes need to connect to classroom and school life, and contribute to a more positive school climate (Elias, 2014). Some suggest, for instance, that only a continuous process of school climate improvement can serve as effective bullying prevention (Clarke et al., 2015; Cohen et al., 2015). Research also suggests the relevance of community-based approaches in socio-emotional learning (Durlak et al., 2011), linking the school to its community (Elias, 2014), involving parents, and establishing wider partnerships in the community. Socio-emotional pedagogies need to mobilise different agents from the student's wider circles, building synergies with out-of-school activities like arts or sports (Clarke et al., 2015), or by creating avenues for parental engagement with the school's practices. School climate enhancement happens most effectively when all stakeholders (e.g. parents, teachers, students, school personnel, district leaders, the private sector, policy makers) share a vision of how they want to improve their school (Cohen et al., 2015).

Finally, technology may well be very helpful through affective computing, virtual worlds, and wearable devices even if it is still under-used for socio-emotional teaching and learning (World Economic Forum [WEF], 2016). The aim should be to integrate those technologies in coherent pedagogical frameworks that promote both subject-related learning and the development of socio-emotional competences. In interdisciplinary programmes, it might be important to choose among the technologies those that, as well as promoting subject-related learning like an interactive platform for science, additionally include features to foster socio-emotional competences such as tools for communication and negotiation.

4.6. Conclusions

Each domain has its own challenges, epistemic nature, teaching traditions, subject-related subcultures, as well as related teacher knowledge, beliefs and emotions. These elements have created different pedagogical trends but robust innovation should ultimately reflect common principles as to how to promote powerful learning. Pedagogical reform in general may well be led by general principles, but specific subjects need enough room to apply these with their own pedagogical solutions.

Innovation is needed in mathematics teaching to increase both student engagement and learning outcomes, especially for female learners. There is a need to find balance between the pure and the applied, and to increase student engagement with open, complex and authentic tasks, promote deeper mathematical reasoning, increase self-efficacy beliefs, and enhance collaboration. The non-native language domain is challenged to find pedagogies that are more effective including by extending instruction to other contexts inside the school, the meso-system, and the wider world. Non-native language pedagogies should emphasise both communication and grammar and are challenged to embed both in

meaningful and authentic contexts. Socio-emotional education needs pedagogies that integrate it into daily curricular activities, looking to improve the whole school climate, and exploring active approaches that impact on students' feelings and relationships.

Competences may be more domain-specific or domain-transcending, and schools should create synergies between them. Promoting general competences means to transcend the barriers of school subjects and infuse them across subjects, finding appropriate formulas to sequence and combine pedagogies to promote both types of competence. Whatever the enthusiasm for learner-centred approaches, they need to be balanced with the more teacher-centred so that students are effectively scaffolded and that they have the chance to acquire both general and specific competences.

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5. Attuning pedagogies to the context of 'new learners' and technology (Marc Lafuente, Educational consultant)

5.1. Introduction

As the learner should be at the centre of teaching concerns (Dumont, Istance, and Benavides, 2010), schools should adjust their pedagogies to get closer to their students and better address their educational needs. Policies cannot be designed and implemented in a vacuum, and should be sensitive to the characteristics of learners as crucial to classroom context. Pedagogical innovation should be informed by learners' interests and needs so as to reshape and optimise teaching.

This chapter presents the notion of "new learners" as they have been depicted in the literature, discussing possible trends, analysing their implications for pedagogy, and examining their potential benefits and drawbacks for learning. It discusses technology: digital technology used in teaching and learning; multimedia materials; multi-tasking and interactive teaching and learning environments; gaming in educational settings; and collaboration and the use of Web 2.0 tools in teaching and learning.

5.2. "New learners"

Some have asserted that there is a new type of young person who learns in new ways: digital natives (Prensky, 2001), the netGeneration (Tapscott, 2009), the iGeneration (Rosen, Carrier and Cheever, 2010), New Millennials (Howe and Strauss, 2000), and many others. Despite variations, they all assume that young people growing up with technology have acquired distinctive ways of learning. For Prensky (2001), digital natives are those born after 1980 as the "first generation" that grew up surrounded by technology. Those born after 1990 are the "second generation" of digital natives (Wang et al., 2014), shaped by the likes of Google, iPods, e-mail and chat rooms. A "third generation" of digital natives would be those born after 2000, in a world of widespread use of cell phones, tablets, cloud-computing tools and social networking.

These depictions of "new learners" coalesce around the following characterisations (Thompson, 2013):

- Constantly using technology: Digital technology is part of young people's landscapes, as they are immersed in a digital world for many purposes, including learning.
- Using multimedia - multimodal materials mixing the verbal and non-verbal: The verbal may be text or the spoken word, and the non-verbal may be illustrations, photos, videos or animation. Young learners are supposed to prefer visual representations such as videos or animation over text, and materials combining the verbal and non-verbal such as video clips.
- Multi-tasking in non-linear and interactive environments: young people are supposed to like to multi-task, where they can choose different paths or jump

from one part of the document to another (e.g. clicking on different webpage links while looking for certain information). They are supposed to do so in interactive environments responsive to the learner's actions.

- Actively using gaming environments: young learners are supposed to prefer active roles such as hands-on tasks, to engage in video games, and to seek entertainment.
- Social and collaborating: their supposed preference is for being constantly connected with peers in activities requiring collaboration.

5.2.1. Sharpening a blurred image

Empirical studies suggest, however, that the reality is more complex than this simple picture (Bennett and Maton, 2010). Some point out that those conclusions drawn mainly from the USA and Europe are not necessarily applicable elsewhere (Cabra and Marciales, 2009). Differences in, for instance, Internet use between older and younger generations are not unbridgeable (Helsper and Eynon, 2010). Younger generations are heterogeneous in technology usage and cannot be assumed to be digitally competent (Kennedy et al., 2010; Li and Ranieri, 2010; Margaryan, Littlejohn and Vojt, 2011). Concepts such as "new learners" may evoke a memorable image, but are misleading when used as stereotypes (OECD, 2012). Such labels lead to a determinism that does not fit the diversity and plurality of young people. The prototype "new learner" wrongly suggests homogeneity across nations and cultures (van den Beemt, Akkerman and Simons, 2011) or that these are necessarily the result of intensive technology use (Carr, 2010; Prensky, 2001; Tapscott, 2010), instead of attributing them to wider social and cultural change (including technology). Some claim (Prensky, 2001) that differences reflect biological, unmodifiable characteristics such that the brain structures and physiology of digital natives are different through being exposed to technology from an early age but they may in fact be developed by anyone intensively exposed to technology-rich environments (e.g. Small et al., 2009).

Beyond debates about generations of learners and labels, what matters is whether learners show new learning tendencies likely to impact school teaching and learning, hence the focus here on "new learning" trends rather than "new learners". Reshaping pedagogies to better meet new learning needs and interests requires a clear picture of what those needs are. Research and more informal classroom observation or community-based studies can provide precious information to inform pedagogy design at the micro-level, taking account of changing learner needs and priorities.

5.3. Technology use

Information and Communication Technology (ICT) is ever more pervasive and young people access it ever earlier and spend more time using it (OECD, 2015a). Households use ICT to access a wider range of services more quickly, mainly for leisure (OECD, 2013). Even on weekdays, teenagers spend on average two hours daily using computers for leisure, especially browsing the Internet for fun and participating in social networks (OECD, 2015a). Likewise, increased smartphone penetration and intensity of use make those activities ever more mobile (OECD, 2015b). There is, however, no easy transition between the informal uses of technology and those commonly proposed in formal schooling.

An argument frequently put forward for using ICT in classrooms is that it can enhance human learning; yet alongside this is another common finding that ICT does not automatically bring about learning improvement as it is only a tool in the service of

instructional goals (Tamim et al, 2011). Improvement needs ICT to be used in certain ways, hence the challenge of identifying those "certain ways".

Meta-studies have generally yielded modest positive results in favour of using technology in classrooms. Tamim et al. (2011) reviewed 25 meta-analyses conducted over 40 years to conclude that the average student in a classroom with technology will perform 12 percentile points higher than a student in a traditional setting without ICT. The size of the effect is higher when technology is used to support students to achieve learning (e.g. the use of simulators or text processors to create documents), rather than for delivering content (e.g. Computer-Based Instruction). Kulik and Fletcher (2016) suggest that a specific technology known as "Intelligent Tutoring Systems" can be perfectly effective for content delivery. In the same vein, Gerard et al. (2015) show that the use of automated adaptive environments can improve learning results when they imitate the guidance typically given by expert teachers.

Meta-research on the use of mobile devices suggests a moderate positive effect on learning (Sung, Chang and Liu, 2016), especially when used with inquiry-based pedagogies and outside schools. In the same vein, meta-studies on one-to-one computer programmes in schools show some evidence of increased academic achievement – mostly in science, writing, mathematics and English, as well as technological competences, although that evidence is still weak (Fleischer, 2012; Zheng et al., 2016). Computers are used mainly in those programmes for exploration (information-seeking), communication (mail and instant messaging), and expression (typing and multimedia authoring).

Likewise, meta-analyses of technology and reading outcomes (Cheung and Slavin, 2012) conclude that ICT can support reading instruction, even more so when integrated with face-to-face teaching - assisting teachers but not replacing them. Similarly, a meta-analysis by Li and Ma (2010) shows that computer technology has statistically significant positive effects on mathematics achievement, especially when using "constructivist" pedagogical approaches that, for instance, help students to construct their mental models or their own knowledge through small-group activities. Another meta-analysis shows that ICT can be used to improve learners' reflection, so long as the technology is appropriate for the instructional context (Kori et al., 2014).

Alongside this, PISA analyses suggest that learning outcomes have not improved in countries that have heavily invested in technology (OECD, 2015a), and ICT may even be detrimental to learning if it is not appropriately integrated into the educational setting.

5.3.1. Pedagogies that harness the power of technology for learning

ICT may thus lead to positive learning outcomes, although the effect sizes are not substantial. It seems that it is more beneficial when conceived as an amplifier of teaching used in combination with teacher and peer support, rather than in isolation, and successful teaching depends precisely on how teachers integrate technology into their daily relations with students.

Teachers can profit from technology when it helps diagnose the student's progress and difficulties, and accordingly provide tailored assistance to encourage moving forward. The applications that yield encouraging results are those that activate the complex cognitive processes involved in deep and meaningful learning such as interacting with simulations, communicating and discussing with peers and educators, and solving complex tasks. It is precisely through these processes that revealing information can be gathered by educators to grasp their students' performance and to inform an adjusted

instructional response. Hence, diverse pedagogical approaches can harness the power of technology when it complements and amplifies the teacher's role, including those that encourage discussion and collaboration, give students an active role, and promote complex cognitive processes such as analysis and solving complex, authentic tasks.

Another important technological potential is its capacity to promote learning engagement and motivation. Students' self-reports in research on one-to-one computer projects show that learners using the computers feel more motivated (Fleischer, 2012; Zheng et al., 2016). Li and Ma (2010) conclude that one explanation of the positive effects of technology on mathematics learning is increased engagement. However, this effect is clearer in shorter than longer programmes, suggesting it may be more a temporary technological novelty effect than about mathematical contents or the learning tasks. Students' motivation to master different subjects is enhanced through pedagogies that motivate students through technology and not to technology. This distinction relates to intrinsic vs. extrinsic motivation (Ryan and Deci, 2000), with intrinsic motivation associated with high-quality learning. Pedagogies should increase student interest in the contents and the competences being promoted, making them aware of the value of learning them and the potential satisfaction of mastering them.

