Agile Education, Lean Learning

David Parsons and Kathryn MacCallum

Abstract There is growing interest in applying both agile and lean concepts in the classroom to improve educational experiences. In this chapter, we draw together the disparate ideas of these two fields from industrial practice and the existing work within this area to develop and frame the major concepts of agile and lean thinking for teaching and learning. The chapter summarises the key ideas relating to how values, processes and techniques from agile software development, overlaid with related concepts from lean thinking, can be translated to the broader needs of education across disciplines for students of all ages. From a review of the available literature, we draw out a simple conceptual framework that we use to present the key themes from the literature around how both agile and lean approaches can be used in education. We conclude by providing some insights into how agile and lean teaching and learning can be applied as an integrated set of educational concepts by identifying the essential skills and practices that can be transferred to the classroom.

Keywords Agile · Lean · Schools · Education · Teaching · Learning

1 Introduction

In this chapter, we look at how agile and lean ideas have been taken from industry and applied in the classroom. Then we take the key themes and concepts from both these approaches and integrate them into a simple conceptual framework that identifies the main ways in which these two industrial practices have been applied to teaching and learning, regardless of subject discipline and level of education. In doing so, we aim to draw out the important skills and practices that are required in making this transition from one domain to another.

D. Parsons (✉)
The Mind Lab by Unitec, Auckland, New Zealand
e-mail: daveparsonsnz@gmail.com

K. MacCallum
Eastern Institute of Technology, Napier, New Zealand

D. Parsons and K. MacCallum (eds.), *Agile and Lean Concepts for Teaching and Learning*, https://doi.org/10.1007/978-981-13-2751-3_1

1.1 Using Agile to Teach Agile and Lean to Teach Lean

The bulk of the literature around applying agile methods to teaching and learning focuses on various aspects of the design and development of software systems. These studies typically focus on the application of agile methods for teaching software engineering (e.g. Melnik & Maurer, 2003), redesigning teaching approaches (e.g. Layman, Cornwell, & Williams, 2006), supporting teamwork (e.g. Rico & Sayani, 2009) and applying agile approaches (like Scrum) to support student development (e.g. Mahnic, 2012). Much of this effort is justified on the grounds that it prepares students studying software systems development with the required industry skills for entering the profession (e.g. Bruegge, Reiss, & Schiller, 2009), rather than providing any exploration of whether agile methods themselves offer new and valuable approaches to pedagogy across a range of educational contexts. Although some authors have attempted to broaden their focus on education, such as Hazzan and Dubinsky's (2014) references to the Finnish education system, many still mainly address software engineering issues.

A similar limitation applies to much of the literature around lean approaches to education. The focus of much work in this area is narrowly directed to higher education institutions, either related to their administrative processes or the use of lean principles to teach certain technical subjects. Most of the chapters in Alves, Flumerfelt, and Kahlen (2016), for example, describe lean approaches to the teaching of engineering or related subjects, typically in higher education, or lean processes at the institutional level. The idea that lean is a mechanism for streamlining the administrative processes of educational institutions is examined even more explicitly in Balzer (2010), where teaching and learning is excluded from the analysis entirely. Francis (2014) notes that much of the literature about applying lean to education reports on institutions adopting the industrial model uncritically, and questions whether this is appropriate. This question is further reinforced by Comm and Mathaisel (2005) who observe that many educational institutions regard lean as a process of cost cutting and outsourcing, rather than one that aims to meet the needs of the learner.

Overall, in the literature we see a lot of work describing the use of agile to teach agile, and lean to teach lean, or work that applies industrial disciplines to the processes of education, as if teaching and learning is the same kind of product as cars or software. Less evident than these approaches, though perhaps more important to education as a whole, is literature that addresses how agile and lean methods can be used more broadly within the classroom, beyond the systems development, engineering or management contexts. That is the focus of this chapter.

1.2 Agile and Lean Education

Although there is a significant body of work that addresses either agile or lean concepts applied to education, they are rarely dealt with together in this context. In

this chapter, however, we seek to identify complementary themes and ideas from both strands of research. The main motivation for this is that both agile and lean approaches have been successfully integrated into software development, a combination that has been extensively discussed in the literature for that field of practice and related areas such as supply chain (Naylor, Naim, & Berry, 1999). One popular example would be the 'Scrumban' software development method, which is a combination of the agile Scrum process and the lean Kanban technique (Ladas, 2008). The two approaches are seen as partly overlapping and complementary, for example Petersen (2011) notes that both share the same goals and define similar principles, though agile has more of a process focus.

In the following sections, we first examine agile and lean approaches in isolation, then bring them together to explore their complementary philosophies. We begin by providing a brief overview of agility and agile software development methods before moving on to how agile methods can be applied more generally in the classroom. We then explore in more detail how agile values, processes and techniques may be reinterpreted in the context of teaching and learning. This is followed by coverage of lean concepts, and how they relate to education, again focusing on values, processes and techniques. The final section of the chapter draws together these various themes and ideas and provides an analysis of how agile and lean can effectively transition from their industrial roots to teaching and learning.

2 Agile Methods

Agile methods for software development evolved as a response to the changing dynamics of the software industry in the 1990s. The focus on customer needs and being responsive to changes in requirements at any phase of development were seen as increasingly important (Dingsøyr, Nerur, Balijepally, & Moe, 2012). The broader concept of agility emerges from the four values and 12 principles expressed within the Manifesto for Agile Software Development (Agile Alliance, 2001). Although agility itself is not formally defined within the Manifesto (its principles only refer occasionally to 'agile processes'), the concept of welcoming change is embodied within these principles, along with collaboration, motivation and reflection. Agility within software development is underpinned by these concepts to rapidly create, embrace and learn from change while contributing to perceived customer value (Conboy, 2009).

2.1 Agile in Education

Embracing change is a fundamental principle of agile software development (Beck & Andres, 2005). In a rapidly changing world, education also has a pressing need to do the same. The aspects of change, flexibility and leanness (a concept borrowed from lean management) introduced above are just as important in education as for

software development. Educators are constantly subjected to change as new and emerging techniques, tools and ways of teaching are assessed and implemented to support the dynamic needs of today's learners (Hew & Brush, 2007).

