Spiral Literature Review

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Table of Contents

1. Report Goals

The goal of this report was to review key literature on collaboration, formative assessment and technology integration/BYOD.

1. Collaboration – the research reviewed supports the view that cooperation and collaboration foster deeper learning. It outlines a set of mechanisms through which learning occurs e.g., articulating one's thinking, or identifying new learning strategies from others. While these mechanisms are important to facilitate through the design of the Spiral apps, the literature additionally shows that collaborative learning best works when the learning task offers interdependencies between team members alongside teacher guidance in developing students' social skills. This suggests that together with an app design that reinforces social interdependencies, teachers must consider collaboration to be a long term pedagogical goal. Given teachers' other competing priorities, and their possible lack of knowledge in social skills development, the Spiral platform could provide them with resources that support them to facilitate collaboration (e.g. through examples of successful cases collected during the evaluation). Finally, since the benefits of collaborative learning can become evident only after students have acquired the necessary collaborative and social skills, it is suggested that evidence of the apps on learning could be collected over a series of repeated visits at schools.
2. Formative assessment – we outline the key features to implementing formative assessment (e.g. sharing learning goals with the students) and technological designs that have aimed to support formative assessment. We find that communication of learning goals and assessment criteria upon which formative assessment relies are critical tools in supporting social interdependence during collaboration. This suggests that collaboration and formative assessment be considered as synergetic goals in the design process i.e. they must work together. While it is recognised that formative assessment is critical to learning, there is no universal model on how to apply formative assessment. There is thus a need for exploratory research into understanding how the Spiral technology may support this process.
3. Technology integration – integrating technology in schools depends on a complex web of factors. These include: teachers' technology proficiency, compatibility between a teacher's pedagogical beliefs and the technology, social awareness and the nature of the innovation being implemented. As part of the Spiral design process, it is recommended that such individual differences between teachers and schools are understood during focused one-to-one sessions that enable teachers to voice their unique concerns and the Spiral team to test the flexibility of the apps across different subject matters/curriculum. Examining the various models to BYOD, we find that whereas some schools may provide the hardware, in other instances students may bring their own devices. Since the factors of technology integration will be in part shaped depending on the BYOD model employed, we suggest a clearer definition of the BYOD model(s) that Spiral is primarily targeting. Finally, as the Spiral apps adoption depends on the successful implementation of BYOD, we highlight an opportunity for the Spiral platform to offer teacher and school resources for tackling the challenges of BYOD, alongside those addressing collaboration and formative assessment.

2. Collaborative Learning

2.1. Definitions

There is a wealth of research on group work that suggests that collaboration, compared with individual work, can foster better problem-solving and greater learning outcomes (e.g. Barron, 2000; Roseth, Johnson and Johnson, 2007; Slavin, 1995; 2011; Webb, 1989; Webb and Palinscar, 1996). Social interaction has a central role in constructivist and sociocultural theories of learning, although there are various interpretations of the mechanism through which it promotes learning (Piaget, 1952; Vygotsky, 1978). Social interaction is at the heart of collaborative learning. However, placing people in groups does not necessarily lead to collaboration or learning. Rather, it is engagement in specific types of interaction that fosters learning.

Broadly speaking, collaborative learning has been conceptualized as a specific form of social interaction that involves a shared goal (Johnson and Johnson, 1999). The term has been used to cover diverse situations that vary in terms of the number of learners, the nature of the learning experience, the structure and medium of communication, and the degree to which learners construct a common understanding (Lipponen, 2002; Dillenbourg, 1999). Collaborative learning situations range, for example, from a pair of students conducting an experiment, to a community of students participating in an online course. This diversity of learning situations is reflected in the variety of definitions of collaborative learning (Dillenbourg, 1999). Further, many researchers distinguish between collaborative and cooperative approaches to group learning. For example, Roschelle and Teasley (1995) argue that "cooperation is accomplished by the division of labour among participants, as an activity where each person is responsible for a portion of the problem solving", in contrast with collaboration that involves the "mutual engagement of participants in a coordinated effort to solve the problem together" (p. 70).

The principal aim of research on collaborative learning has been to understand how to foster social interactions that foster learning. This involves a) identifying patterns of social interaction that facilitate or inhibit learning, and b) understanding the factors that lead to different patterns of social interaction. Researchers have also developed theoretical frameworks to explain how particular social interactions facilitate learning, and have devised instructional approaches to foster positive social interactions in group learning situations (e.g. Slavin, 1995; Johnson and Johnson, 2009).

In this review, we adopt a broad view of collaborative learning that includes what many researchers term cooperative learning, and we focus specifically on literature that has studied collaborative and cooperative learning in the context of face-to-face interactions between learners in primary and secondary school. This broad perspective addresses the Spiral apps developed – whereas some apps posit shared goals (e.g. *Team Up*, where students must jointly solve a problem), others combine individual with group work where learners are not collaboratively addressing a problem, but are working in parallel on a portion of the problem (e.g. *Discuss*, where students post an answer and then critique and improve each other's input).

2.2. Processes that Support Learning

Researchers have proposed several mechanisms (highlighted in italics) through which collaborative and cooperative learning situations may support deeper learning. These include *articulating one's thinking* and *listening to others*, as well as *resolving conflicts* and *building on new ideas*. Research studies suggest that in collaborative learning situations learners have the opportunity to *explain their thinking* (King, 1992; Webb, Troper, & Fall, 1995), *listen to others' explanations* (Webb, 1985; Hatano and Inagaki, 1991; Coleman, 1998) and *resolve differences through argument* (Amigues, 1988; Phelps and Damon, 1989). When explaining, students need to *structure and clarify their ideas*, which develops their understanding as well as their awareness of what they know and what they do not know (Howe, Tolmie, Anderson and Mackenzie, 1992; Cooper, 1999). It is the need to resolve conflicts in collaborative learning situations that *prompt students to provide such complex explanations* (Mercer, 1995; Doise and Mugny, 1984; Howe and Tolmie, 1998). *Discrepancies with the work of others* also prompt students to search for new information to resolve the conflict (Johnson and Johnson, 1979; Doise and Mugny, l979). Students also learn from *listening to others* and *internalising strategies* and information used by others (Damon, 1984; Wertsch and Stone, 1999).