Yet, motivating students to technology makes sense when the aim is acquiring digital literacy. One of the most popular assumptions about young learners is that they are "technology savvy" because they have grown up surrounded by it. This has been widely rejected by empirical research (Kennedy et al., 2010; Li and Ranieri, 2010; Margaryan, Littlejohn and Vojt, 2011). Gu, Zhu and Guo (2013) find that although young learners feel more digitally competent than their teachers and adopt technology at an earlier age, they do not use more ICT than their teachers in terms of duration and frequency. Similar results are found by Wang et al. (2014): school-age learners are not more technology savvy than their teachers and indeed teachers' use of technology, inside and outside the classroom, surpasses that of the students. The myth of the learners as tech savvies is harmful as it assigns them a competence for using ICT for learning purposes that they often don't have. Using technology for social purposes and for life-long learning are different and involve different competences.

Over-estimating digital competence can result in omitting digital literacy from the curriculum, and/or leaving students to work with technology on their own ("because they already know how to use it"). Winters, Greene and Costlich (2008) conclude that for students to exploit computer-based learning environments, they must have reasonable prior skills and knowledge for using technology, relating to general strategies like planning or monitoring their own learning, and prior knowledge about contents. Students must also have prior technological competence, and they generally benefit from learning how to use those technological environments beforehand. Leaving students to interact with technology regardless of their prior competences will likely have detrimental consequences for their learning. Digital literacy is an important ingredient of the so-called 21st century competences and it is not simply acquired through engagement with ICT at an early age.

The potential of technology falls short when it is simply about the presentation of contents by teachers. Teachers using technology with the only aim of transmitting information to students get among the worse results of ICT classroom integration. One of the pitfalls of ICT classroom integration is that teachers adopt traditional pedagogical strategies and become more concerned about how they use ICT, than about the benefits of technology for their students (Fleischer, 2012).

When designing and enacting pedagogy, practitioners should focus on how both the teachers and the students can make the most of it. Meta-research highlights the potential of computers to implement student-centred pedagogies like project-based learning (Zheng et al., 2016). Students perform better in digital environments when they use active strategies - e.g. coordinating different sources of information or making inferences - than the passive strategies of copying, summarising, and note-taking (Winters, Greene and Costlich, 2008). Pedagogies should avoid teachers monopolising the technology and avoid assigning learners merely passive roles. This is especially important to counteract the habits learners often develop outside school (Kennedy et al., 2010), in which many use technology passively in their daily lives as consumers rather than actively through producing or mixing artefacts. The following table summarises the advantages and drawbacks of technology use, together with pedagogical implications:

Table 5.1. Pedagogical implications of technology use

Advantages		Challenges	
Technology can improve learning outcomes.	Technology can improve learning engagement and motivation.	Young learners may not be technology savvy.	Technology may reproduce traditional pedagogies.
How pedagogies can help			
Pedagogies use technology as a complement of teaching and not as a substitute of it. Pedagogies give learners an active role and promote collaboration, while teachers use information to adjust support.	Pedagogies motivate learners "through technology" and not "to use technology". Pedagogies promote intrinsic motivation and avoid reliance on "novelty".	Pedagogies promote digital literacy. Pedagogies assess that students have the prior competence to engage with digital environments.	Pedagogies avoid transmission practices with teachers monopolising the technology. Pedagogies push students towards active strategies in using technology.

5.4. Multimedia

Children spend more time than ever in on-screen activities such as watching television, surfing the web and playing games on computers, tablets and cell phones (Bus, Takacs and Kegel, 2015; Courage and Howe, 2010; Wartella, Richert and Robb, 2010). One of the common features of those activities is the combined verbal and non-verbal information in the same environment (photos, animation, spoken words, text, etc.). Children’s books are changing from traditional paper format to electronic formats on phones, tablets and e-readers (Burnett, 2010). Such e-books enable new features like listening to the story, looking at animated pictures, listening to background sounds and music, and so forth. This poses a challenge to schools in which the main medium of instruction has traditionally been text alone.

The cognitive theories of multimedia learning suggest that humans have independent auditory and visual channels and a limited capacity for processing information, meaning that one channel might get overloaded (Moreno and Mayer, 2007; Schüler, Scheiter and van Genucthen, 2011). However, learning may be enhanced when those two channels process different sorts of media at the same time, such as images being processed through the visual channel, while words are being processed through the auditory channel. Research has shown that the different media may enhance learning, but only if certain conditions are met.

Takacs, Swart and Bus (2015) conduct a meta-analysis of technology-enhanced storybooks to find a small but positive effect of the multimedia on story comprehension and expressive vocabulary learning. Learning is leveraged only when non-verbal information such as animated visualisations, background sounds and music are congruent with, and support, the narration. The advantage of multimedia materials is not the presence of illustrations along with other information, but such features as animated pictures, sounds and music. According to another meta-analysis (Berney and Bétrancourt, 2016), animations are found to benefit multimedia learning when they are accompanied by oral information instead of text.

Likewise, Kalyuga's meta-analysis (2012) of the instructional benefits of spoken words along with pictorial information indicates that when pictures are not self-explanatory, then words should be used and spoken words should be used when information is complex. For instance, if such explanations are displayed on PowerPoint slides and simultaneously narrated by the instructor, the learner needs to relate on-screen text with the oral explanations and pay attention to the pictorial information. Eliminating or reducing on-screen text would improve learning (Kalyuga, 2012). On the other hand, when when pictorial information is clear enough through maps, pie-charts etc., there is no need to add verbal information. Only when the learner requires it, educators should adjust and provide verbal explanation of pictures.

Some studies conclude that multimedia environments are more effective when they imitate the performance of expert teachers, for instance, by providing guidance through animated agents, promoting reflection through posing challenging questions, or providing rich feedback especially for learners with less prior knowledge or skills (Moreno and Mayer, 2007). Eitel and Scheiter (2015) conclude in their meta-review that learners may benefit from multimedia environments that present contents sequentially, but only when less complex information is presented first, and then information of increasing complexity and detail. This facilitates the understanding especially of learners with less prior knowledge. Likewise, Richter, Scheiter and Eitel (2016) conclude in their meta-analysis that meaningful learning is fostered when learners are able to relate verbal and pictorial information; this can be facilitated through signalling cues like using the same colour for corresponding words and pictures. This strategy benefits especially learners with low prior knowledge.

5.4.1. Pedagogies taking advantage of multimedia materials

In summary, the use of multimedia materials may bring moderately better learning outcomes, provided that practitioners and designers follow some specific principles. Multimedia materials embrace a wide range of products - from a PowerPoint presentation, to a videogame, a storybook, or a simulation – and are compatible with a wide range of pedagogies. Their power to enhance the comprehension of narrations can make them a good vehicle to aid mastery of complex skills of oral comprehension and reading. Likewise, their potential to represent and simulate different phenomena - natural, chemical or physical processes, as well as social or historic ones – means they can foster insight on different subjects across the curriculum. Pedagogies based on the use of narrative, such as "learning through storytelling", can take advantage of multimedia materials, so long as they follow sound instructional designs such as making sure the student is presented with increasingly complex and rich contents.

Multimedia materials may also be a resource for powerful learning when students produce a multimedia artefact ("multimedia authoring"). Multimedia authoring has the

potential to support higher-order thinking skills (McFarlane, Williams and Bonnett, 2000). As learners engage in building and refining their artefacts, they also can modify and perfect their conceptual representations (Yuen and Liu, 2011). Moments when students experience disequilibrium - encountering unexpected responses or opposed and conflicting ideas - can highlight misconceptions and help to address them. Thomas (2012) finds that multimedia authoring gives learners the personalised opportunity to express themselves and with varying degrees of sophistication. A challenge lies in balancing the teacher's attention between effectively fostering understanding of contents while promoting the skills to build such complex artefacts.

One of the most studied multimedia products are concept maps. Nesbit and Adesope (2006) conclude through meta-analysis that, although the evidence is quite heterogeneous, concept mapping is more effective than reading passages, attending lectures or studying text passages or lists, and is useful for teaching in a wide range of educational settings. Pedagogies should consider them both as activity in which students produce them, and as pre-constructed objects to support teaching and individual study.

Multimedia artefacts are produced and read differently from texts in classic format, resulting in an ongoing reformulation of grammar to describe the confluence of words, images and sounds (Mills, 2010). Reading and writing using words on paper are necessary but not enough for communicating through multimedia products. Multimedia authoring is certainly a good opportunity to promote such competence. Multimedia authoring may lead to the construction of artefacts by students to master specific knowledge and skills (Papert, 1993). Several pedagogical approaches have come to highlight this principle such as "learning by design" (Kolodner et al., 1998), where students work on the design challenge of creating something that requires some critical knowledge and skills to be learned. Another is the "maker movement" and "learning by doing" (Martinez and Stager, 2013), where learners use technology to make or repair useful artefacts using knowledge from different disciplines.

Multimedia materials have some risks, too and may become a source of distraction. According to Schweppe and Rummer (2014) the most important criterion for designing multimedia learning materials is ensuring that they promote the focus on relevant information and away from "extraneous" information. Some meta-studies conclude that games and extra-animations embedded in multimedia materials can be extraneous material that does not integrate with the relevant story content (Mayer and Moreno, 2002; Bus, Takacs and Kegel, 2015). This diminishes children's language and story comprehension, especially if they are incidental to the story line. If they have a choice, children prefer to play rather than listen to the story and read it. Very young children and learners at risk are especially vulnerable to such distractions. Features like games and extra-animations might enhance learner engagement with the story, but with diminished language acquisition and story comprehension. The authors consider that time spent with screen media cannot replace time spent with print books, unless children are explicitly guided by educators to focus on the reading experience before engaging with any other activities.

It is important for pedagogies that there is awareness that distraction in multimedia experiences can be detrimental to learning. Scaffolding the acquisition of important skills like reading is a complex process that cannot be completely delegated to multimedia technological environments, although some may include functions that imitate the guidance of human experts. That scaffolding process should include designing the learning experience, providing tailored support according to the learner's performance,

and appraising performance until the learners are judged capable of performing on their own. Guidance in using multimedia materials should also help learners to focus on the relevant contents, and make sure that any extra-features contribute to the overall learning experience.

Another potential drawback is cognitive overload. It may occur, first, when multimedia information is presented in a way unsuited for the human capacities for processing it, e.g. using lengthy text and spoken words in addition to pictures when presenting complex information (Kalyuga, 2012); or, second, when the learner engages with interactive elements like games or hotspots, and tries to read or listen to them at the same time (Takacs, Swart and Bus, 2015). Either way, the experience reduces the learner's resources to understand the contents, especially for young children and learners at risk who are less skilled in controlling their attentional focus and school pedagogies should pay attention to these risks. Instructional designers and practitioners should be sensitive to their learners' capabilities to process new information, pay close attention to how the verbal and non-verbal information is displayed, and ensure that the contents can be understood.