It is notable that much of the material available on the specifics of agile teaching and learning comes not from academic sources but from other individuals and organisations who have a practitioner focus. Briggs (2014) notes that agile approaches are being tried out in schools around the world, citing India and Brazil as two examples. Other high-profile practitioners are active in the United States (Agile Classrooms), Peru (Laboratoria), Australia (Agile Schools), and The Netherlands (eduScrum and Scrum@School) among others. Unfortunately, there is a lack of formal literature about these initiatives, but a number of academics have also addressed the relationships between agile and education. For example, Stewart, DeCusatis, Kidder, Massi, and Anne (2009) assert that software development and education have similar methodologies. Both require detailed planning and scheduling, rely on constant assessment and feedback from all involved, and have stringent quality and scheduling criteria. Exploring this link further, they summarise that agile methods can be incorporated into the learning context to enhance project-based learning, collaborative experiences and student-led learning, and can support learning that is goal driven rather than plan-driven.

2.2 Mapping Agile Methods to Classroom Practice

Problems arise, however, when trying to identify more specific mappings between agile methods and classroom practice. Many of the examples in the literature outline agile education in very broad terms. For example, Dewi and Muniandy (2014) draw together some literature on agile approaches to teaching and learning, but their summary of techniques is very general (e.g. small group discussion, problem-based learning, blended learning, cooperative learning, etc.) and it is hard to link these practices specifically to any agile sources. Obrist et al. (2011) examine how the adoption of agile team roles (such as testers, informants and design partners) within design-based activities can clarify and strengthen team participation. However, this discussion only focuses on one aspect of agile, and again the mapping between the specifics of agile industry practice and what might be termed agile teaching practice is at a somewhat abstract level.

Some authors have tried to more closely tie agile methodologies to agile teaching. In particular, Meerbaum-Salant and Hazzan (2010) distil agile practices into three aspects; a pedagogical class management aspect, a social aspect and a project management aspect. In their Agile Constructionist Mentoring Methodology (ACMM) they define a teaching process that supports teachers in guiding their students in software projects. This methodology is based on the seven categories of Shulman's Teacher Knowledge Base Model and constructionism. Their approach is presented within the context of teaching software development, but also has application to other classroom environments. However, these aspects are still largely conceptual in

nature, and although they try to connect agile methodology to teaching and learning this is still very much a broad-brush approach.

These examples perhaps indicate that interpretations of what is 'agile' in the classroom need to be more clearly defined. In addition, more concrete examples are needed to illustrate the specific ways that educators can use agile approaches to transform teaching and learning.

3 Reinterpreting Agile Practice for Teaching and Learning

If we are to be able to make specific recommendations about how educators can use agile practices in the classroom, then we have to break them down into implementable strategies. To do this, we analyse agile teaching and learning at the level of values, processes and techniques.

3.1 Agile Values

Four agile values are expressed in the Manifesto for Agile Software Development (Agile Alliance, 2001). Peha (2011) re-envisions how the four values of the manifesto apply to education in 'The Agile Schools Manifesto'. His version states that:

> We are uncovering better ways of educating children by doing it and helping others do it. Through this work we have come to value:
>
> Individuals and interactions over processes and tools;
>
> Meaningful learning over the measurement of learning;
>
> Stakeholder collaboration over constant negotiation;
>
> Responding to change over following a plan.

It should be noted that some earlier authors have made similar attempts to rewrite the manifesto for agile software development with educational contexts in mind. For example, an alternative reworking of the manifesto's four values was offered by Stewart et al. (2009). However, this interpretation focused particularly on active and collaborative learning. Another reworking by Tesar and Sieber (2010) suggested a similarly narrow focus on 'agile e-learning'. Such efforts tend to drift away somewhat from the original motivations of the values of the manifesto. Kamat (2012) changed every component of the values, while Krehbiel et al. (2017) used a longer and entirely different list of values, which seems to negate the idea that the existing values can be reinterpreted for education, rather than replaced. Given the limitations of these proposals, we will focus here on Peha's version of the manifesto.

There are two questions to be considered when looking at the reinterpretation of the agile manifesto in the context of education. In particular, we need to look at what remains the same, what has been changed, and why? In addressing these questions,

we can explore how agile methods can be seen as being directly applicable to teaching and learning, and also to identify the key measures of progress in education, and the main stakeholders.

What remains the same in Peha's agile values are lines 1 and 4. The fact that these are unchanged is perhaps at the heart of Peha's approach, which is that agile thinking can be applied to education with many of its fundamental ideas intact. However, some changes are essential to align the manifesto to education, in particular the replacement of 'working software' in line 2 as being the primary measure of progress with 'meaningful learning'. Another fundamental change is the replacement of 'customer' with 'stakeholder' in line 3. The concept of 'stakeholder' in education is very important, since it would not be sufficient to simply replace 'customer' with 'student'. Stakeholders in education are the students, but also their caregivers, the learner's wider family, teaching and administration staff, school boards, local and national education authorities and a range of other interested parties. Effective change within educational needs to engage with the beliefs, values, vision and needs of all stakeholders (Zion, 2009). On the right-hand side of the values, the replacement of 'contract negotiation' with 'constant negotiation' is interesting, since many educators feel that they are constantly dealing with changing policies and procedures rather than being able to focus on teaching and learning. The final change Peha makes is to replace 'comprehensive documentation' in line 2 with 'measurement of learning'. Again, many educators feel that assessment takes precedence over learning in many jurisdictions.

In addition to the four values, the Agile Manifesto also includes 12 principles. These can be seen as a set of competencies of individuals and teams that together enable agile development. In reference to education, Kropp, Meier, Mateescu, and Zahn (2014) point out that these agile competencies are not limited to technical skills, but also encompass social skills. While technical skills are important, the agile values and principles are much broader than these alone. Kropp et al. (2014) stress both agile values and attitudes, and outline an agile model based on learning through personal experience, social learning and learning through realistic discourse, and construction of values and value identity. Collaboration and communication are seen as key to these ideals.

It should be noted that the agile values expressed in the literature are generally taken to be those outlined in the Manifesto, but there are other definitions. For example, Beck and Andres (2005) defined the five values of eXtreme Programming (XP, an agile software development method) as communication, simplicity, feedback, courage and respect, which Meerbaum-Salant and Hazzan (2010) use as the basis for the ACMM.

Another approach to capturing the essence of agile in education is the Agile Compass (Delhij et al., 2016). Like the agile manifesto, the compass encapsulates a journey from one state of practice to another, in this case from prescriptive to iterative, content to culture, evaluation to visible feedback and reflection, control to trust and competition to collaboration. Although this interpretation is not based directly on the concepts of the original agile manifesto, it does capture the key idea of how agile transformation leads to change across a range of learning areas. Another

set of agile 'advantages' are outlined by Scrum@School (n.d.) and no doubt there are other examples. They key issue in interpreting these sets of values is to recognise what practical changes they imply in the classroom. In this chapter we discuss a range of examples from the literature where agile values have been put into practice.