In addition to the above, collaborative learning has been found to *encourage students to be active participants* in their own learning (Webb, Troper and Fall, 1995). Student motivation has been linked to higher cognitive engagement and learning outcomes (Ames and Archer, 1988; Pintrich and De Groot, 1990; Pokay and Blumenfeld, 1990). As Slavin (2014) discusses, the motivational perspective on collaborative learning emphasises that motivation to engage in a task is fundamental to learning and the driving force behind cognitive processes, involved for example in resolving conflict. Collaborative learning situations in which students care about the group and the individuals within it lead to engagement with the task and better learning outcomes.

2.3. How to Foster Collaborative Learning

Section 3.2 explained the mechanisms involved in collaborative learning. Now, we focus on the human barriers to collaborative learning and interventionist approaches to overcoming these barriers.

There is evidence that collaborative learning can *result in more positive relations* between students (Roseth, Fang, Johnson and Johnson, 2006; Slavin, 1995; Johnson, Johnson and Maruyama, 1983), but as Tolmie *et al.* (2010) discuss, researchers have different views on *whether positive relations are a precondition to collaborative learning*, a directly-related consequence of it, or a separate outcome. Their discussion concludes that positive relations can arise from collaborative learning situations (rather than being a precondition), as long as students are *prepared by teachers* for the communication requirements of collaborative learning. In other words, it is a precondition for students to understand how they are expected to work together. Collaborative learning, and the development of positive social relations between students, are enhanced when students are explicitly supported to develop the skills that promote sharing with and a positive attitude towards others (Johnson, Johnson and Holubec, 1993).

In observing collaboration and cooperative dynamics, researchers have identified several factors that are essential to *ensuring* effective collaborative learning. One psychological theory that has been tested/iteratively developed in over 750 research studies and has been used in an interventionist capacity is the theory of *social interdependence*. Johnson and Johnson (2009, 2002) discuss five factors that mediate the effectiveness of collaborative and cooperative interactions. Below, we consider each factor, along with strategies that support it. Where relevant, we note contingencies between strategies. This literature review avoids providing contextualised examples of problematic collaboration dynamics (such examples have been already observed during the Spiral research) and rather focuses on guidance developed on the basis of empirical research on how to avoid these barriers. It should be noted that while some of these factors can be reinforced through the design of technology, it is naïve to think that technology alone is the solution to these dynamics. Thus, these factors need to be supported by Spiral teachers who must consider the development of social and collaboration skills as part of the learning process.

(1) Positive interdependence refers to the situation where "individuals perceive that they can attain their goals if and only if the other individuals with whom they are cooperatively linked attain their goals" (Johnson and Johnson, 2009). Empirical studies have shown that groups achieve more when positive interdependence is structured into an activity (e.g. Jensen, 1996; Jensen, Johnson and Johnson, 2002). All learners have individual responsibility for the goals, reward and outcome of group work. Strategies for achieving positive interdependence include:

1) Structuring the learning task so that participants cannot attain their goal (goal interdependence) without others attaining theirs
2) Structuring the learning task so that participants cannot attain their reward (reward interdependence) without others attaining theirs
3) Dividing resources amongst members
4) Assigning different roles to different members (e.g. reader, recorder etc.)
5) Dividing the task so that each member does one aspect
6) Enhancing group identity so that members see themselves as an entity (e.g. provide them with a specific work area, enhance their similarities)

Now that we have covered the key strategies of positive interdependence, we must recognise that these strategies are not all of equal importance (Johnson and Johnson, 2009). Goal interdependence (1) is the most important strategy without which other strategies will not work. For example, group identity (6) does not lead to collaboration without the existence of a shared goal. Reward interdependence (2) has an additive effect to goal interdependence (1). It increases achievement more than goal interdependence alone and doing work on an individual basis. The effect of losing or gaining a reward is equal on achievement, suggesting that performance reward systems can be designed flexibly. Resource interdependence (3) is detrimental without goal interdependence (1). If individuals need others' resources without sharing a common goal, the tendency is to take rather than to give.

(2) Individual accountability refers to a process of assessing individuals' performance against a set of standards (in addition to assessing the group's performance) and presenting the results back to the group as well as to individual group members. This has been found to increase individual accountability and feelings of personal responsibility, which increase individuals' motivation to contribute to the group (e.g. Hooper, Ward, Hannafin and Clark, 1989). Strategies for achieving individual accountability are:

1) Assessing the group's overall performance with results compared against a standard of performance and clear goals. Students must be able to measure whether they are successful as individuals and whether the group is successful
2) Avoiding social loafing by creating smaller groups (3-4) where members can clearly see that their contribution is needed and where groups are stable over time (one to several years)

(3) Promotive interaction results from *positive interdependence.* It refers to individuals' actions to encourage and facilitate each others' efforts in order to accomplish group goals. In contrast, oppositional interaction occurs when individuals obstruct each other's efforts, for example, in order to prevent them from being more productive. Promotive interaction results in behaviours that facilitate learning such as exchanging resources, e.g. information, providing feedback to other members in order to improve their performance and challenging other members' reasoning or conclusions to reach a higher quality outcome.

(5) Appropriate use of social skills cannot be taken for granted. Effective collaboration relies on individuals being able to: "a) get to know each other, b) communicate accurately and unambiguously, c) accept and support each other, and d) resolve conflicts constructively" (Johnson and Johnson, 2009, p. 369). A key strategy for achieving appropriate use of social skills is:

- Providing members with individual feedback on how well they managed social skills

Group processing refers to the group reflection on the progress of the group, which results in an evaluation of which actions are constructive and what changes need to be made. Strategies for ensuring group processing include:

1) Each member provides and receives positive feedback on their contribution to the group. Feedback should be positive so that it generates momentum towards improving performance.
2) Students analyse and reflect on the feedback they've been given.
3) Students and groups set goals for improving their work. Individuals can pick a particular social skill to use more effectively. Groups can decide on a collaborative skills to work on next time.
4) Groups celebrate the hard work and contributions of the members as well as the success of the group. Celebrations provide students with encouragement to continue improving their group work

2.4. Research Approaches and Research Goals for Collaborative Learning

Producing evidence for technology-enhanced learning can be approached from different perspectives. In grappling with how the Spiral team may understand collaborative learning, we must broadly examine the questions and approaches used in the past. Research on collaborative learning is driven by a wide range of questions and associated methodological approaches. The focus is on understanding the value of collaborative learning in terms of *outcomes*, as well as *linking outcomes to collaborative processes*. To do this we need measures of outcomes that are relevant to the learning objectives of a specific activity students are engaged in, as well as subject-independent objectives, such as increasing student motivation and developing collaboration skills. We also need methods for studying the interactions between students, through which we can define the quality of their collaboration.