Pedagogies can take advantage of certain interactive features because they appeal to learners. Practitioners should follow a clear instructional sequence that helps the learners to achieve the intended goals, clarifying the objective of multimedia tasks before engaging with them. Likewise, the instructional design should avoid parallel activities likely to overload the students' capacity of understanding. The learning sequence should ensure that the learner has enough prior knowledge and skills to engage with whichever multimedia materials are selected.

Table 5.2. Pedagogical implications of multimedia materials

Advantages		Challenges	
Multimedia materials can improve learning outcomes.	Students can engage in multimedia authoring.	Multimedia materials can create distraction.	Multimedia materials can create overload.
How pedagogies can help			
Pedagogies use sound instructional designs and adequately integrate them, Pedagogies take advantage of their power to represent narratives.	Pedagogies focus on promoting multimedia literacy especially in the construction of artefacts.	Pedagogies accompany the learner and scaffold their use of the material. Pedagogies focus on relevant contents and productively integrate multimedia extra-features.	Practitioners make sure that multimedia contents can be understood by learners. Practitioners clarify the use of multimedia features and ensure that learners are able to use them.

5.5. Multi-tasking, non-linear and interactive environments

Research shows that the average number of online activities per user has increased in OECD countries, especially in younger people (OECD, 2016). Young people are thus regular multi-taskers, constantly switching or performing different tasks at the same time: watching videos, reading, playing videogames, listening to music, texting, etc.. This is driven partly by "internal" factors such as the desire to stay connected with others and the "fear of missing out", addiction to the Internet or cell phone, or the wish to change from doing a task viewed as boring. "External" factors include devices calling for attention through beeps or pop-up signals, and the in-built technological facilitation of multi-tasking through the possibility to open multiple windows or tabs and to work on different applications simultaneously (Carrier et al., 2015).

Research using laboratory experimental data generally shows that multi-tasking is less efficient than single-task performance whether in time invested or accuracy achieved (Cardoso-Leite, Green and Bavelier, 2015; Carrier et al., 2015; Courage, 2015). Tasks that involve responses requiring conscious control such as having a conversation or reading a text, or that involve verbal information, are especially affected when multi-tasking. Young children with their immature attention processes are especially subject to the limitations associated with multi-tasking (Courage et al., 2015; Rothbart and Posner, 2015). Multi-tasking necessitates control over attentional focus, switching between tasks, avoiding distractions and pursuing goals. The underlying executive function that enables such behaviours is only slowly acquired by children and young people from age 3 onwards.

Some claim that young learners have developed more effective multi-tasking skills but whatever young people themselves might think this is not supported by evidence (Kirschner and van Merriënboer, 2013). Young people who frequently multi-task are no more capable of avoiding distraction than those who multi-task only occasionally (Carrier et al., 2015). Coaching on task-switching and better grasping tasks might enhance multi-tasking but there is little or no transfer of those benefits to other tasks performed at the same time (Cardoso-Leite, Green and Bavelier, 2015; Rothbart and Posner, 2015).

On the other hand, research contradicts the idea that multi-tasking damages attentional and learning brain circuits. It is not extended exposure to technological environments per se that shortens children's attention or causes attention deficit, but rather that children with such deficits get their required level of stimulation through those media (Courage et al., 2015). Likewise, the amount of time devoted to screen media may correlate negatively with academic outcomes, not because it is damaging in itself but because it displaces time for other activities such as reading or studying.

As for interactive and non-linear materials, meta-studies show that learners generally benefit from being able to control the information appearance pace and choose their own learning path (Moreno and Mayer, 2007; Wouters, Tabbers and Paas, 2007). Likewise, meta-research shows that these environments are generally more effective when they provide elaborated feedback like giving an explanation, instead of simple feedback as in informing on the correctness of the answer (Van der Kleij, Feskens and Eggen, 2015). However, these interactive features are not always beneficial when, for instance, learners experience "usability problems" such as disorientation, distraction, and cognitive overload; when they have poor prior knowledge and skills, or inadequate abilities to regulate their own learning, or negative attitudes towards learning. The interactive environments might also lack a clear design based on sound pedagogical approaches. (Scheiter and Gerjets, 2007)

5.5.1. Pedagogical implications

The daily use of technology inside and outside the classroom tends to produce multi-tasking and yet multi-tasking generally adds very little to learning, unless it is carried out for very specific instructional purposes. Some media multi-tasking may support the learning activity in specific circumstances, such as when learners gather data and analyse them on-the-fly, but many forms of multi-tasking are clearly detrimental to learning such as the student answering unrelated texts during a lecture. Since younger learners are especially vulnerable to distraction and cognitive overload, designers and practitioners need to factor this into the technological and learning environment. Older learners should become capable of judging by themselves the consequences of multi-tasking in different

tasks and contexts, to test its consequences, and find effective ways to control their learning or work performance (Carrier et al., 2015).

The ability of learners to judge the consequences of multi-tasking and to handle it requires capacities of self-control - the executive function - that are only slowly acquired during the primary school years. This developing capacity should be recognised in different pedagogies. So long as learners consider that multi-tasking is productive and necessary, and so long as they are not aware of its potential negative consequences, they will keep doing it.

On the other hand, certain pedagogies may depend on technological environments where learners can follow their own learning path or control information appearance. Such environments need to be designed and implemented according to sound pedagogical approaches such as the web-based inquiry science approach where students engage in projects to design scientific solutions to problems, debate science controversies, and critique scientific claims (van den Broek, 2012). Students collect evidence and articulate their ideas, test their predictions, get feedback, and reflect on their progress. Effectiveness is not so much about the technology as about the promotion of high quality learning.

Pedagogies should especially take account of learner characteristics: the learner must have the knowledge, skills and attitudes to engage with the contents and follow a clear path towards learning. Practitioners should choose the environment according to their learners' characteristics and pedagogical approaches, and technological environments should be flexible enough to adapt to different learning profiles (Wouters et al., 2007). Pedagogies may also take advantage of data automatically gathered on student's performance ("learning analytics") (Sharples et al., 2014). Teachers may use data to make adjustments in the instructional design or provide more assistance to struggling students. Before engaging with interactive environments, students can also benefit from specific training either on the environment characteristics or contents knowledge (Moreno and Mayer, 2007).

Pedagogical design should also factor in the so-called "butterfly defect" (Kirschner and van Merriënboer, 2013). Learners may behave like "butterflies fluttering across the information on the screen, touching or not touching pieces of information (i.e., hyperlinks), quickly fluttering to a next piece of information, unconscious to its value and without a plan" (p. 171). Having the possibility of jumping from one piece of information to another might open possibilities for students quickly to connect different pieces of information, to establish connections between contents, and to build richer networks of knowledge in their minds. To achieve such benefits, however, they should have relevant prior knowledge, the skills to relate them to familiar frameworks, and consequently to analyse their value. Students using interactive learning environments should be aware of the task goal, be capable of delineating a plan and following a procedure, and evaluate when they have achieved the goal.

Pedagogies should incorporate knowledge frameworks so that students can interpret the information they are presented with. Practitioners can help students to "activate" or use what they already know in order to understand new information. Without such frameworks, the danger is that students will not understand what they find and will activate strategies that lead to poor learning (e.g. copying and pasting irrelevant information), or "flutter" endlessly on the web. Teaching should thus promote the capacity to make connections between ideas from different fields that may seem unrelated, and ensure that students have sufficient skills to "regulate" their navigation

through the technological environment. Teachers should make students aware of the goals and the task requirements, assisting in the creation of a plan, and supervising its success.

Table 5.3. Pedagogical implications of multi-tasking and interactive environments

Advantages		Challenges	
Teaching can prepare students for a world of distractions.	Interactive and non-linear environments can support learning.	Multi-tasking can be detrimental to learning.	Interactive and non-linear environments can encourage the "butterfly defect".
What pedagogies can do			
Pedagogies promote awareness of multi-tasking and its consequences. Pedagogies foster self-control and judicious use of multi-tasking in the classroom.	Environments are designed and implemented according to sound pedagogical approaches. Designers and practitioners ensure that environments are suitable for learners.	Pedagogies actively address harmful multi-tasking. Pedagogies are especially careful about multi-tasking regarding younger learners.	Pedagogies promote use of knowledge frameworks by learners. Pedagogies ensure that learners have sufficient competence to navigate the environment.

5.6. Active learning and gaming environments

Popular claims about young learners generally assign them a preference for playing active roles in daily activities and the need for constant rewards and positive feedback if they are to persist in tasks; carrying out hands-on activities rather than being passive such as attending lectures, and preferring to play games, especially video games. Nearly three-quarters of US teenagers play video games on a computer, game console or a portable device such as a cell phone and teenagers view them as entertainment and a way to socialise. The pedagogical challenge is to take advantage of the appeal of gaming for learning purposes (Lenhart et al., 2015).

There have been two main educational responses to this challenge so far:

- The Game-Based Learning approach - using videogames, either entertainment or specifically educational ones, in school settings. There is growing use of video games across different curricular areas, mostly in secondary and higher education, and most notably in health, business and social subjects (Connolly et al., 2012). In primary education they are mainly used in mathematics, science, languages and social areas (Hainey et al., 2016).
- The Gamification approach which does not involve videogames themselves but uses game elements such as rewards, points, and top-score leader boards in classroom activities (Domínguez et al., 2013).

Video games may enhance students' learning outcomes, although results from some meta-analyses are limited in effect sizes, restricted to some subjects and type of outcomes, and very much depending on the instructional conditions under which the games are used. Jabbar and Felicia's (2015) meta-analysis of digital and analogue games concludes that role-playing instils a sense of immersion that supports engagement and learning improvement. However, students might not really be motivated to learn but just to play and to compete against peers. Complex games might hinder content learning as they call on more cognitive resources simply to play the game. Clear goals, unambiguous feedback and a sense of control by students are key for experiencing game conflicts in a positive fashion.

Clark, Tanner-Smith and Killingsworth's (2016) meta-analysis concludes that digital games can enhance students' learning compared with non-game conditions. Games that have been enhanced for educational purposes show particular benefits. Sitzmann's meta-analysis (2011) suggests that digital simulations may enhance learners' declarative and procedural knowledge, retention and self-efficacy. Connolly et al. (2012) conclude that entertainment and serious games generally yield positive outcomes. Serious games generally result in positive knowledge acquisition, and entertainment games result in positive affective and motivational change. It is possible that serious games are more effective than conventional instruction in terms of knowledge retention but not in motivation (Wouters et al., 2013). Hainey et al. (2016) show that innovation in primary education tends to be more focused on serious games involving strategy, solving puzzles and role-playing, rather than the entertainment games. Their literature review suggests that serious games impact especially knowledge acquisition, although they do not provide quantitative meta-analyses.

A more sceptical conclusion on serious games comes from the meta-analysis of Young et al. (2012) which found improved student outcomes only for language games and, to a lesser degree, physical education games. They conclude on the importance that instructional design must give to aligning game objectives and learning objectives. Teachers need to promote learning transfer to other contexts and reflection on the game experience. They conclude that learning effectiveness depends less on features of the game and more on the wider pedagogical context in which it is used.