3.2 Agile Processes

Educational institutions are full of processes, and some of these might benefit from a more agile, adaptive, change-embracing approach. Agile processes are essentially iterative cycles of creation and reflection, where budgets and timescales are fixed, and quality is a given. Thus, agile planning is based on trading off coverage against priority. Agile processes tend to either emphasise engineering (e.g. XP) or management (e.g. Crystal). Another essential feature of agile methods is that they are iterative and adaptive. An example of this approach in an educational context is the Successive Approximation Model (SAM) for developing learning products, with an emphasis on iterative, short work cycles (Allen, 2012).

Agile processes are not just adaptive. Being adaptive is often emphasised when discussing agile organisations, but adaptivity alone would lead to lack of direction and strategy. Agile organisations and teams need to be adaptive within a controlled, managed and interactive framework, so that in adapting to change, they are able to realistically negotiate priorities and resources with all stakeholders. It is this framework for adaptivity that agile processes provide.

Scrum is a very popular agile software development process with a management focus, which Peha (2011) suggests would help to establish shared practices supported by clear ownership and roles across the school. In a Scrum process, the product backlog (of user stories, which capture user requirements) is broken down into a series of sprints (timeboxed activities). In agile methods such as Scrum, the user stories are often captured using index cards on storyboards, which let people see what others are doing and help management track progress and plan (Cohen, Lindvall, & Costa, 2004). In each sprint, a priority list of stories (the sprint backlog) is chosen for completion, during which time the stories will move across the storyboard as they are completed. The sprint lasts for a certain period of time (e.g. 2 weeks, 30 days etc.). There are daily stand-up meetings during the sprint, and at the end of each sprint a working increment of the software is delivered. In other words, it is only a successful sprint if it delivers something useful. Peha (2011) re-applies the sprint concept to schools, where they can incorporate learning backlogs, rapid turnaround of learning and integrated assessment. He states that breaking down the traditional teaching durations of months or the school year to short sprints would help make learning more focused and reflective. This would mean that time is not wasted on ill-conceived ideas over long periods of time but that students can be reflective and able to adapt, with learning constantly reassessed and reshaped as learners progress through each sprint. This, implemented alongside backlogs of learner stories, would help to track learning progress and identify and focus learning goals.

3.3 Agile Techniques

Although a reworking of the agile values and principles provides a set of relevant competencies for agile teaching and learning, and processes provide overall frameworks for activities, it is at the level of techniques that we can really identify specific classroom practices that can be considered agile. Fortunately, there is a broad range of agile techniques that can easily be adapted to the classroom.

A number of authors have started to identify specific techniques from agile software development that can be applied to teaching and learning. For example, Peha (2011) examines a number of agile techniques (which he calls patterns of practice) that can be applied in schools, these include stand-up meetings, paired teaching, user stories and test-first development. Stand-up meetings could be used for both staff meetings and classroom meetings with students, though as Peha notes this would require certain levels of autonomy for both teachers and students to be effective. Paired teaching can help the sharing of knowledge and expertise and improve learning as teachers can each lead different parts of the learning experience based on their particular expertise. Peha confines his discussion to only paired teaching, but the same idea could also apply to paired learning, whereby learners are paired up to support and facilitate learning. Switching roles within pairs between 'driver' and 'navigator', and regularly switching pair partners, are effective ways of sharing knowledge between peers. Further suggestions by Peha to adopt user stories and test-first development relate strongly to making learning more connected to the learners and responsive to individual learning. For example, user stories enable a teacher to re-state generic learning outcomes in terms of specific user stories where the students are considered as the 'users', making the learning standards more relevant to individuals. Similarly, test-first development would help to clarify learning targets and make learning achievements more visible and responsive to the needs of the learner.

In addition to those mentioned above, a range of agile techniques applied to education have been suggested in several other sources. In their review of the literature around the use of agile principles in active and cooperative learning, Stewart et al. (2009) report on teachers using stand-up meetings, retrospectives, rapid feedback, regular measures of progress and collaborative teams in their classes. Manamendra, Manathunga, Perera, and Kodagoda (2013) discuss how they used stand-up meetings to manage communication between research students and their supervisors. Kessler and Dykman (2007) also recommend stand-up meetings, and pairing, along with several other aspects of the Crystal Clear agile method including frequent delivery, reflection, improvement, osmotic communication and burn charts (information radiators). Allen (2012) stresses prototyping, which has specific roles in agile methods, both as initial throwaway prototypes ('spikes') and also as architectural prototypes that can be further evolved.

As indicated above, although Peha (2011) suggests paired teaching, the concepts behind the agile technique of pair programming can also be an effective approach to learning, as other authors have proposed. If we take away the task of programming, the other components of pairing remain valid, in particular the continuous inspection

and the ability of the navigator to think more broadly and strategically about the problem being solved than the driver. Such pairing can be seen in other contexts, for example Vanhoenacker (2015) points out that when a pilot and co-pilot are in the cockpit of an aircraft, regardless of which one of them has their hands on the controls at a particular time, they are both simultaneously flying the plane. It is a paired activity. Therefore, this idea of mutual support and peer learning can be applied in multiple contexts and with many kinds of participants from various stakeholder groups.

In addition to the techniques suggested in these studies, there are possibly other agile techniques that could be considered as relevant to teaching and learning. Some of those not mentioned explicitly above include refactoring, regression testing, colocation, common coding guidelines, continuous integration and single sourcing information (Parsons, Ryu, & Lal, 2007). Even techniques that seem very much rooted in the development of code, such as refactoring and continuous integration, can perhaps be reformulated for an educational setting. The important thing is to identify the transferable concepts behind such techniques.

4 Making Learning Agile

Bringing these various ideas together, agile education might focus on the ideas of an iterative, adaptive process of student directed learning, built around learning stories created by the students themselves. Students would work mostly in pairs and self-organising teams, providing each other with constant support, feedback and mutual learning. Regular learning checks would take place through stand-ups and retrospectives, giving an opportunity for reflection on learning and embracing change where necessary. Students would be encouraged to develop broad skill sets and base their learning on real-world problems. Educators would act primarily as coaches, guiding learners rather than directing them, and the constant emphasis would be on meaningful learning above all other concerns.