For those who focus on outcomes, the choice of measures to assess learning outcomes depends on the learning objectives of the activity, and needs to be specific to the age of the students. These tests/questionnaires are administered to individual students, both before and after the activity, in order to assess the learning gains of each student. The use of standardised measures enables researchers to compare findings across different studies.

For those who focus on processes, collaborative interactions are studied through classroom observation. Using a coding scheme enables researchers to record and analyse patterns of interactions in the context of group work. For example, Blatchford *et al.* (2005) devised a framework that allows observers to capture on a 3-point rating scale (not true, partly true, very true) the presence during their observations of key features relating to (a) the quality of the learning context; (b) the suitability of tasks and activities; (c) the nature of adult (teacher) involvement; and (d) the group-work skills displayed. Similarly, coding schemes can be used to analyse the verbal interactions between students (e.g. Webb, 1985).

The purpose in studying both learning outcomes and the learning process, is to go beyond simply evaluating the effectiveness of a given instructional approach in a specific context. Increased learning outcomes could be due to a variety of different factors. For example, the use of technology may in itself increase learners' engagement and, therefore, their performance, without in fact having an impact on the way they interact. The aim is to develop a deeper understanding of whether and how a specific approach facilitates learning.

Much research is conducted in researcher-led experiments, rather than in the context of everyday teaching practice. There are suggestions that the former type of research does not lead to an understanding of the real-world difficulties of applying specific approaches to collaborative learning (Gillies and Boyle, 2010) and more studies are needed that are situated in the classroom context.

2.5. Summary of Key Points

What you need to know about collaborative and cooperative learning

- It is not guaranteed when placing people in groups
- It needs to be designed around particular types of social interaction
- It encompasses a wide variety of group configurations and settings
- It involves either (1) a coordinated effort to jointly solve a problem and the division of labour in solving a problem, or (2) a division of labour among participants where each person is responsible for a portion of the problem solving

it can lead to better problem solving and greater learning outcomes

Mechanisms for fostering collaborative and cooperative learning

- Articulating and explaining thinking with a view to show what the student knows or doesn't know
- Listening to others' explanations and arguments, and learning new strategies
- Resolving conflicts and differences through argumentation and using discrepancies as an opportunity to find new information
- Building on new ideas
- Placing the learner in an active role in their learning

How to foster constructive dynamics in collaboration or cooperation

- Factors that underpin successful collaboration/cooperation are:
  - Positive interdependence – individuals achieve their goals only when others achieve theirs
  - Individual accountability – assessing an individual's work against a set of standards and presenting this to the individual and the group
  - Promotive interaction - individuals' actions to encourage and facilitate each others' efforts in order to accomplish group goals
  - Appropriate of social skills – social and communication skills that are foundational to collaboration
  - Group processing – assessing how the group as a whole has progressed, what worked and what can be improved

- Some strategies for achieving these factors are:
  - Structuring the learning task so that participants cannot attain their goal (goal interdependence) without others attaining theirs
  - Structuring the learning task so that participants cannot attain their reward (reward interdependence) without others attaining theirs
  - Dividing resources amongst members
  - Assigning different roles to different members (e.g. reader, recorder etc.)
  - Dividing the task so that each member does one aspect
  - Enhancing group identity so that members see themselves as an entity (e.g. provide them with a specific work area, enhance their similarities)
  - Assessing the group's overall performance with results compared against a standard of performance (e.g. assessment criteria)
  - Assessing the individual's overall performance with results compared against a standard of performance (e.g. assessment criteria) and fed back to the individual and group
  - Creating smaller groups where members can clearly see that their contribution is needed
  - Providing members with individual feedback on how well they managed social skills
  - Each member provides and receives positive feedback on their contribution to the group. Feedback should be positive so that it generates momentum towards improving performance
  - Students analyse and reflect on the feedback they've been given

- Students and groups set goals for improving their work. Individuals can pick a particular social skill to use more effectively. Groups can decide on a collaborative skills to work on next time
- Groups celebrate the hard work and contributions of the members as well as the success of the group. Celebrations provide students with encouragement to continue improving their group work

3. Formative Assessment

3.1. Definitions

'Formative assessment' is one of those educational terms that is almost as widely interpreted as it is used, yet is something that 'everyone knows' improves learning (Hargreaves, 2005; Lau, 2015; Shepard, 2005). Originating in 1960's curriculum studies as formative 'evaluation' (Striven, 1967), it was first defined, in contrast to the more common summative evaluation tests, by Bloom and colleagues (1971). Whereas summative evaluations (which may be characterised as 'assessment *of* learning') are usually designed for the purpose of grading students or for evaluating a curriculum, formative evaluations ('assessment *for* learning') were described as "another type of evaluation which all who are involved—student, teacher, curriculum maker—would welcome because they find it so useful in helping them improve what they wish to do" (Bloom *et al.*, 1971, p. 117).

Subsequently and inevitably, across the thousands of published academic papers and many books (*cf.* Andrade and Cizek, 2009) that include 'formative assessment' in their title, formative assessment has been defined in multiple ways (Dorn, 2010). However, the definition given by Black and Wiliam in their seminal literature review (1998a), summarized in the well-known booklet 'Inside the Black Box' written especially for teachers and policy makers (Black and Wiliam, 1998b), is one of the most widely cited. Formative assessment, they write, encompasses "*all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged*" (1998a, pp. 7–8). Put another way, "assessment becomes 'formative assessment' when the evidence is actually used to adapt the teaching work to meet learning needs" (Black *et al.*, 2004, p. 10).