On gamification, Hamari, Koivisto and Sarsa (2014) conclude that although the majority of studies on gamification and learning yields positive outcomes, the wider instructional context seems to have more impact than the gamified activity itself and that some learner cognitive and affective characteristics importantly contribute to success. Faiella and Ricciardi (2015) suggest that research is still unable to explain specifically how gamified elements work and how they interact with learner characteristics.

5.6.1. Video gaming to support learning

Evidence suggests that video games may be educationally valuable, provided that other key factors are met. The most important element is an adequate pedagogical integration of the game into the instructional context (Arnab et al., 2012). The game play must help students to achieve the learning objectives (Young et al., 2012) and the teacher plays a fundamental role in realising the potential benefits of the gaming experience. Additional structured activities developed before, during and after the game contribute: presenting the objectives and contents before playing; mediating and assisting learners during the game play when they experience difficulties; fostering post-game discussions and reflections; and promoting transference of learning to other contexts. Collaborative learning can be part of game play in which students share resources and solutions. Some meta-research suggests that video games can foster better engagement when learners are allowed to play for longer in more adequately spaced sessions (Clark, Tanner-Smith and Killingsworth, 2016; Young et al., 2012).

Many pedagogical approaches fit with the use of videogames in schools. For instance, case-based instruction or scientific inquiry-based approaches may make the most of immersive "virtual worlds" (Dede, 2014). Students assume the role of real professionals (e.g. scientists) and explore a natural phenomenon occurring in the virtual environment, gather data, and analyse them in order to answer certain research questions. These digital environments may help students to master abstract principles and skills through

exploration and analysis of real-world situations through authentic simulations. Authentic simulations give learners the chance to visualise processes and manipulate representations that would be difficult to replicate in the real world (e.g. the chemical processes involved in the greenhouse effect). These are typically serious games designed for educational purposes, or, at least, they are entertaining games augmented to allow learners to work precisely on a particular phenomenon such as an historical, social, natural or physical process, or an artistic movement.

Meta-research on video games nevertheless reveals some potential drawbacks, especially of entertainment video games. They often provide unnecessary contents and procedures for mastering the intended knowledge and skills. While rich narratives and visual complexity might be appealing for young people, games with no narratives might be more effective than those with an elaborate narrative (Clark, Tanner-Smith and Killingsworth, 2016). Students might be attracted for these reasons, and have fun rather than focusing on the learning.

When the game involves complex rules and procedures, the learner may also allocate significant cognitive resources to playing the game, at the expense of reasoning and understanding contents (Jabbar and Felicia, 2015; Young et al., 2012). While video games can engage students, when there is a mismatch to their abilities and they are perceived as too difficult, they can cause frustration. Games need simple mechanics and narratives to ensure that the learner can engage. Pedagogies that embrace video games should ensure adequate learner support and feedback to reinforce persistence in the learning task. Student's own knowledge, expectations, and skills should be part of the instructional design to align the student's learning capacity and the gaming experience.

Table 5.4. Pedagogical implications of gaming environments

Advantages		Challenges	
Gaming can yield positive learning outcomes.	Gaming can promote authentic learning.	Gaming can promote extrinsic motivation.	Gaming can cause overload and frustration.
What pedagogy can do			
Pedagogies ensure sound integration of video games into the instructional context. Pedagogies promote complementary structured activities to maximise the gaming experience.	Pedagogies ensure exploration and manipulation of realistic scenarios. Designers and practitioners ensure access to high quality digital games.	Practitioners focus students' attention on essential elements of learning. Pedagogies rely on simpler video games.	Pedagogies provide useful feedback to the learner. Pedagogies match the learner profile with the gaming experience.

5.7. Collaboration and social activities

Young learners are often assumed to need constant connectivity with peers - communicating, texting each other, and sharing information. This image is grounded in the pervasive teenage use of social media, the popularity of social networking sites, and the omnipresence of mobile devices. A more specific image is their preference to do school work through social contact and collaboration. t. Some studies have identified a preference by some for collaborative settings and technology rich-environments (e.g. Bekebrede, Warmelink and Mayer, 2011), but so much depends on cultural environment, personal characteristics, and the specificities of the learning activities in question.

This new learning tendency is associated with “Web 2.0” tools. Hew and Cheung (2013) review 27 studies where secondary education students use podcasts, wikis, blogs, virtual worlds, or social networks like Twitter. The authors conclude that the evidence cannot identify causal relationships between such tools and student achievement gains though they see them associated with a positive impact on students’ outcomes, not because of the technologies themselves but how they are integrated into education and support learning. This happens when, for instance, podcasts provide supplementary or more comprehensive learning contents, blogs the relevant scaffolding, or when Twitter gives the platform for productive conversation between students and teachers. Overall, however, an understanding of how social media can be used in the education is still largely lacking (Blazer, 2012; Kidd, Carpenter and Stephen, 2014; Manca and Ranieri, 2013).

5.7.1. Harnessing Web 2.0 tools for collaborative learning

How to take advantage of learner enthusiasm to use technology for communicating and sharing with peers, to promote collaborative learning (which is associated with increased student outcomes [Kyndt et al., 2013; Slavin, 2010]). A meta-analysis of “adaptive environments” concludes that they can support content knowledge and collaboration skills acquisition (Magnisalis, Demetriadis and Karakostas, 2011). Although evidence is still not extensive, research suggests that for Web 2.0 tools to be effective in schools, certain fundamental pedagogical aspects need to be present. It is not so much about integrating Web 2.0 tools in the classroom, but about implementing the underpinning principles of Web 2.0 activities. This means students: being authors and agents of their own learning; deciding the course of their own projects according to their interests; interacting and collaborating; making and sharing their own materials; and engaging each other and exchanging constructive feedback.

So, it is the “Web 2.0 pedagogy” that is important, with blogs, podcasts, social networking sites and virtual worlds as tools to realise this approach. Such pedagogical approaches demand that teachers mentor and foster competence for self-regulated learning, compatible with learners as (pro-)active and collaborative. One such approach is teacher “orchestration” (Dillenbourg and Jermann, 2010; Hämäläinen and Vähäsantanen, 2011): learners are guided by their teachers who “orchestrate” the social and collaborative activity, finding a balance between structuration (scripting activities and giving routines), and improvisation in collaborative processes (allowing students to take their own courses of action).

When Web 2.0 tools are implemented under traditional pedagogical approaches, tensions and issues arise: “educational practice does not seem to be easily bringing these elements into an expected alignment” (Crook, 2012: 64). For instance, transmission based on the teacher providing all the contents is ill-matched to a technological environment full of information and multiple voices. Students need to deal with informational complexity and uncertainty, and gain competences in searching and analysing information. Pedagogical approaches that relegate the student to a passive role or to automatic routines are not promising avenues for learners to construct personal artefacts or collaborate in solving complex problems. Neither is the omnipresent use of texts in schools which does not suit the receptivity of young people to the multimedia information embedded in Web 2.0 tools. And, the traditional school conception of individual and sole authorship does not suit the practices characterised by producing, mixing, re-mixing, and sharing materials.

For pedagogies to make the most of collaborative activities using Web 2.0 tools they have to address student distraction when confronting unrelated contents, or when socialising

for other than learning purposes or when there is disruption (Blazer, 2012). Students need to be able to self-regulate their learning and to keep focused; teachers need to monitor their student's learning and work with students in advance to prevent and avoid distraction.

Addressing the potential downsides requires time and energy but the benefits of exploiting collaborative, participatory settings with popular technologies may be substantial. They might well help students not only to improve teamwork but also to learn new and more productive ways of using those tools for collaboration. Young learners might be used to using social media for socialising but less for formal collaboration and learning. Using technologies for networking outside the school and extending learning beyond the classroom walls is important for students to become life-long learners.

Table 5.5. Pedagogical implications of collaborative and Web 2.0 environments

Advantages		Challenges	
Web 2.0 tools need to be implemented through adequate pedagogies.	Common Web 2.0 tools can be harnessed to improve collaboration competences.	Web 2.0 tools used with traditional pedagogies gives rise to issues and tensions.	Web 2.0 tools can cause distraction.
What pedagogy can do			
Implement the "Web 2.0 principles". Practitioners adopt a mentor role and support self-regulated learning (e.g. orchestration).	Pedagogies use "real" tools to show new venues and ways of collaboration. Learning goes outside the classroom and students gain competences for life-long learning.	Avoid transmission approaches and the automatisation of routines. Avoid the omnipresence of text and traditional conception of authorship.	Practitioners promote abilities to self-regulate the learning activity and stay on task. Practitioners and students work together to prevent and avoid common distractions.

5.8. Conclusions

Pedagogical innovation should be sensitive to context. In this chapter, we have seen that new learning tendencies and priorities offer potential leverage to teaching innovation. Practitioners and policy makers need more and clearer data about the profile of young learners and their tendencies. Five broad trends have been identified and reviewed: the use of technologies; multimedia materials; multi-tasking and non-linear and interactive environments; games; and collaborative activities using Web 2.0 tools. All hold positive possibilities to enhance learning but also disadvantages, and which it is depends importantly on pedagogical practices and their deep integration into the instructional context.

Existing meta-analyses support an optimistic view of the use of computers and other technologies in the classroom, the utilisation of multimedia materials, video gaming, and collaborative activities. Those studies also tend to conclude that outcomes improvements are small and that multi-tasking has negative effects.

Since pedagogy is key, policies should focus especially on teacher learning and practices. Professional learning should look to enhance teachers' technological pedagogical content knowledge (Harris, Mishra and Koehler, 2009), as well as empower them to generate educational innovation. The goal is not to learn how to run technological devices in the classroom, but to design and implement suitable pedagogies that use technology to better meet student needs. There needs to be professional learning where practitioners form learning communities and share materials and best practices. Investing resources in

technology is not enough if teachers do not have the competence to use them in a pedagogically sound fashion; otherwise, technology in the classroom can even have detrimental consequences (OECD, 2015a).

If schools do not meet young learners "halfway", students will feel that their expectations and preferences are being ignored, causing disengagement and detachment. Leveraging new learning trends can activate educational areas associated with innovative learning eco-systems (OECD, 2015c) by:

- Promoting learner motivation and engagement through pedagogies that match the needs and interests of young learners. Pedagogies foster motivation through technology, not to technology, and should avoid extrinsic motivation as the means to encourage persistence on task.
- Promoting learner agency and voice, with pedagogies revolving around learners' priorities and needs. Teachers will often adopt a mentoring role, with pedagogies promoting self-regulation of young people's own learning and minimising distraction.
- Using mixed, personalised pedagogical practices, adjusting teaching to the learner's needs by identifying learning tendencies at the national or regional level, and at the micro level (e.g. individual tendencies that might differ from student to student in a classroom).
- Encouraging the development of curriculum and new learning materials, creating and using video games, multimedia and highly interactive environments. Such materials should be carefully designed and embedded in sound instructional approaches, with students able to exploit them across many learning activities with the support of teachers and peers.
- Using digital applications and social media: pedagogies use digital applications and tools to encourage social and collaborative learning. Students are introduced to new avenues for collaboration, and learn about using popular technologies for pedagogical purposes. Learners construct social networks that embed the formal and the informal, and gain competence for lifelong learning.