5 Lean Manufacturing

So far in this chapter we have been focusing on agile concepts and ideas and how they might be applied to education. We now turn our attention to the concepts and ideas of lean manufacturing, and how these have been transferred into the world of software development and, more importantly, on into the world of teaching and learning. So, what is lean, and how can it act as a complement to the agile ideas that we have been exploring so far in this chapter?

5.1 From the Toyota Production System to Lean Software Development

Lean is an approach within manufacturing, that has its roots in the Toyota Production System from the second half of the twentieth century. Lean production was conceptualised as a way to reduce waste, upskill workers, improve quality and provide more variety in products than was possible with mass production (Womack, Jones, & Roos, 1990). More recently, it has been applied to the development of software in what might be termed the post-agile period (Poppendieck & Poppendieck, 2003; Anderson, 2010). Since then, many people have been looking for ways of applying these lessons to their own work contexts by applying lean thinking, which addresses how the lean production ideas from the car industry can be applied to a range of other industries (Womack & Jones, 2003).

5.2 Lean Concepts in Education

An important question for educators is why they would concern themselves with concepts about reducing inventory and shortening the supply chain, if their product is something very different, like intellectual property and graduating students, rather less tangible than many products of industry. The challenge here is to try and look at educational systems through new eyes, to understand the value streams that underlie them. Womack (2006) defined lean education as three processes; designing, making and using. Breaking this down further, 'designing' means creating the knowledge to be delivered, 'making' means providing learning experiences for students, and 'using' means students being able to experience continuous learning. The question for educators is whether it is possible to make all these processes lean. Bringing such concepts right down to the classroom level, it is possible to assist students to appreciate lean thinking through practical learning activities. For example, Swanson (2008) describes a 'lean lunch' exercise, which helps students to understand the 'Point-of-Use Staging' technique, designed to reduce waste by shortening the supply chain. With a broader focus, Ncube (2010) outlines how the 'Lean Lemonade Tycoon' game can be used with students to help them to understand lean principles. From such small activities, lean thinking can be developed in students. According to Barney and Kirby (2004), educators can learn from lean production the importance of empowering teachers by training them to problem-solve and then expecting them to be self-reflective and to continuously improve their practice (many of these factors are also apparent in agile).

6 Reinterpreting Lean Thinking for Teaching and Learning

In section three, we identified specific strategies from agile methods that could be implemented in the classroom. From an agile perspective, we looked at values, processes and techniques. In this section, we analyse lean thinking using related categories; value, the value stream and perfection, lean processes and lean techniques.

6.1 Value, the Value Stream, and Perfection

Three of the original five lean principles outlined by the Lean Enterprise Institute are value, the value stream and perfection (Womack & Jones, 2003)—the others being pull and flow (discussed later). Value is both the end product and the chain of processes that deliver it. The value stream is each step in the value process, designed to be as efficient as possible in meeting customer expectations, while perfection is pursued through continuous improvement.

One of the key challenges of lean is the difficulty of knowing how to add value. Womack and Jones (2003) question why is it hard to start at the right place, to correctly define value. This is partly because most producers want to make what they are already making and partly because many customers only know how to ask for some variant of what they are already getting. Educators, too, tend to work with traditional views of teaching, and learners are also likely to expect the established, familiar model of learning. It is difficult for both types of stakeholder to see how they might redefine the value of education. An interesting point, made by Dahlgaard and Østergaard (2000), is that one difference between mass production and education is that if there is a defect in mass production, then customers are likely to notice that defect (e.g. a fault in a product) quite quickly, whereas in education they may never notice the defect at all.

A lean approach to value and the value stream in education would aim to precisely specify the value of each learning experience and identify how it fits into the wider value stream, so that every step in the educational supply chain delivers value to the learner. To follow this approach, questions have to be continually asked, such as: Does this part of the curriculum deliver value? Does this form of assessment deliver value? Does this step in the enrolment process deliver value? The constant focus should be on how the educator delivers value to the learner.

The lean principle of perfection requires a constant focus on improvement. Improvements may be operational, administrative or strategic, but they must be clearly seen and demonstrated by satisfied customers (Womack & Jones, 2003). There are two types of improvement; kaikaku (radical improvement) and kaizen (continuous, incremental improvement). Bicheno (2001) discusses the differences between incremental and ‘breakthrough’ improvement, and suggest that that these need not always be driven by enforced processes but may also be passive, through

ongoing incentives such as quality circles. The main principle is to pursue perfection through continuous improvement of educational processes, methods and materials.

6.2 Lean Processes

One of the concepts of process that comes from mass production is the batch and queue approach (Poppendieck, 2011), and we tend to adopt this mass production view in many areas of education. Every semester/term we might deliver a set of classes over a fixed period of weeks, but this may have no relationship to how long it might take someone to actually learn something. Every year we produce a batch of graduating students, but often we do not know whether they are in fact ready to take advantage of the opportunities around them.

The two remaining principles of lean thinking are 'flow' and 'pull' (Womack & Jones, 2003). Flow replaces batch and queue processes that transform raw material into an end product. The goal is to provide continuous flow with minimal waste. In education, we aim to make learning flow without interruptions by right-sizing what is offered to the learner. Rather than broadcasting batches of content in mass production lecture halls or traditional classrooms, the lean educator would be engaged in the whole learning value stream, working closely with their colleagues across the whole process, moving away from batch blocks of material to smaller, more flexible learning components. A simple example of flow from a student perspective would be the ability to continue directly to the next stage of a course when they are ready, rather than waiting on institutional calendars (Isaksson, Kuttainen, & Garvare, 2013). In a similar vein, Alp (2001) suggests students being able to study at their own pace.

The principle of 'pull' means that the customer pulls the content they require, rather than having it pushed at them. The pull concept states that nothing should be built until a customer 'pulls' the product or service down the value stream (Womack & Jones, 2003). In education, content is often pushed towards the learner over timescales dictated by institutions. In a lean approach, the learner would pull from the educator the value they need, when they need it. One example where pull might be applied to education is by flexibly integrating demand from employers into vocational education programmes, giving students better prospects for employment on finishing their courses (Isaksson et al., 2013). Another idea is that students could create their own cross-disciplinary assignments to suit their needs (Alp, 2001). In a further example, Allen (2012) describes how pull was successfully used in an introductory Psychology class, allowing learners to take ownership of their own learning by choosing what they wanted to learn through discussion and priority setting.