For their analysis, Black and Wiliam examined two previous reviews (Crooks, 1988; Natriello, 1987) and 250 academic papers on subjects as diverse as classroom practices, assessment practices, student motivation, learning theory, questioning, and feedback – a scope necessary because before that time very few studies used the term formative assessment. Their core conclusion (1998a, 1998b) was that improving formative assessment in the classroom leads to greater improvements in learning than do other typical educational interventions, with effect sizes ("effect size is the most important tool in reporting and interpreting effectiveness" Higgins *et al.*, 2013, p. 6) ranging from 0.40 to 0.70: an effect size of 0.40 "should be used as the benchmark to judge effects in education.... [effect sizes above 0.40] are worth having" (Hattie, 2008, p. 16). However, while these effect sizes are widely cited as justification for implementing formative assessment practices (*cf.* Boston, 2002), Black and Wiliam's own later studies (Wiliam *et al.*, 2004) showed a smaller effect size, 0.32, while a recent meta-analysis (Kingston and Nash, 2011, 2012; contested by Briggs *et al.*, 2012) found only a weighted mean effect size of 0.20. The magnitude of these effect sizes is, however, not as important as the relative scarcity of studies that might be included in any meta-analysis (Kingston and Nash, 2011) because, it has been argued, most published studies "lack the statistical reliability expected of assessment practices" (Clark, 2011, p. 165), which makes it difficult to draw robust conclusions about the general efficacy of formative assessment.

In short, while there are reams of qualitative, correlational or small-scale studies that support using formative assessment in classrooms (*cf.* Bell and Cowie, 2001; Dorn, 2010; Herman *et al.*, 2006), such that most educators ‘know’ that formative assessment ‘improves learning’ (“assessment which is explicitly designed to promote learning is the single most powerful tool we have for both raising standards and empowering lifelong learners”, Assessment Reform Group, 1999, p. 2), there is surprisingly little quantifiable supporting evidence of the type required by many researchers and policy makers (Dunn and Mulvenon, 2009; Higgins *et al.*, 2013; Kingston and Nash, 2011).

3.2. How to Implement Formative Assessment

While there is no definitive manual of formative assessment, the Assessment Reform Group (1999) provides a useful digest of the key features: formative assessment, they summarise, “is embedded in a view of teaching and learning of which it is an essential part; it involves sharing learning goals with pupils; it aims to help pupils to know and to recognise the standards they are aiming for; it involves pupils in self-assessment; it provides feedback which leads to pupils recognising their next steps and how to take them; it is underpinned by confidence that every student can improve; [and] it involves both teacher and pupils reviewing and reflecting on assessment data” (Assessment Reform Group, 1999, p. 7). However, despite broad agreement on these features, and no shortage of authors putting forward ‘principles’ for successful classroom implementation (*cf.* Clarke, 2014; Furtak, 2009; Keeley, 2008), the realisation of a formative assessment approach in a typical classroom is not straightforward: “there is no one simple way to improve formative assessment” (Black and Wiliam, 1998b, p. 8) and “no prescribed model of effective classroom action” (Wiliam *et al.*, 2004, p. 51). Nevertheless, there is some agreement about the key areas of classroom practice to which a formative assessment approach might contribute positively, core examples being: questioning, feedback, peer- and self-assessment, and the formative use of summative tests (*ibid.*).

Questioning

There is much research evidence that typical classroom dialogue, including the use of questions, is far from ideal: “many teachers do not plan and conduct classroom dialogue in ways that might help students to learn” (Black *et al.*, 2004, p. 11) and “at its worst, classroom talk does the opposite of what one might reasonably expect it to do: it disempowers the student” (Alexander, 2006, p. 5). A formative approach to questioning moves away from the typical ‘fact’ or ‘guess what’s in my head’ type of questions, posed too often in too many classrooms, often with too little wait time for the student to gather their thoughts and reply usefully, to refocus on open questions that aim to evoke discussion or promote collaborative activities between students: “asking simple questions, such as “Why do you think that?” or “How might you express that?” can become part of the interactive dynamic of the classroom and can provide an invaluable opportunity to extend students’ thinking through immediate feedback on their work” (Black *et al.*, 2004, p. 13).

Feedback

Formative feedback has been extensively researched (see Shute, 2008), such that a summary is beyond the scope of this review. However, the key feature of formative feedback as advocated by Black and Wiliam is the complete replacement of numerical marks or grades with written comments that "identify what has been done well and what still needs improvement and give guidance on how to make that improvement" (Black *et al.*, 2004, p. 14). The evidence is that numerical marks are inevitably perceived negatively, while combining marks and comments leads the student to ignore the comments and focus on the marks. Most importantly, "a numerical score or a grade does not tell students how to improve their work, so an opportunity to enhance their learning is lost" (*ibid.*, p. 13).

Peer and self-assessment

'Students can achieve a learning goal only if they understand that goal and can assess what they need to do to reach it. So self-assessment is essential to learning' (*ibid.*, p. 14). Self-assessment also contributes to self-regulated learning (Nicol and Macfarlane-Dick, 2006) and to working at a metacognitive level (Lajoie, 2008). In this context, Black and colleagues also introduce a very practical strategy, the use of 'traffic lights', suggesting that teachers encourage their students to identify their self-assessed level of understanding by marking their work green, amber or red (Black *et al.*, 2004). Meanwhile, peer-assessment can be valuable for various reasons: students may be more willing to accept criticism of their work from one another, they are likely to express their comments in a language style and pitch that the recipient also uses, and they learn from having to consider critically an approach alternative to their own and from having to articulate their thoughts. A practical strategy suggested to support peer-assessment is 'three stars and a wish', where the peer reviewer has to identify and comment upon three things in the work that have been successful and one thing that could be improved (Bennett, 2011).