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6. Technology-enhanced innovative pedagogy: The challenge (Nancy Law, University of Hong Kong)

6.1. Scaling technology-enhanced innovative pedagogy: The challenge

From the 1990s onwards, many countries have launched ICT in education masterplans, often in conjunction with major education reform initiatives (Plomp et al., 2003, 2009). These national Technology-Enhanced Learning initiatives (TEL) generally involve major investments to furnish schools with the necessary computing devices, internet connectivity, extensive training and professional development of teachers, as well as providing schools with the means to hire technology support staff and digital learning resources. The rationale for such extensive efforts and investment is often connected with the expectation that learning through the use of ICT would be able to transform the learning process (Pelgrum and Law, 2003) to achieve 21st century outcomes such as collaboration, communication, creativity and critical thinking (Partnership for 21st Century Skills, 2009).

Given the high expectations and scale of investment involved, it is not surprising that the IEA Second Information Technology in Education Studies (SITES) conducted in 1998 (Pelgrum and Anderson, 1999) and in 2006 (Law, Pelgrum and Plomp, 2008) showed a huge improvement in the ICT infrastructure in all the countries that participated in both studies. Of the 22 education systems participating in SITES 2006, with the exception of South Africa, nearly 100% of the schools surveyed reported having computers for use by grade 8 students (which was the target grade level for the survey) for teaching and learning purposes; in 20 of the surveyed systems, over 90% of the schools reported having access to the Internet. On the other hand, the percentage of principals indicating that the use of ICT was very important for achieving various pedagogical goals was low, and the percentages were particularly low for principals in economically developed countries with high computer:student ratios and high levels of Internet access. The SITES 2006 survey results from the grade 8 mathematics and science teachers further show that the percentages reported using ICT in their teaching varied from about 14% to almost 50% (not including South Africa because of its low level of ICT access). Further, most of the pedagogical practices for which teachers reported using ICT were traditional instructional activities such as completing worksheets or answering tests.

More worrying than the rate of pedagogical uptake of ICT use in classrooms is the impact of ICT use on students' learning outcomes. The PISA 2009 (OECD, 2011) results show that access to ICT at school may not bring about heightened digital literacy. For example, Hong Kong students scored 533 on the print reading scale but only 515 on the digital reading scale. Results from PISA 2012 (OECD, 2015b) show marked increases in the percentage of students reporting using ICT for various learning activities in school between 2009 and 2012. However, students reporting higher frequencies of computer use in schools had lower achievement scores in most learning outcomes even after adjusting for demographic differences. While different explanations have been put forward to account for such observations, further research is needed to reach a better understanding.

On the other hand, it is well documented in the research literature that use of digital technology per se may not bring about enhanced learning outcomes, as much depends on the pedagogy adopted (Watson, 2001; Fisher, 2006). In fact, e-Learning needs to be an integral part of a deep pedagogical transformation in order to bring about the kinds of 21st century outcomes often mentioned in policy documents (Law, 2008a; Somekh and Davis, 1997).

The recognition that pedagogical innovations are needed to realise the potential of ICT to bring about desired learning outcomes stimulated studies of technology-enhanced pedagogical innovations (or TEPI in short). The first such large-scale international comparative study was SITES-M2 (Kozma, 2003), which found exemplars of innovative pedagogy even in economically less developed countries with low computer:student ratios. Law, Yuen and Fox (2011) identified six dimensions of innovativeness from the SITES-M2 case studies, and found that among those six, the roles played by the teacher and by the students in the learning process were the two most highly correlated with the innovativeness - the non-traditional nature - of the learning outcomes achieved. Further, the pedagogical innovativeness of the case studies had no correlation with the sophistication of the learning technologies adopted.

There are two noteworthy observations from the SITES M2 study. First, notwithstanding the decades of university-led TEL research and development projects, none of the 174 TEPIs reported by the national research teams in the 26 participating countries mentioned that the innovation originated from university-led projects. Instead, the cases were generally identified as initiated within the schools concerned, either by the teachers or the school leaders. This result could be related to two of the criteria used in the case selection as stipulated by the study: evidence of sustainability and scalability of the TEPI. Another observation is that the pedagogical approaches pioneered in these innovations, e.g. collaborative inquiry and learning from authentic problems involving the participation of members of the community, are still rare in classroom practice in countries around the world as revealed by large international studies conducted more than a decade later, such as ICILS 2013 and PISA 2012. These findings point to the importance of school-based agency and ownership as well as the significant challenge in scaling up TEPIs.

Research evidence gathered in the second decade of the new millennium shows more examples of systemic improvement efforts that have scaled. The collection of papers in Section 2 of the Second International Handbook of Education (Hargreaves et al., 2010) on systemic changes in education that have taken place in countries around the world testifies to the progress made in this area. In comparing seven case studies of technology-enhanced learning innovations (another name for TEPIs) that have achieved some level of scale collected in Europe and Asia, Law, Kampylis and Punie (2013) find that the innovations implemented at larger scale tend to have less ambitious educational goals as a common strategic basis for participation, requiring lower levels of innovativeness in the pedagogical practices. On the other hand, the level of innovativeness does not necessarily determine the scale of implementation. In particular, the study found the Singapore ICT Masterplan 3 (mp3) to have achieved a scale higher than expected given the level of innovativeness it was targeting, while the scale achieved by the e-Learning Pilot Scheme in Hong Kong and the e-Textbook project in South Korea were both lower than expected. The comparative study of European and Asian TEPIs that scaled show that while scaling TEPIs is challenging, it has been achieved to differing degrees in countries that differ widely in their culture, socio-political and education systems. Law, Kampylis and Punie, (2015) further show that there are multiple pathways to scaling TEPIs.

OECD/CERI conducted three strands of studies on pedagogical innovations under the broad framework of Innovative Learning Environments, starting from a clear focus on learning research to identify the cognitive and social processes needed to underpin learning effective in preparing learners for life in the knowledge era (OECD, 2010). This provides a theoretical basis from learning sciences research for the need for pedagogical innovations if technology use in teaching and learning were to deliver the promise of fostering 21st century capacities, as well as arguments for the constituent features of innovative learning environments. A further study was of 125 cases of learning innovations collected from more than 20 countries (OECD, 2013). The analyses go beyond a focus on classrooms to examine the elements and dynamics at the core of the "ecosystems" that contribute to learning in these cases. The findings reveal that effective learning environments extend beyond the traditional classroom through social and cultural partnerships with parents, families, professional communities and networks. The third study (OECD, 2015a: 11) pushes the research agenda further to examine what it takes to go from innovative learning environments to building "learning eco-systems" that can bring about systemic transformations.

6.2. Mechanisms of change at multiple levels for scalability

This section reviews some key theories of change and educational innovation to examine what insight these might bring to understanding the conditions for scaling TEPIs. Before discussing the different models of change, there is a need to clarify the meaning of "scalability". Here we take as our point of departure Clarke and Dede's (2009) five dimensional model of scalability, which are depth, sustainability, spread, shift and evolution (the first four dimensions were proposed by Coburn [2003]).

6.2.1. Diffusion models of innovation adoption

The most often cited approach for scaling innovations is Roger's diffusion model (Rogers, 2003). The model highlights that even for innovations that are effective, they may not be adopted by those who would benefit from them. The model is grounded in a theory of communication, the efficacy of which depends on the channels of communication available as well as the features of the social system involved. This model is popular in studies of education technology adoption studies as it provides an apt description of the bell-shaped distribution of the positions taken by people in response to an innovation: innovators, early adopters, early majority, late majority and laggards. This model highlights the importance of communication and the need to attend to the social context and connections of the targeted audience for adoption. However, it takes innovations as ready solutions that only need to be implemented whereas technological tools and resources are only the media for the realisation of the innovative pedagogical ideas in the TEPIs. The technologies in the TEPIs are not ready solutions as in the case of boiling water to ensure that it is safe. The "adoption" of a new pedagogy, which is the core of the innovation, requires a constructive process of interpretation and adaptation on the part of the teachers and the schools concerned.

Innovation propagation also depends on the accountability structure involved. Whether one boils water before drinking is an individual decision that only affects the adopter, who is thus the legitimate adoption decision-maker. On the other hand, TEPI requires resource support beyond the individual, and the primary purpose of the adoption is not self-focused, but to change the learning experiences and outcomes of students. Hence, even when a teacher has made an individual decision to adopt a TEPI, that decision has to

be supported by a wide set of stakeholders for it to attain a legitimate status in implementation.

Another challenge in applying Roger's (2003) model to TEPI is that the physical process of diffusion is a unidirectional process, which cannot be reversed once triggered, and will necessarily achieve an ultimate state of uniform density. This means, taken literally, a diffusion model would predict that ultimately an innovation would spread. The only significant variation is in the time taken to reach uniform adoption. TEPIs, on the other hand, can sometimes have just a transient presence in the adoption schools in the same way that non-indigenous species introduced into a foreign ecology may simply go extinct (Law, Yuen and Fox, 2011). A model for understanding the scalability of TEPIs needs to include mechanisms for evolution and change in the innovation adoption process.

6.2.2. Design-based research: Teachers as co-designers in TEPIs

TEPIs require deep changes in teachers' practices and roles in the classroom, thus requiring new knowledge, skills as well as beliefs about the goals and processes of learning (Law, 2008a). Literature on teacher learning for TEL implementation has shown that training models focusing on imparting knowledge and skills are not effective in bringing about change in pedagogical practice. Models that report successful change are similar in providing experiential, action oriented learning involving teachers collaborating in communities of practice (Looi, Lim and Chen, 2008). In particular, collaborative design of curricular materials has been found to be an effective form of teacher professional development as it provides a situated context for the learning, agency for change by the teachers, and a cyclical mode of learning for continuous improvement and change (Voogt et al., 2015). Engaging teachers as co-designers in the design and implementation of technology-enhanced learning activities results in the greatest integration of technology-rich activities in teachers' practices compared with them being re-designers or simply executors of designed activities (Cviko, McKenney and Voogt, 2014). In fact, engaging teachers as co-designers is a common methodology for working with teachers in design-based research in the learning sciences community to pursuit of more effective models of learning and teaching in classroom settings (Cobb et al., 2003).

Co-design is an effective form of teacher professional learning activity for change as it is underpinned by the same learning science principles as have been identified for effective student learning: collaborative, inquiry-focused, and addressing authentic real-life problems (OECD, 2008; 2010). This form of learning gives agency to teachers as learners, and fosters the development of professional learning communities (Lieberman, Campbell and Yashkina, 2015).

However, the implementation of TEPIs requires change at not only the teacher level. Classrooms as sites of teachers' pedagogical practices are nested within schools, within school districts, state/ regional/national education systems and influenced by the wider educational ecology constituted by commercial, political, bureaucratic, and professional organisations at local, national and international levels as well as the interactions between them (Davis, 2008). Models of scaling TEPIs through supporting teachers as co-designers of TEPIs offer an effective model for innovation focused learning at the teacher level, but do not address the complex interplay of factors at other levels. In order to understand the wider contexts within which TEPIs emerge and develop, the SITES-M2 study collected information about school, regional and national level contexts pertaining to each case study of TEPI in addition to the in-depth descriptions of the pedagogical innovations at the classroom level (Kozma, 2003).