At the highest level of lean processes there is the concept of the 'lean enterprise', which spans the whole value chain, and may involve many organisations (Womack & Jones, 2003). For a given school, the lean enterprise may involve the other schools that feed students into it, and the various schools, higher education institutions or workplaces that these students might move onto afterwards. All of these institutions are potentially part of the same lean enterprise. The difficult challenge is to convince

all of the stakeholders in that value chain to cooperate in becoming a single lean enterprise, by setting aside their own agendas. This would be a major task but is an important part of lean transformation. Godbey and Richter (1999) define the 'agile-virtual organization' as being cooperative, customising, fast and flexible, valuing human capital and relationships. Their description resonates strongly with the lean enterprise, with its vision of multiple institutions working together as a single enterprise. In education, they emphasise relationships over technology, while recognising the power of technology for collaboration and reach. As Comm and Mathaisel (2005) suggest, "Imagine a collaborative, higher education environment where duplicate functions do not exist but have shared resources with other institutions" (p. 236).

6.3 Lean Techniques

Pull and flow can be managed in a lean classroom by using Kanban (visual card) boards, which are one of the most widely used lean techniques, perhaps because of all the Japanese techniques it is the most exportable, relying little on its cultural context (Briggs, 1988). Kanban boards are similar to the agile storyboards mentioned earlier in this chapter, but the way that the user story cards are managed through the process is different because of the focus on pull and flow, concepts that are not specifically applied with agile storyboards. Within software development the Kanban board is a tool to support workflow management as it is used to visualise workflow, track work-in-progress (WIP) and embodies the pull system approach to manufacturing (Heikkilä, Paasivaara, & Lassenius, 2016; Goldman, 2009). The Kanban board is used to indicate progress in a transparent way and reinforces motivation and commitment to tasks. The Kanban board in education works in a very similar manner, but with more focus on learning flows or around tasks for assessment or learning activities. For example, it can be used in an individual or group activity to visually track student progress (Agile Classrooms, n.d.; ALC, n.d.). The Kanban board can be used to capture learning stories and then track progress in a visual manner and limit the WIP of an individual or student team. Examples of its use in education include an Education Kanban system used with trainee doctors (Goldman, 2009). The Kanban was used to record learning goals, identified in a collaborative manner, and record progress clearly and efficiently. The trainees were able to pull goals and work on them in a way that enabled them to take ownership of their own learning. In another example, at the Agile Learning Center, students use stand-up meetings alongside the use of Kanban boards to track their progress (ALC, n.d.).

Another key technique used in lean is the identification and methodical removal of 'muda' (waste). There are two types of muda. Type one muda is the waste caused by fixed components in the way that the system currently operates, for example an unwieldy student enrolment system, or a learning management system with inadequate functionality. In contrast, type two muda is waste that can be eliminated immediately. Of course, educators will encounter a high degree of type one muda. They tend to work within very bureaucratic organisations, sometimes very large ones,

with systems that are very difficult to change. Nevertheless, type one muda can be addressed by applying lean principles. A good example of how type one muda can be removed in education is outlined in Doman's (2011) study of a group of students who were introduced to lean principles and then tasked with re-engineering their institution's grade change process. They took a manual process that had evolved in a haphazard fashion over 50 years or so, and performed a lean analysis on how it could be improved. Their new online system design was adopted by their institution and proved to be both more efficient than the old system and to result in better outcomes for all stakeholders.

While addressing type one muda requires considerable effort and time, educators are also likely to encounter a large amount of type two muda that can be identified and removed from the value chain much more quickly and easily. The Toyota Production System includes seven categories of waste (Hines & Taylor, 2000). Since it is probably more appropriate to look at evaluating education as a service than a product, it may be helpful to examine these definitions as forms of service waste (adapted here from Bicheno & Holweg, 2000):

1. Overproduction—Are too many courses being offered, or is there too much information in classes, and is the right education being produced at the right time?
2. Defects—Are learning materials of good enough quality? Are there frequent errors in learning and administrative materials? Are classes well delivered (face to face or online)
3. Unnecessary inventory—Is there too much material in a learning management system or course? Does it take a long time to provide learning materials or give feedback? Are certain services half finished?
4. Inappropriate processing—Do people have to put in excessive effort in order to deliver a service? Do reports, exam results, etc. use over complex and slow systems?
5. Excessive Transportation—Do educators and/or students have to physically move themselves, or materials around? Does information move around unnecessarily?
6. Waiting—Do stakeholders have to wait a long time for information? Are processes unnecessarily delayed, waiting for something else to a happen? Is information flowing correctly and efficiently?
7. Unnecessary motion—Are activities, paperwork and other efforts unnecessarily juggled?

Since the creation of the initial list of seven wastes, there have been a number of suggestions for adding further types of waste to the list as the '8th waste'. One of those adopted by a number of organisations is the waste of human talent—are skills being under-utilised? Are staff performing tasks that are not adding any value to the organisation? (Oppenheim, Murman & Secor, 2011). Using these ideas around the various forms of service waste, we may identify both type one and two muda. For example, Doman's (2011) study found type one muda with inappropriate processing and waiting, but any educational set of processes is also likely to reveal many examples of type two muda. There are probably many courses being offered where there

is too much material, for example, and where educators can easily begin to address this type of muda.

Another important lean technique is selecting and designing where students learn. Womack (2006) discusses the 'gemba' (the 'real place', sometimes written as 'genba'), where problems are visible, and from where the best improvement ideas will come. In lean education, he suggests teaching process thinking and problem-solving by doing. With a focus on learning in real-world environments, he proposes developing a range of gemba for applied learning. This could be done by building relationships with industry. However, in many cases it may be hard to find suitable other organisational venues, so the learning institution can equally be used as a gemba. Perhaps by providing environments such as Makerspaces, schools and higher education providers can become more effective gemba. Böhmer, Beckmann, and Lindemann (2015) suggest that Makerspaces can be part of an open innovation ecosystem that embraces other agile and lean principles. In whichever physical context, it is important to grade students on the degree to which problems are actually solved using a rigorous method. This ties in closely with the concept of real-world learning and problem-solving as being a core twenty-first century skill (ITL Research, 2012). One example of using the learning context as a gemba and requiring students to solve problems within it is Marley's (2014) description of students making lean-related videos as part of their assessment.

A related concept is the 'gemba walk', which means visiting the real place to identify problems and muda. As lean educators, it is therefore important to enable students to work in real places related to their learning, with a specific task to solve problems and/or identify waste. A clear example of this, referred to earlier in this chapter, was the students who used their own institution as the gemba and removed waste from the grade change system (Doman, 2011).