Formative use of summative tests

"From their earliest use it was clear that the terms 'formative' and summative' applied not to the assessments themselves, but to the functions they served" (Black and Wiliam, 2003, p. 623). Given that it is likely classroom and high-stakes summative assessments are not going to go away, how can this assessment *of* learning be appropriated to support learning? One approach is to use the impending arrival of a summative test as a further reason for the students to undertake self-assessment, identifying (perhaps with 'traffic lights') those topics that are sufficiently understood and those that need further effort. Encouraging the students to generate and answer their own questions on topics to be covered by the test can also be especially useful. Peer-marking of the finished tests can also support learning, especially if the students have themselves been involved in developing the marking rubric or if they use the 'three stars and a wish' approach. Peer marking also has the practical benefit of freeing the teacher from the chore of marking thirty scripts and, more importantly, of enabling them to spend more time exploring and discussing the questions in class, especially those that most students found especially challenging.

3.3. Formative Assessment and Technology

One of the earliest (and most cited) researchers to explore the efficacy of formative assessments is David Royce Sadler, whose work specifically involved instructional systems. Given that he was writing a quarter of a century ago, it is unsurprising that he thought technology might only contribute to the simplest of formative feedback: "it would be difficult if not impossible... to automate or develop a computer-based system for feedback or formative assessment, or for generating remedial moves and appropriate corrective procedures" (Royce Sadler, 1989, p. 139).

Nonetheless, more recently, the usual technological suspects have been researched for their potential to enhance formative assessment practices. These have included: e-learning and learning management systems (Wang, 2007); the Internet (Buchanan, 2001, 1998; Chen and Chen, 2009; Wang *et al.*, 2006); mobile technologies (Hwang and Chang, 2011; Isabwe, 2012; Susono and Shimomura, 2006); blogs (Olofsson *et al.*, 2011); classroom response systems (Beatty and Gerace, 2009; Feldman and Capobianco, 2008); and computer games (Broussard, 2014; Delacruz, 2011; Tsai *et al.*, 2015). More general computer-based approaches (Bull *et al.*, 2006; Jenkins, 2004; Lewis and Sewell, 2007; Peat and Franklin, 2002; Whitelock, 2007) and other less specific 'technology-enhanced' approaches to formative assessment (Landauer *et al.*, 2009; Vendlinski *et al.*, 2005) have also been proposed.

Inevitably, as is typical of research into learning and technology (Selwyn, 2013), these research outputs are almost entirely positive but their coverage is patchy and there is little useful consensus. The nearest to a review of the field is provided by Russell, in 'The Handbook of Formative Assessment' (Andrade and Cizek, 2010). Russell (2010) identifies four 'promising' ways in which computer-based technologies might be used to support formative assessment: (1) systematically monitoring student progress to inform instructional decisions; (2) identifying misconceptions that may interfere with student learning; (3) providing rapid feedback on student writing; and (4) collecting information about student learning needs during instruction.

The first of these involves students using handhold devices (such as tablets or mobile phones) to self-monitor their understanding and progress in class topics, thus providing the teacher with large amounts of individual data, perhaps by means of easy-to-digest graphics, that they can use to inform discussions about the student's weaknesses and strengths and decisions about how best to support their learning needs. The second possible use requires somewhat more sophisticated technology: online diagnostic tests that in addition to providing a score automatically identifies what, if any, misconceptions the student holds about the topic in question. Students can then be directed to remedial learning activities. Russell's third possible technology is more complex still: automatic essay marking (based on techniques such as Latent Semantic Analysis or Bayesian Essay Test Scoring), repurposed to provide students with almost instantaneous feedback on their writing. Such systems might provide information about the student's use of English, the content of their writing, and the way in which they have structured their ideas, allowing them to rethink and revise their approach. The fourth technology identified by Russell, classroom response systems, are less technically sophisticated but are contingent upon how they are configured by the teacher. While they might enable teachers easily to identify patterns in individual responses, assess understanding and inform individualised teaching, they depend entirely on the quality of the questions and possible responses provided to the students.

Interestingly, of these four possible uses of technology to support formative assessment, in only one, automatic essay marking, is the student directly supported by the technology. The others are described as providing what might be called ‘in-direct’ formative assessment, by focussing on giving information to the teacher, to enable them to provide any necessary remedial support. However, this appears to be a limit of Russell’s approach, rather than anything specific to the technologies, each of which might be reconfigured to provide the students with direct opportunities to self-assess how they are progressing and how they might improve their own learning trajectory.

3.4. Summary of Key Points

Definition of Formative Assessment

- Assessment becomes “formative assessment” when the evidence is used to adapt the teaching work to meet learning needs
- Quantitative evidence of formative assessment is weak owing to methodological challenges in implementing educational interventions

Key features of formative assessment implementation

- Sharing learning goals with pupils
- Help pupils to know and to recognise the standards they are aiming for
- Involves pupils in peer and self-assessment
- Provides feedback which leads to pupils recognising their next steps and how to take them
- Involves both teacher and pupils reviewing and reflecting on assessment data
- Given the lack of a universal model of how to undertake formative assessment, implementation needs to be flexible and adaptive to teachers’ needs

Strategies for undertaking formative assessment around key areas of practice

- Move away from questions on facts to open questions that invite discussion such as ‘why is this’, ‘how might you express this?’ where the teacher can provide immediate feedback on the student’s understanding
- Avoiding numerical scores and focusing on written comments that identify what has been done well and what still needs improvement and give guidance on how to make that improvement
- Embed peer and self-assessment strategies:
    - Students identify their self-assessed level of understanding by marking their work green, amber or red
    - Peer-assessment is ‘three stars and a wish’, where the peer reviewer has to identify and comment upon three things in the work that have been successful and one thing that could be improved
    - Students identify (perhaps with ‘traffic lights’) those topics that they have sufficiently understood and those that need further effort
    - Students generate and answer their own questions on topics to be covered by the test (summative assessment)
    - Peer-marking of tests (summative assessment) where the students have themselves been involved in developing the marking rubric or if they use the ‘three stars and a wish’ approach