The study findings show that school level factors such as leadership involvement and school culture had an important influence on the initiation and development of the TEPIs studied. In a further secondary analysis of these case studies, Law, (2008b) found school leadership engagement to be a strong contributing factor to the sustainability of the innovations. Cases where the school leadership supported teacher collaboration and the establishment of teacher communities of practice connected with the TEPI showed higher sustainability, as these provided mechanisms for sustained teacher learning. The transferability of the SITES-M2 innovation cases was found to be influenced by both school-level ICT policy and system level education policy. Where the system-level policy encouraged and supported cross-school, multi-stakeholder collaboration networks around pedagogical innovations, the cases were more likely to have been scaled up within the same school and/or to other schools. Clearly, models of scalable TEPIs need to take account of the interdependence between teacher learning and conditions at the other levels within the educational ecosystem.

6.2.3. Models of change as theories-in-action of system level actors

Another important line of research into the scalability of educational reform comes from scholars involved in studying and guiding system level changes. Many of the researchers in this community have been in close collaboration with policy makers in driving change, either as a member of the reform team or as a consultant at the system level. Fullan and Hargreaves (2009) and Hargreaves et al. (2010) offer rich accounts and analyses of system level change in different parts of the world.

Andy Hargreaves has provided a succinct overview of the four ways of implementing education reform goals by policy makers in the Anglo-Saxon world since the 1960s (Hargreaves, 2009). The First Way was characterised by a focus on supporting professional freedom and flexibility, and the result was great diversities in outcome due to the lack of leadership for consistency in effort or impact. Standards-based reforms were subsequently launched to create coherence. Unfortunately, the reform goals could not be achieved simply through the stipulation of common educational standards.

The Second Way (from the mid-1990s to mid-2000s) attempted to enforce standards through market mechanisms such as league tables, standards-based accountability, competition, prescription and punitive actions. This resulted in the alienation of the teaching profession as well as damaged innovation and creativity. The Third Way is described as the post-standardisation response from policy makers characterised by three possible strategic foci: tighter regulation and market competition, strengthened statistical surveillance to monitor progress, and encouraging improvement processes through peer-driven networks (e.g. setting up mentor schools) or resource incentives for innovation initiatives.

These three ways are grounded very much in practice, but it is practice as experienced by people driving/implementing change at the policy level, and is very different from the practice of those at the classroom level. Learning at the student, classroom and teacher levels is considered as part of solutions to be implemented. How individuals and groups learn, and the finer details and complexities of instituting change and learning at these lower levels, are not considered as important in policy decisions for change at the system level beyond the general principles of motivation, support, incentives, and accountability.

Michael Fullan (2009) proposes that a theory of action is needed to realise whole system improvement in education, and that such a theory needs to satisfy three criteria: (1) it can address the needs of a whole system and not just a selection of schools; (2) it will result in

sustained improvement; and (3) it is motivating for different actors. Hargreaves, (2009) identifies "theory-in-action" of the Fourth Way, comprising principles to guide the strategic actions of policy makers: five pillars of purpose and partnership (highlighting the importance of having an inspiring vision, partnership and corporate responsibility as well as adequate resource provisions), three principles of professionalism (highlighting the importance of professional learning through communities, and having teachers as their own custodians of professional standards), and four catalysts of coherence (emphasising the need for leadership to be distributed, knowledgeable about learning, non-controlling, focusing on responsibility rather than accountability and supporting coherent bottom-up improvement initiatives.

Fullan's Theory of Action for System Change (TASC, 2009) is similarly a set of guiding principles, this time with six components. The first, direction and sector engagement, parallels Hargreaves's five pillars of purpose and partnership, but puts into sharp focus the need for a guiding coalition of key leaders (politicians) from the very top of the system, and not just the minister of education, as well as leaders at other levels of the system. The second and third components are similar to Hargreaves's principles of professionalism and leadership characteristics serving as catalysts of coherence. The three other components in Fullan's TASC are guidelines for managing the change process: managing the distractors, continuous evaluation and inquiry, and two-way communication; these describe the mechanisms providing feedback and communication to help maintain focus and bring alignment while navigating change in large complex systems.

In summary, there is emerging from this rich body of literature a deepening understanding of the complexities of change and the need for theories of change that take account of the alignment of different levels of the system, and that recognise professional learning is of paramount importance.

6.2.4. Building architectures for learning to support pedagogical innovations at multiple levels

Reform agendas stipulated at the policy level need to be enacted by teachers in classrooms for the envisioned impact on students' learning outcomes to be realised. However, unlike the contexts studied in design-based research, where the participating teachers are generally innovators or early adopters and scale is not a focal issue, systemic change requires buy-in from the majority of teachers to change their practices. For change to be implemented at scale throughout an entire system, the reform agenda has to be operationalised through the different levels of the system, usually involving district education offices and schools. Hence, our understanding of the nuances involved in scaling pedagogical innovations can be enriched by literature on the implementation of pedagogical change at school and district levels, focusing on the role of school and district level leadership.

In a study of how school leadership, particularly principals, in four demographically different schools mediated the implementation of curriculum policy by teachers, Spillane, Parise and Sherer (2011) observe the creation of organisational routines as "coupling mechanisms" to change teachers' practices. The use of the term organisational routines as defined by Feldman and Pentland (2003: 95) refers to "a repetitive, recognisable pattern of interdependent actions, involving multiple actors". These routines serve to connect specific elements of the policy regulation to the formal structure and administrative practice of the school to achieve greater alignment between teachers' practices and the core policy concerns. For example, the Five Week Assessment routine set up in one of the

schools coupled the government curriculum standards with regular five-week cycles of tests to measure student progress and indirectly to monitor the teaching, as well as provide the focus for staff meetings to review the test outcomes. By creating mechanisms and expectations for teachers to regularly share important aspects of their practice, such as content coverage and grading criteria of student work, the organisational routines also make these practices more transparent and subject to monitoring.

In some educational systems, there are intermediary levels of jurisdiction, such as school districts, that are responsible for the implementation of system level policy. Stein and Coburn (2008) studied how two school districts went about implementing a new mathematics curriculum in their schools. Adopting a theoretical lens that views implementation and alignment as learning challenges, and that learning takes place through appropriate forms of engagement, curriculum implementation by the districts could be conceptualised as designing the conditions conducive to meaningful learning by teachers. There are different stakeholder groups, which can also be referred to as communities, involved in the implementation process: district leaders, district math leadership team and instructional specialists, principals, math coaches and teachers - each with their own practices. Successful implementation requires effective channels of influence across community boundaries, such that there can be interactions not only among teachers within the same school, but also interactions of teachers with other communities within and outside their own school. They adopted Wenger's (1998) concept of “architectures for learning”, as the organisational environments that foster teacher learning through communities of practice, to investigate the conditions for learning available to teachers in different schools in the two districts studied.

They found that the most significant variation in outcomes was between the two districts rather than between schools within each of the districts. The more successful district provided more organisational structures for cross-level and cross-school interactions through a variety of strategies such as sharing the coaching role between two math teachers instead of having one single math coach in each school. The concept of organisational routine as used by Spillane et al. (2011) is an example of Wenger’s architecture for learning (1998) in an institutional context: “architecture for learning” is a generic concept that can also be applied across the levels and organisational units of a system.

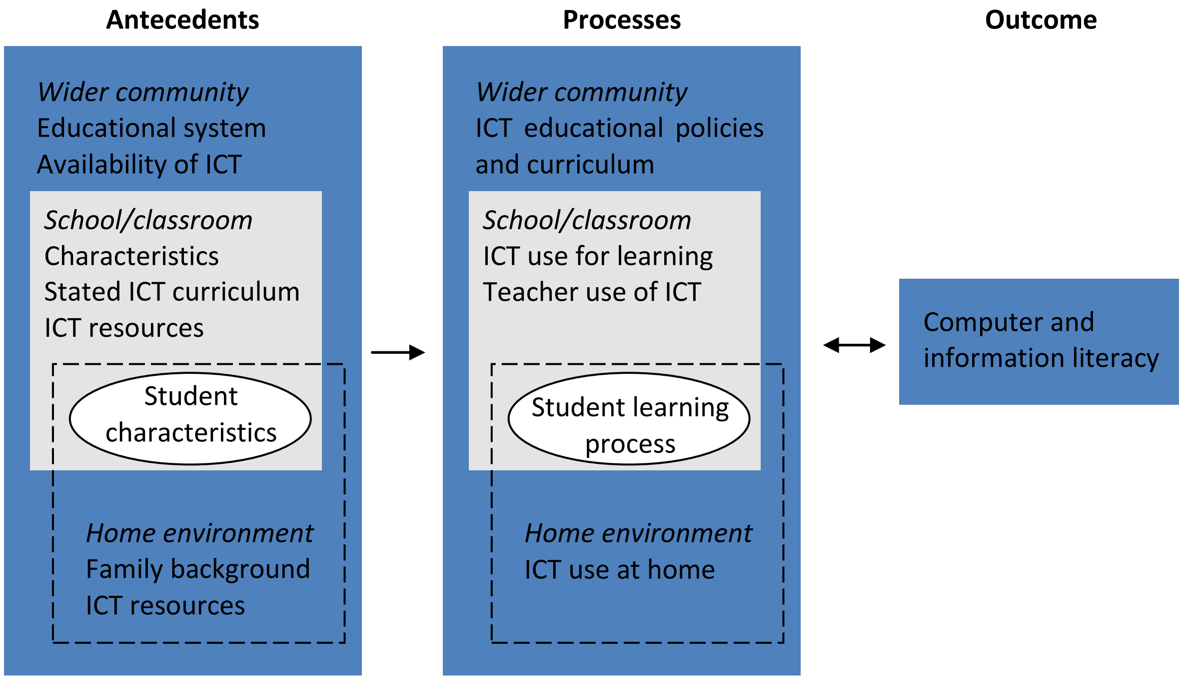
Research on change and leadership at the school and local (district) levels therefore provides an important link between studies of change at the system and classroom levels, and some of it conceptualises implementation and change as a learning process, providing a parsimonious continuity to studies of teacher and student learning.

6.3. In search of multilevel interdependencies for TEPI success

Education systems are complex systems characterised by interdependencies across and within units at each level. The previous section reviewed literature on models of change at different levels of the education system. However, studies on the scalability of TEPIs would be inadequate if they didn’t explore interactions and interdependencies across levels. Hence, similar to other large-scale international comparative studies (e.g. TIMSS) and national evaluation studies, ICILS 2013 collected data at student, teacher, school and system levels. Figure 6.1 shows the framework adopted by ICILS to conceptualise the relationship between the various contextual factors (referred to as “antecedents”), the learning process and student outcomes. As is common with the design of such studies, the

contextual factors and the learning processes at each of the different levels are grouped together.