7 Making Learning Lean

Bringing these various lean ideas together, we might make some proposals about what lean learning might look like. There might be a curriculum delivered by multiple organisations, tailored to suit the learner, across a Lean Enterprise. There would be no restrictions on hours per week of learning, or the total time span of a learning process, or on how different learning components might be combined. Batch and queue delivery of learning would be replaced by flow, with walk-in, lifelong enrolment. There would be all possible combinations of blended learning modes, so providers of learning would have a pull approach rather than push, and there would be instant assessment feedback, for example, perhaps just one way in which we might think about removing inventory from our system.

8 Agile Education, Lean Learning

In this chapter, we have discussed various approaches to applying agile and lean methods to teaching and learning. In this closing section, we put the various concepts together to analyse how agile and lean methods can effectively transition from the contexts of software development and manufacturing into a coherent model for education. Figure 1 shows the major applications of agility and leanness in education that we have examined, structured around the concepts of values, processes and techniques. These concepts are expressed as a pyramid where techniques build on processes, and processes on values. At each of these levels we have examined how agile and lean practices may usefully transition to the context of teaching and learning.

First, we examine agile and lean values, which we summarise as agency, outcomes and improvement. One of the key concepts from the values and supporting principles of the Manifesto for Agile Software Development is that agile approaches give agency to both developers and customers. Giving students a similar sense of empowerment and agency over their own learning is an important challenge for twenty-first-century approaches to teaching and learning (Lindgren & McDaniel, 2012), while developing the broad skill sets encouraged in multi-skilled agile teams also reinforces learner agency. In agile software development, the key measure of progress is working software, and creating this requires well-developed technical skills. In education, the key measure of progress is meaningful learning, and in the twenty-first century this is primarily skills-based, not just technical skills but broader capabilities such as adaptability, collaboration, knowledge construction, real-world problem-solving

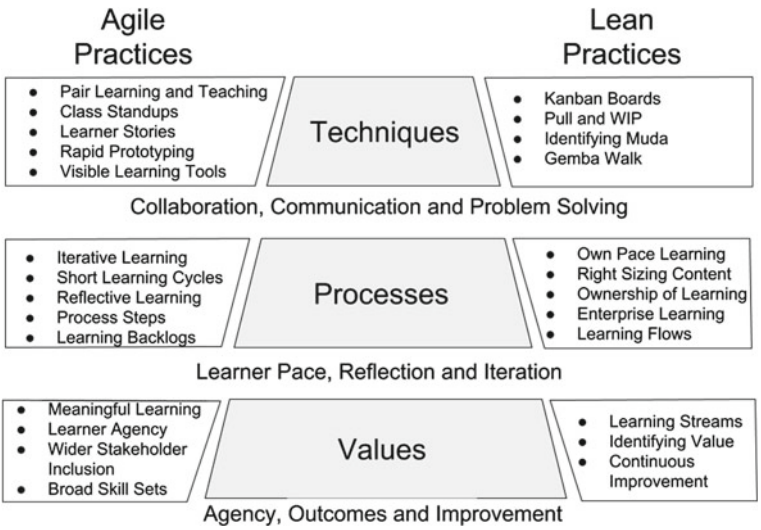

Fig. 1 Agile and lean values, processes and techniques, applied to learning

and innovation (ITL Research, 2012; World Economic Forum, 2016). Further, there is a broadening out of stakeholders in education to include learner's families and communities, so empowerment and agency can spread to these other stakeholders. From a lean perspective, it is important to identify the value and the value stream in the educational process, to identify the outcomes from each step in learning as well as from the overall experience. Underpinning this people-centric approach to skills development is the lean value of perfection; applying both kaizen and kaikaku to continually improve.

When we look at processes, we emphasise learner pace, reflection and iteration. Agile processes include regular evidence of progress and the ability to iterate over and reflect on solutions until they are as good as they can be. Short learning cycles, like sprints in agile software development, support a sustainable pace of learning, with regular feedback and reflection on actual learning outcomes. The steps in an agile process allow learners to address a specific learning backlog in manageable and self-directed time boxes. From lean, the concepts of pull and flow suggest that these processes need to be student-driven and adaptive to student needs by enabling learners to right-size content and learn at their own pace. Learners need to have ownership over their own learning so that they have control over how their learning value stream is constructed. Ideally, learning needs to be able to flow across an integrated learning path that spans multiple institutions in a lean educational enterprise. This might, for example, mean individual students in school having different personalised timetables, including learning sessions where they connect and collaborate with people beyond their physical environment to generate and critique new ideas (Starkey, 2012).

In examining techniques, it is difficult to focus on a particular subset and regard this as representative of agile and lean techniques as a whole, because there are so many. However, we consider that the most important techniques are those that support collaboration, communication and problem-solving. One of the agile techniques we have discussed in this chapter is pairing, which provides inbuilt peer support and collaborative learning. Similarly, class stand-ups provide collaborative peer support on a regular basis. Learner stories capture not just the 'what' of classroom activities but also the 'who' and the 'why', emphasising the need for relevance in learning activities. Students creating their own stories increase agency and self-regulation. In agile software development, prototyping means creating software prototypes. In the classroom, it can mean a broader set of activities including, for example, design thinking, with students being able to create prototypes not just with software but with 3D printing, craft materials, electronics, etc. However, the outcomes are the same; a deeper understanding of the customer and the product, not just from a business perspective but for social innovations such as creating alternative learning environments (Brown & Wyatt, 2010). In agile teams, information radiators such as burndown charts communicate visible records of progress. In the classroom, similar tools can be used to bring the same level of visibility to learning progress for both individuals and teams, echoing Hattie and Yates' (2013) emphasis on the importance of seeing outcomes from the learning process. The Kanban board is probably the most commonly used lean technique integrated into agile processes, adding the concepts of pull and work-in-progress to the management of story cards. Again, it is a practice that provides

students with agency over the content and pace of their own learning. It is probably also the most commonly used lean technique in the classroom, with many teachers using Kanban boards with their students (e.g. Beidleman, 2012). Another important lean technique that can work well in education is identifying wasteful practices (various types of muda) to try to remove these from the learning value stream and ensure that all activities that take place in the classroom and in the administration of learning are worthwhile. The final lean technique included here is contextualising learning in real-world problem spaces (gemba). As one of the six twenty-first-century skills outlined by ITL Research (2012), real-world problem-solving and innovation is a key activity in contemporary learning. The concept of the gemba walk, where problems are identified and resolved in their real-world contexts, supports this skill development and also relates closely to the learning theory of situated cognition, whereby knowledge "indexes the situations in which it arises and is used, without which it cannot be fully understood" (Brown, Collins, & Duguid, 1989, p. 16).