Examples of how technology has been used for formative assessment

- e-learning and learning management systems
- Mobile technologies
- Blogs
- Classroom response systems
- Computer games
- Students self-monitor their understanding and progress in class topics, thus providing the teacher with large amounts of individual data that they can use to inform discussions about the student's weaknesses and strengths and decisions around these
- Online diagnostic tests that in addition to providing a score automatically identifies what, if any, misconceptions the student holds about the topic in question. Students can then be directed to remedial learning activities
- Automatic essay marking repurposed to provide students with almost instantaneous feedback on their writing
- Classroom response systems in which teachers identify patterns in individual responses, assess understanding and inform individualised teaching. These depend entirely on the quality of the questions and possible responses provided to the students

4. Enablers and Barriers to BYOD

4.1. Definitions of BYOD

With school budgets shrinking, students bringing their own devices to schools seems to be a promising solution for technology-enhanced learning, although it is noted that costs are shifted in part to the parents and to support the technological infrastructure required to deploy BYOD. In a report that surveyed the various models to BYOD, several models were identified each with its own benefits and limitations (Dixon and Tierney, 2014):

- **School-defined single platform laptop:** the school determines the technology choice in consultation with stakeholders. The laptop is funded by the school or parents, or a combination of both. This model ensures that all students are working with similar equipment that can support pedagogical requirements, be serviced in the school, while service providers can be held accountable if something goes wrong.
- **School-defined single platform laptop, plus another device:** this model offers the benefits of a single platform laptop and also allows students to benefit from using a device they own. It nonetheless introduces liability, maintenance and security considerations as the second device is owned by the student.
- **School-defined multi-platform laptops:** this is similar to the first model covered, but it gives parents the flexibility to choose a platform of their own choice. As a result, however, there may be cross-platform compatibility issues.
- **Student-choice of laptop or tablet or 'bring your own whatever connects to the Internet'**: students bring their own device, which is funded by parents. Schools have little say on the configuration. Teachers must therefore plan learning activities with the lowest capability device in mind. This also introduces more work on network configuration and the requirement that teachers understand the different technology platforms. On the part of the service provider, the requirement is to build software for the lowest common denominator.

In 2013, British Educational Suppliers Association surveyed 327 primary school subject co-ordinators and 305 secondary school heads on their attitudes toward BYOD noting that 67% believe that BYOD is important, a rise from previous years. However, as the variety of BYOD models suggest, integrating technology in the classroom is not straightforward. The next section focuses on the conditions and processes that may help achieve technology integration broadly, and where guidance exists it contextualises the discussion to BYOD.

4.2. The Conditions for Integration

Technology integration is a complex process - one that is almost too complex to fully conceptualise (Howard & Thompson, 2015). Many different factors have been identified as enablers of or barriers to technology integration, including *resources, curriculum and assessment, teachers' attitudes and beliefs, knowledge and skills, and the institution and subject culture* (Howard & Thompson, 2015). An influential study of the successes and failures associated with technology integration (Zhao *et al.*, 2002) identified a series of conditions as being influential. These included:

- technology proficiency;
- compatibility between a teacher's pedagogical beliefs and the technology;
- social awareness (important in negotiating the politics of the institution and managing change); and
- the nature of the innovation being implemented (elaborated below).

However, they noted some qualifications around these. For example, *technology proficiency* alone was not enough to guarantee success; "our observations suggested that an additional dimension of technology proficiency plays an equally important part: knowledge of the enabling conditions for a technology – that is, knowing what else is necessary to use a specific technology in teaching" (p. 489). For BYOD initiatives, this is of particular relevance as teachers must have some knowledge of the multiple platforms being used, and how to troubleshoot them and manage situations where hardware requirements become a barrier (Dixon and Tierney, 2014).

Zhao *et al.* analysis of the *nature of the innovation* in particular was complex, involving several sub-conditions, which they classified in terms of 'distances' and 'dependence'. For example, innovations were described in terms of their distance from the dominant school culture, as understood by the values, pedagogic practices and beliefs in the school; from the teacher's existing practice, such as whether similar projects had been undertaken before; and from available technological resources (contrasting those where technologies were already on hand with those that needed to be procured, developed, etc). Dependence was understood in terms of dependence on other people (autonomous teachers were more successful); and on technological resources (more complex implementations were less successful). No doubt BYOD introduces a high dependence of teachers on technical staff, which in turn poses a risk in implementing BYOD.

Zhao *et al.* also discuss the school 'context' as an important influence; this draws together some of the preceding conditions, discussing the human infrastructure, the technological infrastructure and social support as influences. Few schools will be in the ideal position of all these influences being ready and in place; however, sensitivity to the strengths and weaknesses that characterise specific implementation sites may help to manage and mediate the challenges of integration. The school context is a consideration of particular relevance to BYOD. If students are bringing their own devices, a central technological infrastructure decision must be made with regards to security. This spans protecting students, faculty, administrators, and databases filled with private information (Ackerman and Krupp, 2012). Thus, the risks to be mitigated may require different responses – from security protections to prevent outside attacks to school policies stipulating how devices must be used between students. Schools must therefore recognise the investment needed in managing a variety of technologies that enable learning alongside informal communication between students (Dixon and Tierney, 2014).

Teachers' Beliefs

Teachers' beliefs are obviously influential in the decision about whether to adopt new technologies. Donnelly *et al.* (2011), for example, discuss teachers' orientations towards learning or assessment, and whether they feel powerful or helpless about their adoption of technology. Subject requirements can also influence teachers' beliefs about technology, and their willingness to integrate it - there are, it seems, some subjects which 'match' and others that 'clash' with beliefs about technology and their willingness to ask students to use technology (Howard *et al.*, 2014). Specific to BYOD, mobile and tablet devices constitute a shift toward collaborative learning at the school level; thus, teacher beliefs must also be shared and supported by students, parents, school principles and technology departments (Ackerman and Krupp, 2012). Additionally, empirical evidence on the efficacy of BYOD programmes is still required. A recent influential study found that mobile phone presence at schools resulted in lower achievement amongst secondary school students (Beland and Murphy, 2015), albeit without examining whether mobile phones were purposefully used for learning and what school policies governed their use. Thus, more research is needed that includes additional predictors of achievement such as pedagogical uses and policies.