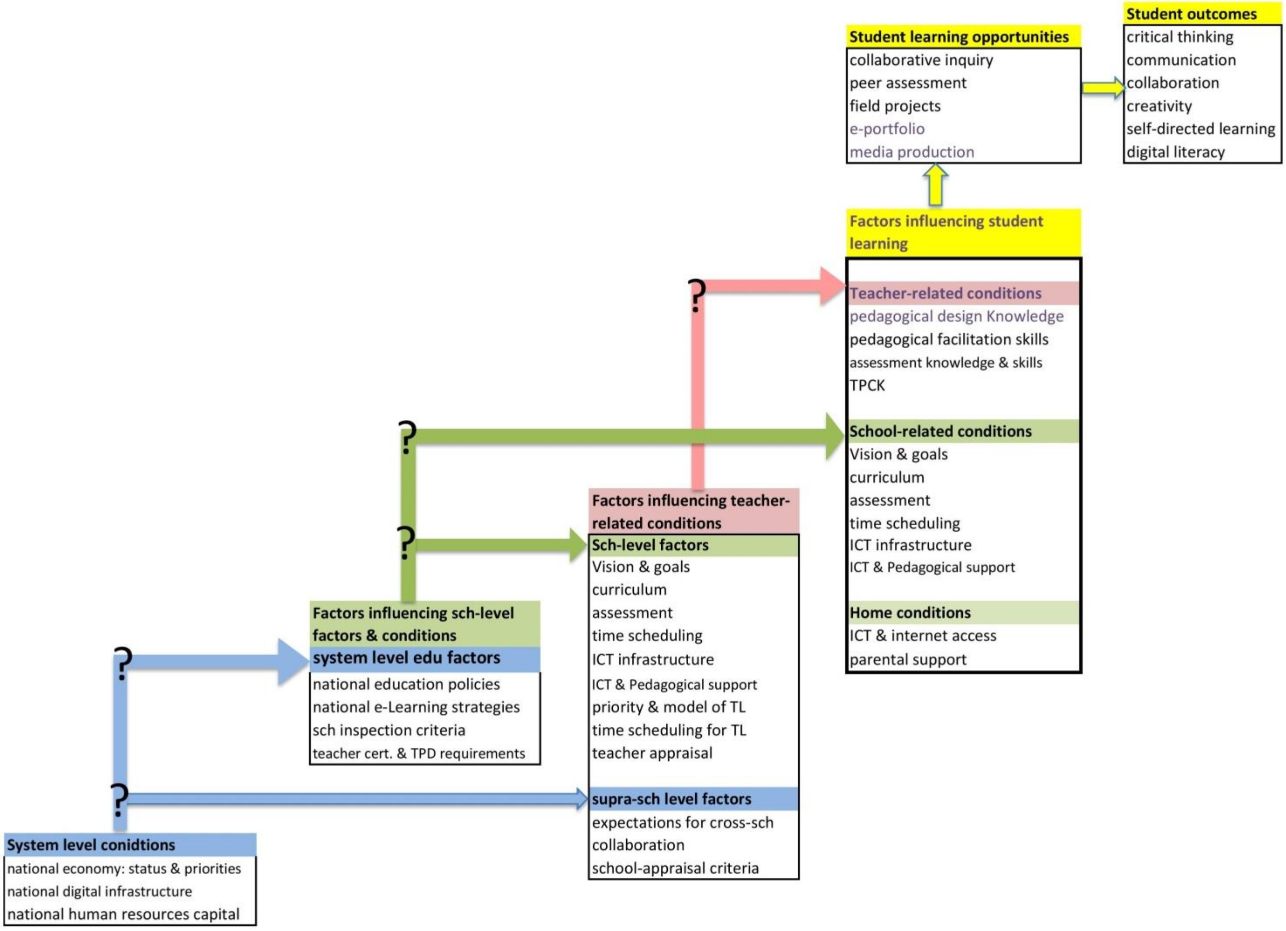
Figure 6.1. Conceptual framework in ICILS 2013 relating context to learning outcomes



Source: Fraillon, J., W. Schulz, T. Friedman, J. Ainley and E. Gebhardt (2015), *International Computer and Information Literacy Study 2013 Technical Report*, International Association for the Evaluation of Educational Achievement (IEA).

There is a need to unpack the intricate interdependencies in order that the massive amounts of contextual data collected can be used to provide valuable information about how school and classroom level factors influence student learning outcomes. Drent, Meelissen and van der Kleij (2013) report on a carefully constructed meta-study of published secondary analysis studies on TIMSS data up to March 2010 - so including TIMSS 1995, 1999, 2003, 2007 - focusing on the contributions of these studies to understanding the relationships between school and classroom contextual factors with student achievement. The study found relatively few papers that met basic quality criteria and actually reported significant findings between these contextual factors and students' cognitive outcomes in science or mathematics; where significant findings were reported, they are often inconsistent across countries. In addition to whether important scales and parameters have been included in the design, and the limitations of the cross-sectional design of these studies (Goldstein, 2004), there is a need for research designs to take account of the nuances of the multilevel dependences of these various factors. Here, as an illustration, Figure 6.2 unpacks the interdependencies implicit within the model underpinning the ICILS 2013 study.

Figure 6.2. Schematic of the constructs at different system levels included in ICILS 2013



Note: ? indicates the absence of descriptors or constructs on mechanisms that underpin the directional arrows of influence assumed in the studies.

6.3.1. Factors influencing students' learning interactions.

The nature and attainment level of students' learning outcomes depend very much on the learning opportunities available, which are represented under "student interactions" in Figure 6.2. The kinds and quality of learning opportunities are dependent on a number of factors. At the teacher level, they are related to teacher pedagogical capacities and practices (e.g. whether the teacher has the requisite pedagogical design knowledge, facilitation skills and technological pedagogical content knowledge [TPCK to organise collaborative inquiry activities for students); at the school level they are related to the vision and goals of the school, the curriculum and assessment policies of the school practices adopted, ICT infrastructure and pedagogical support available, as well as being related to home and personal factors.

6.3.2. Factors influencing the teachers' classroom practices.

The school-related conditions that affect students' learning opportunities such as the school vision and curriculum also affect the priorities teachers give to different kinds of pedagogical and assessment practices. Furthermore, where teachers are expected to

engage in active collaboration with other schools, such engagement may also influence their classroom practice.

6.3.3. Factors influencing school level conditions.

System-level education policies and strategies influence school leaders' formulations of school level vision, goals, curriculum, assessment as well as TEL implementation strategies, all of which may support or pose obstacles to teachers using ICT in classrooms.

6.3.4. General system level factors.

The national survey, which was completed by a knowledgeable ministry official nominated by the National Research Coordinator, provides information about the country's education system, structure, and curriculum. The ICILS 2013 survey included questions about ICT development in the country as reflected by the broadband penetration in family homes, as well as questions about policies for ICT in the school curriculum and its implementation in schools, including ICT infrastructure, digital learning resources, and teacher professional development requirements and opportunities.

There are question marks in Figure 6.2, indicating a "black box" in understanding the interactions across the different levels. The assumption is that these are causal influences from one level to the next, and essentially top-down, from higher to lower levels. In recent years, research has pointed to the need for dynamic models of studying educational effectiveness to better inform policy and practice that make explicit the assumptions about these interactions (Creemers and Kyriakides, 2008, 2010).

6.4. A multi-level multi-scale (MLMS) model of learning for scalable TEPIs

Building on work that argues for multilevel, longitudinal and dynamic models to understand student learning outcomes, this paper puts forward a model for studying the interdependencies using a parsimonious learning framework. A dynamic model focuses on the changes that happen at each of the levels. The proposed framework views change at each of the levels as requiring learning, and that the learning within and across levels are interdependent. The efficacy and scalability of change depend on the efficacy and scalability of the interdependent learning systems involved. A diagrammatic representation of this model is presented in Figure 6.3, and the key postulates or principles of this model are described below.

6.4.1. Changes at each level are conceptualised as learning.

The core concept is that the conditions or factors at different levels influencing student learning should be conceptualised as learning outcomes of those levels. Hence, teachers' TPCK and assessment skills are learning outcomes at the teacher level; the organisational structures, curricula, assessment and appraisal systems of schools are the learning outcomes at the school level; and national education policies, e-Learning strategies, teacher certification requirements and school inspection criteria are learning outcomes at the system level. Such a learning model highlights the importance of pedagogical design (i.e. designing the learning environment and learning interactions within and across these different levels) in achieving the targeted outcomes. In the educational change literature, as reviewed above, mechanisms for change are often conceptualised within a particular level. Diffusion models and design-based research literature focus on change at the

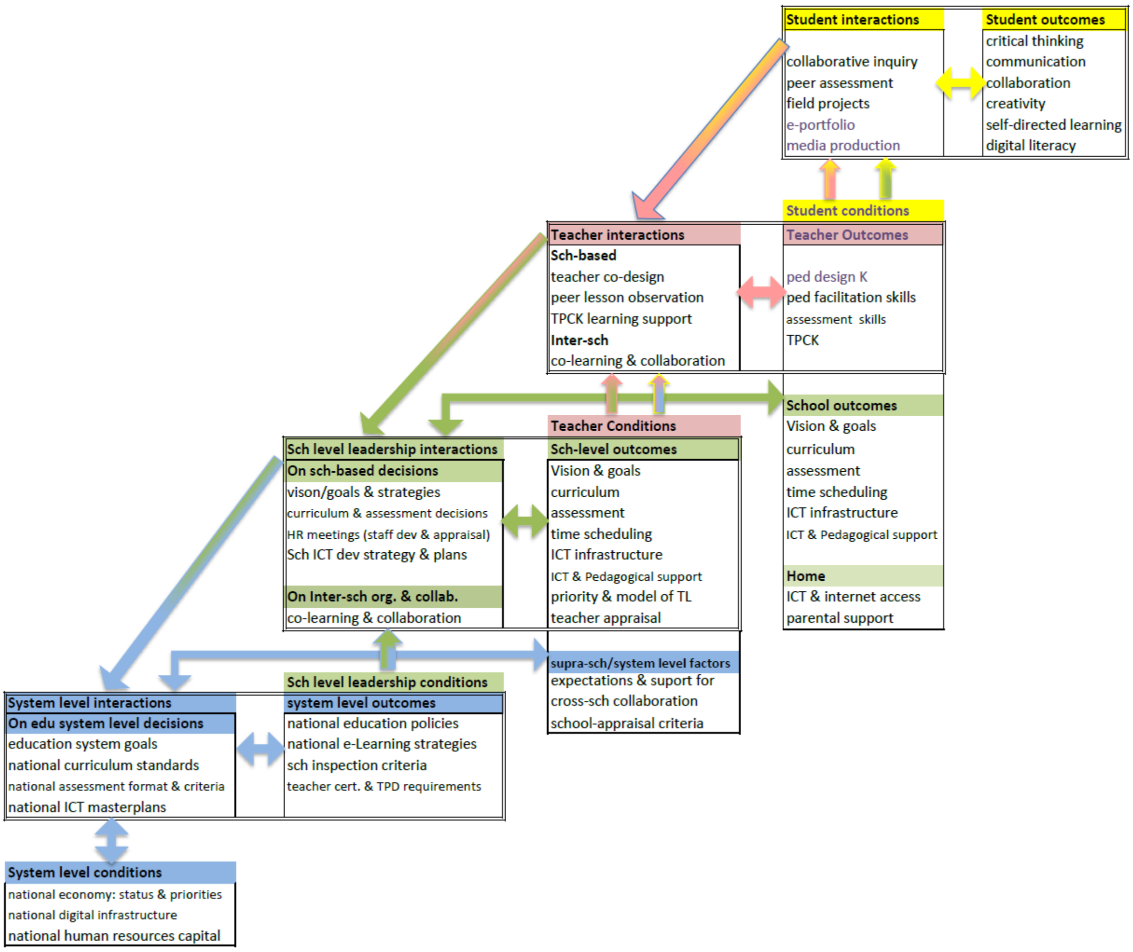
teacher and classroom levels, and the latter often does focus on learning but primarily at the teacher level. In research on system change, the focus tends to be at the strategic level in ensuring focus and alignment in navigating change in large complex systems (e.g. Fullan and Hargreaves, 2009). While these models of managing change recognise the importance of supporting professional learning, they do not perceive change at the system level as learning. Research on architectures for learning in the literature on change and leadership in schools and districts (Spillane et al., 2011; Stein and Coburn, 2008) shows that organisational environment and routines have a major impact on teacher learning due to the different channels of communication and influence that these provide to foster interactions among different professional communities, and hence contribute importantly to different outcomes in terms of changes in teachers' practices. These findings provide crucial support to the model being proposed here.