9 Conclusion

In this chapter we have provided a brief summary of the various themes and ideas gathered from the literature on agile and lean approaches to education. In Fig. 1 and the associated commentary we have brought together what we see as the most important ideas from the relevant literature, in order to provide a simple overview of how agile and lean approaches to teaching and learning can be integrated into new ways of thinking about what goes on in the classroom and in the wider world of learning.

In conclusion, we believe that there are significant opportunities for educators to adopt aspects of agile and lean practices. Although some interesting work has already been undertaken in this area, our investigation of the literature suggests that there is much more that could be done to bring the benefits of agility and lean thinking into the classroom. In this chapter, we have attempted to provide a clearer understanding of the ways that agile and lean approaches can be applied to teaching and learning at three specific levels; values, techniques and processes, and we have summarised the core skills and practices that we believe are the essential components in reinterpreting agile and lean concepts for teaching and learning. These are the values of agency, outcomes and (continuous) improvement, processes for reflection and iteration at a pace managed by the learner, and techniques for collaboration, communication and (real world) problem-solving.

References

ALC. (n.d.). *Agile learning center tools & practices*. Retrieved from http://nycagile.org/about/tools/.

Alp, N. (2001, November). The lean transformation model for the education system. In *Proceedings of the 29th International Conference on Computers and Industrial Engineering* (pp. 82–87).

Agile Alliance. (2001). *Manifesto for agile software development*. Retrieved from http://agilemanifesto.org/.

Agile Classrooms. (n.d.). *21st century learning resources*. Retrieved from https://www.agileclassrooms.com/resources.

Alves, A. C., Flumerfelt, S., & Kahlen, F. J. (Eds.). (2016). *Lean education: An overview of current issues*. Springer.

Anderson, D. (2010). *Kanban: Successful evolutionary change for your technology business*. Sequim, WA: Blue Hole Press.

Allen, M. (2012). *Leaving ADDIE for SAM: An agile model for developing the best learning experiences.* ASTD Press.

Balzer, W. K. (2010). *Lean higher education: Increasing the value and performance of university processes*. CRC Press.

Barney, H., & Kirby, S. N. (2004). Toyota production system/lean manufacturing. In B. Stecher & S. N. Kirby (Eds.), *Organizational improvement and accountability lessons for education from other sectors* (pp. 35–50). Santa Monica, CA: Rand Corporation.

Beck, K., & Andres. C. (2005). *Extreme programming explained: Embrace change* (2nd ed.). Addison-Wesley.

Bicheno, J. (2001). Kaizen and kaikaku. In *Manufacturing operations and supply chain management: The LEAN approach* (pp. 175–184).

Bicheno, J., & Holweg, M. (2000). *The lean toolbox* (Vol. 4). Buckingham: PICSIE Books.

Beidleman, P. (2012). Using Kanban in the Classroom. *Planview LeanKit*. Retrieved from https://leankit.com/blog/2012/01/guest-post-using-kanban-in-the-classroom/.

Böhmer, A. I., Beckmann, A., & Lindemann, U. (2015, December). Open innovation ecosystem-makerspaces within an agile innovation process. In *ISPIM Innovation Symposium*. *The International Society for Professional Innovation Management (ISPIM)* (p. 1).

Briggs, P. (1988). The Japanese at work: Illusions of the ideal. *Industrial Relations Journal, 19*(1), 24–30.

Briggs, S. (2014). Agile based learning: What is it and how can it change education? *InformED*. Retrieved from http://www.opencolleges.edu.au/informed/features/agile-based-learning-what-is-it-and-how-can-it-change-education/.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher, 18*(1), 32–42.

Brown, T., & Wyatt, J. (2010). Design thinking for social innovation. *Development Outreach, 12*(1), 29–43.

Bruegge, B., Reiss, M., & Schiller, J. (2009, April). Agile principles in academic education: A case study. In *Sixth International Conference on Information Technology: New Generations, 2009. ITNG'09* (pp. 1684–1686). IEEE.

Cohen, D., Lindvall, M., & Costa, P. (2004). An introduction to agile methods. *Advances in Computers, 62,* 1–66.

Comm, C. L., & Mathaisel, D. F. (2005). An exploratory study of best lean sustainability practices in higher education. *Quality Assurance in Education, 13*(3), 227–240.

Conboy, K. (2009). Agility from first principles: Reconstructing the concept of agility in information systems development. *Information Systems Research, 20*(3), 329–354. https://doi.org/10.1287/isre.1090.0236.

Dahlgaard, J. J., & Østergaard, P. (2000). TQM and lean thinking in higher education. *The Best on Quality: Targets, Improvements, Systems, 11,* 203–226.

Delhij, A., et al. (2016). *Agile in education compass.* Retrieved from http://www.agileineducation.org/.

Dewi, D. A., & Muniandy, M. (2014, September). The agility of agile methodology for teaching and learning activities. In *2014 8th Malaysian Software Engineering Conference (MySEC)* (pp. 255–259). IEEE.

Dingsøyr, T., Nerur, S., Balijepally, V., & Moe, N. B. (2012). A decade of agile methodologies: Towards explaining agile software development. *Journal of Systems and Software, 85*(6), 1213–1221. https://doi.org/10.1016/j.jss.2012.02.033.

Doman, M. S. (2011). A new lean paradigm in higher education: A case study. *Quality Assurance in Education, 19*(3), 248–262.

Francis, D. E. (2014). Lean and the learning organization in higher education. *Canadian Journal of Educational Administration and Policy, 157,* 1–23.

Godbey, G. C., & Richter, G. J. (1999). Technology, consortia, and the relationship revolution in education. *New Directions for Higher Education, 1999*(106), 85–91.

Goldman, S. (2009). The educational Kanban: Promoting effective self-directed adult learning in medical education. *Academic Medicine, 84*(7), 927–934.

Hattie, J., & Yates, G. C. (2013). *Visible learning and the science of how we learn*. Routledge.

Hazzan, O., & Dubinsky, Y. (2014). *Agile anywhere: Essays on agile projects and beyond.* Springer International Publishing.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development, 55*(3), 223–252.