Teacher Knowledge

Teachers' knowledge is clearly linked to their beliefs, and the two are often considered together, but a separate body of literature exists that explores this issue. One influential framework for understanding teacher's knowledge about technology is TPACK (Mishra & Koehler, 2006). This framework builds on Shulman's model of pedagogical content knowledge, which was developed as a critique of teacher education courses. Using a Venn diagram, Shulman argued that teacher education courses build knowledge about subject matter (content) and about how to teach (pedagogy), but not about the specific intersection of these two: how to teach *this subject*, rather than in general. This intersection was referred to as pedagogical content knowledge, from which the name of the model derives. Mishra & Koehler extended this model by adding a third overlapping circle for technology, in order to extend the kinds of knowledge that they could discern:

- Content knowledge
- Pedagogical knowledge
- Technological knowledge
- Pedagogical content knowledge (how to teach this subject)
- Technological content knowledge (what technologies are used in this subject)
- Technological pedagogical knowledge (what technologies are used in teaching)
- Technological pedagogical content knowledge (what technologies are used in teaching this subject)

Although their model was developed as a critique of gaps in initial teacher education, it has been widely adopted as a design specification for courses and interventions, and also used as an analytical tool to discern problems in technology integration by identifying what kind of knowledge seems to be lacking in specific situation. Voogt *et al.* (2013), for example, identified 243 published references to TPACK within a period of six years, including the development of interventions, analyses of teacher' beliefs and theoretical development, although they noted that the conceptual foundations of the framework remain unclear.

4.3. Processes of Integration

Integration takes work, particularly where any of the conditions outlined above act as barriers rather than enablers. For example, where teachers lack knowledge about possible uses of technology, staff development might be required - and in particular, staff development that allows teachers the opportunity to undertake design-based work in order to understand the links between specific technologies and local conditions (Lawless & Pellegrino, 2007). Specific to BYOD, a misconception is often that technology will drive education, without an understanding of the pedagogical uses and practices that need to be in place for schools to observe any learning benefits (Dixon and Tierney, 2014).

Howard & Thompson (2015) use a systems perspective in order to highlight the way that integration takes place over time. They use cycles reminiscent of action research steps (planning, implementing, observing, reflecting) to show how teachers' beliefs change over time, based on experiences of trying technologies in the classroom; and also show how professional development can help to build teacher readiness for further uses of technology. Frequently, teachers learn informally, through trial and error – however, such learning can be enhanced through formal elements, such as supervision (Hoekstra & Korthagen, 2011).

Such processes can also take place in relation to infrastructure, although this can be more of a challenge. Ideally, teacher-led inquiry can inform policy, shape practice and promote school-based innovation (Rust, 2009); however, it may not be easy nor quick to persuade a school's senior management team to invest in the development of its technological infrastructure, or even to change policies around the control of software and hardware within a school.

Affective Responses to Integration

Integrating technology is a risk; it is also a process that requires teachers to feel comfortable about *taking* that risk (Howard & Gigliotti, 2015). This is something that involves emotional as well as rational responses to a situation. Anxiety about the impact of technology failing, for example, can outweigh any perceived benefits to learning, whilst growing comfort with technology use leads to more frequent risk-taking, as does the development of coping strategies that can be used when problems arise.

4.4. Summary of Key Points

- There are four modes to BYOD which differ on the basis of hardware and ownership of the device:
    - School-defined single platform laptop
    - School-defined single platform laptop, plus another device
    - School-defined multi-platform laptops

    - Student-choice of laptop or tablet or 'bring your own whatever connects to the Internet'
- The challenges of successfully implementing BYOD will differ depending on the model applied
- Conditions to successful integration of technology are:
    1. Teachers' technology proficiency and knowledge of what else is necessary to run a technology
    2. Compatibility between a teacher's pedagogical beliefs and the technology
    3. Social awareness (important in negotiating the politics of the institution and managing change)
    4. The nature of the innovation being implemented
        a. The innovation may be distant from the dominant school culture
        b. The innovation may be distant from a teacher's existing practice
        c. Dependence on other people (autonomous teachers were more successful)
        d. Dependence on technological resources (more complex implementations were less successful).
    5. Teacher beliefs
    6. Teacher knowledge

Processes of integration include:

- Professional development where teachers undertake *design* work to understand how technologies fit in with their *conditions*
- Encouraging action-research and informal work while introducing a form of supervision or mentorship
- Teacher-led inquiry can promote school innovation and lead to changes in technological infrastructure

Specific considerations for integration of BYOD are:

- The endorsement of BYOD and collaborative learning by the school and parents
- The implementation of clear policies for use of devices at school
- The implementation of a technical infrastructure for managing multi-device incompatibilities, security and maintenance
- Teacher training to develop technical proficiency and technology-enhanced mobile learning

5. Literature Review Implications

This report has covered three areas: (1) collaborative/cooperative learning, (2) formative assessment and (3) technology integration. This final section pulls out the implications of the literature review for Spiral focusing on the three areas of design, evaluation and implementation.

5.1. Design Implications

There are three phases to design – the problem setting, generative and synthetic phase.

- *Problem setting* is where the design team explores how things are currently done to identify a perspective for addressing a perceived problem. In Spiral the problem has been broadly defined as one where students are not actively engaged and motivated in their learning.
- The *generative phase* involves coming up with ideas on how to address the problem at hand. The theory described in Section 3, 4 and 5 are a response to this. However, while theory should be at the forefront of design, when developing technologies for education, as Section 5 points out, understanding practice and how the apps may fit in the classroom is equally important and must also be addressed.
- The *synthetic phase* is where ideas are synthesised into a cohesive gestalt. In other words, ideas from the generative phase need to fit with the overall design so that synergy exists between the different parts of the technology. Even though it is easy to brainstorm design ideas for instantiating theory (e.g. adding visual cues to highlight individual and collective accountability), the viability of such ideas will very much depend on the purpose of the app and how ideas align with other decisions. To this end, it should be also noted that the review demonstrates a bi-directional relationship between *formative assessment* and *collaborative learning* that has not been necessarily recognised in the project. On the one hand, the standards used for purposes of formative assessment enhance the effective operation of collaborative/cooperative learning e.g. group processing is effective when team members deliver feedback to one another structured based on performance criteria. On the other hand, peer feedback for purposes of formative assessment in part depends on students' collaboration skills.