6.4.2. Tangible and conceptual artefacts as learning outcomes.

Figure 6.3 is a schematic of learning within and across the multiple levels of stakeholders within an education ecosystem. There are three sets of constructs at each level: learning outcomes, learning interactions, and conditions for learning, colour-coded yellow, pink, green and blue for student, teacher, school and system levels respectively. The main focus for learning outcomes at the student level is on 21st century abilities such as critical thinking, collaboration and communication, which are best fostered through collaboration in solving authentic problems. Likewise at the other levels, the outcomes are policy and implementation decisions, ideally arising from collaborative problem-solving interactions.

The schematic in Figure 6.3 shows that there are two types of feedback loops: those connecting the constructs within each level and those connecting constructs across the different levels of the education system.

Figure 6.3. Schematic of the feedback loops within and across levels of the education



Note: The bi-directional arrows indicate within level learning, where the learning outcomes also feedback on the planning and organisation of the learning interactions. Two sets of one-directional arrows connect each pair of adjacent levels, representing between-level learning feedback to allow for multilevel alignment.

6.4.3. Scale matters: Peer collaboration and inquiry as core mechanisms for effective learning at all levels.

Peer collaboration and inquiry are key pedagogical characteristics of classroom practices for fostering 21st century learning outcomes in students. In implementing TEPIs, stakeholders at each level have to generate the learning outcomes through a process of authentic problem solving. Hence, these stakeholders themselves have to engage in 21st century learning.

Through analysing promising propagation strategies for implementing innovative learning environments collected from 26 countries, the OECD ILE project (OECD, 2015a) identified six threads underpinning the diverse initiatives, three of which are directly related to supporting learning at multiple levels: culture change, capacity creation, collaboration and cooperation. In particular, the study highlighted the importance of collaborative professionalism and networks based on voluntary engagement for learning at the meso and meta levels. These findings indicate that collaborative inquiry is important at the student and teacher levels but also to learning at

the more macro levels of the education system; they also point to the significance of learning-focused networks in the scaling of innovations.

The arrows connecting the learning interactions and learning outcomes within each level are bi-directional, highlighting the importance of stakeholders at each level reviewing and reflecting on the outcomes of their learning for iterative improvements of the learning process. Furthermore, idea diversity is an important knowledge building principle (Scardamalia and Bereiter, 2003) and a pre-requisite for idea improvement through collaboration. Hence, interacting with peers from outside of the specific unit serves the significant function of enriching the learning at each level, whether it be the school, the district or the education system. It follows that scale matters in the scalability of TEPIs. Models of scaling that start with pilot projects involving one or very few schools developing innovation prototypes before wider dissemination are generally less successful than those that start as innovation networks (Law, Kankaanranta and Chow, 2005). As pointed out by Law, Yuen and Fox, (2011), pedagogical practices identified as innovations are by definition alien species within their education ecology. Hence, the concept of "innovation adoption" is misleading if taken literally, since any "adoption", if successful in becoming sustainable, will bring about changes in the local ecology. This also implies that stakeholders at different levels of the local ecology need to be engaged in a process of learning associated with the innovation for it to be scaled.

The outcomes of scalable "adoptions" are likely to be products of evolution (Clarke and Dede, 2009) and hence would rarely be high-fidelity replications of the original. A Europe-wide initiative to promote intercultural awareness through an online collaboration platform to connect classrooms in different countries, eTwinning, became a wellspring of technology-enhanced learning innovations when additionally supported by national/regional strategies to encourage teachers to engage in experimentation in these directions (Kampylis and Punie, 2013). This is a prime example of how TEPIs may evolve through the provision of an effective network infrastructure for connecting potential innovation units at scale.

6.4.4. Architectures for multilevel stakeholder engagement and participatory decision-making.

In Figure 6.3, there are three pairs of adjacent levels along the diagonal: student-teacher, teacher-school and school-system. For each of these pairs, there are two sets of unidirectional arrows representing between-level learning feedback that can be leveraged to achieve cross-level alignment. For example, the school-level outcomes constitute the immediate conditions affecting teacher learning interactions; these in turn affect school-level decision-making if there are channels for the leadership to understand the tensions and obstacles to teachers' learning in realising the school's e-Learning goals. Conditions for learning at the different levels such as classroom and school routines, staff appraisal criteria, national curriculum and assessment methods, are interdependent. For the innovation to develop at scale, these conditions need to evolve organically and interdependently over time through self-organising learning interactions across the different levels. This in turn depends on whether there are appropriately crafted channels of communication and mechanisms for participatory decision-making involving multilevel stakeholders - i.e. an architecture for multilevel learning - to ensure systemic alignment during innovation implementation.

The schematic in Figure 6.3 may give the impression that all learning interactions need to be rigidly scripted but learning interactions takes place through a balance of formal and

informal channels in authentic situations (OECD, 2015a). The descriptions and arrows in the schematic seek to disentangle the different levels and factors. However, the interactions in the education ecosystem are dynamic and the elements will change organically over time.

6.5. Implications of the multi-level multi-scale model for scalable TEPI

Taking MLMS learning as the core mechanisms for scaling TEPI, there are a number of implications to derive from the principles described above.

6.5.1. Scaling TEPIs

One important advantage of conceptualising the change process as MLMS learning is that it can guide scaling strategies. TEPIs are not static formulations to be copiously followed, but are dynamic systems. As depicted in Figure 6.3, change may be initiated at any level, but the change agents need to engage in intentional design learning interactions within and across levels, to provide opportunities for dynamic, self-organising alignment for the gradual changes in the education ecosystem to come about that favour the TEPI's long-term sustainability.

6.5.2. R&D on pedagogical designs for MLMS learning

Human beings learn through experience and reflecting on those experiences, which may not be associated with intentional learning settings. In the same way, teachers, schools and societies sometimes learn - change - without conscious planning or design. However, without intentional planning and design in formal or informal settings, the learning outcomes are likely to replicate the status quo within the particular ecosystem if there are no changes in the environment. Given rapid technological and socio-economic change and the pace of globalisation, such a laissez-faire approach is recognised by many policy makers to be untenable - hence the emergence of educational reform and various IT-in-education initiatives. While such initiatives may be accompanied by research on curriculum and pedagogical designs for classroom learning, and increasingly on teacher learning as well, the same is rarely available for learning at the school level, system level and across levels. The MLMS learning model provides a theoretical framework for much-needed R&D to advance the theory and practice of scaling TEPIs.

6.5.3. Evaluation of TEPI plans and their implementation

An advantage of conceptualising change at each level as learning is that it facilitates distinguishing between surface and deep learning. At the individual level, if the outcome is only the result of rote learning without understanding, it may well not withstand the test of time, or be sustainable when the context for application of the knowledge or skill changes. Similarly, policy decisions in schools or systems may not be understood or supported by the professionals, students or the community even when decided upon and implemented. In some cases, such decisions will be reverted in the face of strong stakeholder dissent. Deep learning at the institution or system level involves cultural change, requiring multichannel and sustained interactions over time. MLMS learning can serve as an intentional design framework for scalability. It can also serve as a powerful lens for the examination of TEPI implementation projects/plans to gauge their likelihood of successful scalability.

Many countries have invested enormous resources and efforts to launch education reforms and ICT-in-education masterplans since the turn of the Millennium. These efforts are often designed and implemented as standalone, one-off efforts to achieve a set of well laid-out goals, objectives, and conditions as depicted in Figure 6.2. The intrinsic flaws of this approach were described in the previous section, particularly in the lack of understanding that the changes needed at the various levels are not to be achieved in one step, and have to be negotiated through sustained, multilevel, interdependent learning. TEPI plans and implementation strategies that do not make provisions for multilevel multiscale learning and alignment are intrinsically deficient in scalability and long-term sustainability.

6.5.4. Predicting the scalability of change – the "formative evaluation" of TEPIs

In education, we are familiar with the need to specify learning outcomes, pedagogical and assessment designs so that they can be appropriately evaluated; there has been much research on assessment as learning, encompassing design principles and designs for learning activities to reveal learning progression in individual learners so that the designs can be adjusted according to learners' needs. If student learning, which typically takes place within days or weeks, needs formative feedback, it is even more important for this to feed into MLMS learning at the organisational and system levels. Learning outcomes in schools, such as routines, staff appraisal and incentive systems, assessment methods, and staff competence, and in systems, such as national education policies, school inspection criteria, teacher certification criteria, typically take months and years. For these school and system level changes to have measurable impacts on student learning takes even longer. Hence, it is even more important to design the change management mechanisms to assess the alignment of the learning outcomes within and across levels, and for the findings to feedback formatively to the multilevel learning process that is the innovation. There needs to be research on methodologies to identify key interdependencies, the state of alignment, and effective mechanisms for self-organising alignment. A preliminary proposal for the design of a multilevel system of quality technology-enhanced learning and teaching indicators based on the MLMS model was discussed at the EDUsummIT 2015 (Law et al., 2015) and further elaborated in (Law et al., 2016).

6.6. Conclusions and discussion

Empirical studies of TEPIs in Europe and Asia (Law, Kampylis and Punie, 2013; 2015) reveal that agency for change can be various and sometimes multiple, depending on specific contexts. Socio-political and education systems differ, and change strategies should pay attention to the local ecological contexts to build "architectures for MLMS learning". Learning outcomes include not simply beliefs, knowledge or skills. Such factors as organisational structures, decision-making mechanisms and processes, rules and regulations, and physical and digital infrastructures affect the efficacy of learning. In this model, artefacts, social, physical and digital infrastructure and organisational routines are important learning outcomes at the different levels. This conception of learning outcomes lies at the core of the MLMS learning model, with consequences for theory, policy and practice.

Based on this MLMS model, existing conditions for learning within and across each of the levels can be identified, and whether changes are needed to achieve the targeted

learning outcomes. Structures and mechanisms for interactions and decision-making can be intentionally designed to foster self-organised learning towards the overarching vision and goals for student learning. There are always variabilities and imbalances as the system moves forward, and this model highlights the need for building within- and cross-level learning interactions for alignment and dynamic systemic advancement. This proposed model can be used to guide pedagogical and assessment design, feedback and evaluation of MLMS learning for scalable TEPI. It can also serve as a framework to guide policy-makers, practitioners and researchers towards research findings and models of learning to shape their planning and implementation of TEPIs at scale.

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