Heikkilä, V. T., Paasivaara, M., & Lassenius, C. (2016, May). Teaching university students Kanban with a collaborative board game. In *Proceedings of the 38th International Conference on Software Engineering Companion* (pp. 471–480). ACM.

Hines, P., & Taylor, D. (2000). *Going lean* (pp. 3–43). Cardiff, UK: Lean Enterprise Research Centre Cardiff Business School.

Isaksson, R., Kuttainen, C., & Garvare, R. (2013). Lean higher education and lean research. In *16th Toulon–Verona Conference; Faculty of Administration, University of Ljubljana, Slovenia; 29–30 August 2013*.

ITL Research. (2012). *21CLD learning activity rubrics*. Retrieved from https://education.microsoft.com/GetTrained/ITL-Research.

Kamat, V. (2012, July). Agile manifesto in higher education. In *IEEE Fourth International Conference on Technology for Education (T4E)* (pp. 231–232). IEEE.

Kessler, R., & Dykman, N. (2007). Integrating traditional and agile processes in the classroom. *ACM SIGCSE Bulletin, 39*(1), 312–316.

Krehbiel, T. C., et al. (2017). Agile manifesto for teaching and learning. *The Journal of Effective Teaching, 17*(2), 90–111.

Kropp, M., Meier, A., Mateescu, M., & Zahn, C. (2014). Teaching and learning agile collaboration. In *IEEE 27th Conference on Software Engineering Education and Training (CSEE&T)*.

Ladas, C. (2008). *Scrumban: Essays on Kanban systems for lean software development*. Seattle, WA: Modus Cooperandi.

Layman, L., Cornwell, T., & Williams, L. (2006). Personality types, learning styles, and an agile approach to software engineering education. *ACM SIGCSE Bulletin, 38*(1), 428–432.

Lindgren, R., & McDaniel, R. (2012). Transforming online learning through narrative and student agency. *Educational Technology & Society, 15*(4), 344–355.

Marley, K. A. (2014). Eye on the gemba: Using student-created videos and the revised bloom's taxonomy to teach lean management. *Journal of Education for Business, 89*(6), 310–316.

Meerbaum-Salant, O., & Hazzan, O. (2010). An agile constructionist mentoring methodology for software projects in the high school. *ACM Transactions on Computing Education, 9*(4), n4.

Mahnic, V. (2012). A capstone course on agile software development using Scrum. *IEEE Transactions on Education, 55*(1), 99–106.

Manamendra, M. A. S. C., Manathunga, K. N., Perera, K. H. D., & Kodagoda, N. (2013, April). Improvements for agile manifesto and make agile applicable for undergraduate research projects. In *2013 8th International Conference on Computer Science & Education (ICCSE)* (pp. 539–544). IEEE.

Melnik, G., & Maurer, F. (2003, August). Introducing agile methods in learning environments: Lessons learned. In *Conference on Extreme Programming and Agile Methods* (pp. 172–184). Berlin, Heidelberg: Springer.

Naylor, J. B., Naim, M. M., & Berry, D. (1999). Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain. *International Journal of Production Economics, 62*(1–2), 107–118.

Ncube, L. B. (2010). A simulation of lean manufacturing: The lean lemonade tycoon 2. *Simulation & Gaming, 41*(4), 568–586.

Obrist, M., Moser, C., Fuchsberger, V., Tscheligi, M., Markopoulos, P., & Hofstätter, J. (2011, June). Opportunities and challenges when designing and developing with kids@ school. In *Proceedings 10th International Conference on Interaction Design and Children* (pp. 264–267). ACM.

Oppenheim, B. W., Murman, E. M., & Secor, D. A. (2011). Lean enablers for systems engineering. *Systems Engineering, 14*(1), 29–55.

Parsons, D., Ryu, H., & Lal, R. (2007). The impact of methods and techniques on outcomes from agile software development projects. In T. McMaster, D. Wastell, E. Ferneley, & J. DeGross (Eds.), *Organisational dynamics of technology-based innovation: Diversifying the research agenda*, *Proceedings of IFIP 8.6 Conference, Manchester, UK, 14–16 June 2007* (pp. 235–249). Springer.

Peha, S. (2011, June). Agile schools: How technology saves education (Just not the way we thought it would). *InfoQ*. Retrieved from https://www.infoq.com/articles/agile-schools-education.

Petersen, K. (2011). Is lean agile and agile lean?: A comparison between two software development paradigms. In A. Dogru & V. Biçer (Eds.), *Modern software engineering concepts and practices: Advanced approaches* (pp. 19–46). IGI Global.

Poppendieck, M. (2011). Principles of lean thinking. *IT Management Select, 18,* 1–7.

Poppendieck, M., & Poppendieck, T. (2003). *Lean software development: An agile toolkit*. Boston MASS: Addison-Wesley Professional.

Rico, D. F., & Sayani, H. H. (2009, August). Use of agile methods in software engineering education. In *Proceedings Agile Conference, 2009. AGILE'09.* (pp. 174–179). IEEE.

Scrum@School. (n.d). *Advantages*. Retrieved from http://www.scrumatschool.co.uk/.

Starkey, L. (2012). *Teaching and learning in the digital age*. Abingdon, Oxon: Routledge.

Stewart, J. C., DeCusatis, C. S., Kidder, K., Massi, J. R., & Anne, K. M. (2009). Evaluating agile principles in active and cooperative learning. In *Proceedings of Student-Faculty Research Day, CSIS, Pace University*, B3.

Swanson, L. (2008). The lean lunch. *Decision Sciences Journal of Innovative Education, 6*(1), 153–157.

Tesar, M., & Sieber, S. (2010). Managing blended learning scenarios by using agile e-learning development. In *Proceedings of the IADIS International Conference E-Learning* (Vol. 2, pp. 125–129).

Vanhoenacker, M. (2015). *Skyfaring: A journey with a pilot*. London: Chatto & Windus.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The machine that changed the world*. New York, NY: Free Press.

Womack, J. P., & Jones, D. T. (2003). *Lean thinking: Banish waste and create wealth in your corporation* (2nd ed.). New York, NY: Free Press.

Womack, J. P. (2006). *Lean thinking for education*. Paper Presented at the 2006 Lean Educator Conference, Worcester, MA.

World Economic Forum. (2016). *New vision for education: Fostering social and emotional learning through technology*. Retrieved from http://www3.weforum.org/docs/WEF_New_Vision_for_Education.pdf.

Zion, S. D. (2009). Systems, stakeholders, and students: Including students in school reform. *Improving Schools, 12*(2), 131–143.