With this in mind, four broad recommendations for revising the design process are made:

1. To be more explicit in how the apps link to theory
2. To consider formative assessment and collaborative learning design decisions *in tangent* in order to ensure that one serves the other
3. To involve teachers and students in activities that address focused questions derived from the literature review
4. To introduce research that recognises the BYOD context

Below we suggest a step-wise plan for conducting the design and co-design process according to these four recommendations. It is noted that this plan is not inflexible and can be revised according to the time span and access to schools.

1. Team Brainstorming (builds upon Sections 3, 4, 5)

Goal
- To develop a first set of innovative ideas which are grounded in theory

Methods/Process
- Participants: Spiral team
- Theoretical concepts presented in this lit review are collated in a summarised form (e.g. mind map, post its). The mind map serves as a basis for coming up with a broad number of ideas on how each theoretical concept could be instantiated and designed in the context of an app
- Process: ideation; all ideas are valid at this stage (the more diversity, the better) although validity of ideas depends on how well the proposer can defend the idea given the theoretical framework guiding the work

2. Design Research and Student Brainstorming (builds upon Sections 3 and 4)

Goal
- To expand on the first set of innovative ideas by capitalising on students' creativity whilst addressing social barriers as defined by students

Methods/Process
- Participants: Students, Spiral team
- Provide students with a partially complete prototype/a pre-designed learning activity and low fidelity materials including relevant icons, scissors, pencils etc.
- Students design their app in teams of 2-3 and present to each other their ideas in the end
- The workshop would take place over 2-3 sessions
- Provide students with a design brief and a set of design goals
- Possible design goals and tasks on *collaboration*:
    - Students design creative input modalities for the learning activity [workshop materials: text, image, video, audio icons…]
    - Students design corrective mechanisms that will motivate them to revise or flag up answers that they got wrong [workshop materials: edit, question mark, public/private, share within group icons…]
    - Students design tools for collecting responses or ideas from other students that they like and want to use in the future [workshop materials: save, clone, add comments icons…]
    - If the app is collaborative, students design a mediation interface that helps them constructively manage a disagreement with another student's response [workshop materials: version control, comments on version, red flag icons]
    - Students design how their group should be visually represented in the white board [workshop materials: pre-set icons, design their own icons…]
- Possible design goals and tasks on *formative assessment*:
    - Students will be given the learning aims and assessment criteria of the learning activity they are working on and will redesign them to be 'student friendly' in terms of language and visual presentation [workshop materials: target, focus icon…]

    - Students will devise a teacher and student view of the assessment criteria, design how they should be applied to a piece of work and how students can relate the criteria to individual and group performance (e.g. how to highlight that an area needs development, rules for positive and negative feedback) [workshop icons: traffic lights, in progress, star, danger icons, a user policy for feedback, sketching for rewards]
- Process: co-design; researchers facilitate the workshops by ensuring students are oriented to the design goals. Researchers are not leading but only probing with 'why' questions while leaving the space open for students to propose novel (and sometimes irrelevant) ideas. Students will thus be given freedom – this freedom might lead to lots of garbage but also gems that the team may not have considered previously. There is no right or wrong way of addressing the task
- Interpretation: Some inspiration will be drawn from students' ideas but there will not always be a mapping between features proposed by students and the final app. The validity of students' ideas should be appraised on the basis of the empirical evidence presented in this review

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3. Design Research for Understanding the Challenges of BYOD

Goals

- Different BYOD models introduce different demands. For instance, in the case of students bringing their own devices, it remains unclear how a student who has forgotten their device may still use Spiral. Thus, two goals are proposed:
    - To understand BYOD model implementation across countries of interest
    - To gather design requirements to support Spiral's use across a number (or subset) of BYOD models

Methods/Process

- Participants: schools (teachers, technical support, headmasters) with running BYOD policies
- Survey research to understand dominance of models of BYOD in key market segments, how these are implemented and what the main challenges are in terms of device use

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4. Design Research for Ensuring the Apps Fit with Existing Practice (builds upon Section 3 and 5)

Goals

- To understand the planning and performance requirements for the learning activity under question and existing time demands that could be reduced with the aid of Spiral
- Given that Spiral depends on how well students can collaborate with each other, we will also gather design requirements for supporting teachers in managing the development of collaboration skills

Methods/Process

- Participants: Teachers, Spiral team

- Observations of classroom practice around the specific activity in question and the management of collaboration skills in situ
- Interviews with individual teachers. In the first part, teachers will bring and discuss with the Spiral team the design materials for the activity examined (e.g. think-pair-share). In the second part, the Spiral team will explore how willing teachers are to develop children's collaboration skills whilst focusing on their main curriculum targets
- Classroom observations will be triangulated with the interviews with observations directing some of the interview questions
- Process: the researcher is taking an objective perspective to understand existing practice
- Interpretation: implications for Spiral are extrapolated from reflection on these observations

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5. Team Brainstorming and Synthesis of Ideas (builds upon Sections 3, 4 5 and consolidates all the previous steps)

Goals

- A low fidelity prototype that demonstrates all the key functionality i.e., a powerful idea for a learning technology that can be clearly defended by designers through the lens of theory and practice

Methods/Process

- Create an additional mind-map or representation that captures the key user findings from steps 2-4
- Return to the ideas from step 1 and add new ones that follow from the design research
- Cut down ideas to a subset which address the pedagogical and contextual requirements
- Create a low fidelity prototype
- Critique (and revise) the prototype using the mind-maps as a guide before finalising it

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6. Design research to ensure the apps are flexible enough but also targeted to be utilised across different subjects and by teachers of variable expertise (builds upon Sections 3, 4 and 5)

Goals

- Revised low fidelity prototype

Methods/Process

- Participants: teachers who have different technological expertise and work in different subject areas, Spiral team
- Workshops will be held with individual teachers to understand how the design works for them
- At the start of the workshop, the researcher will ask the teacher about their expertise with technology – how confident they feel, how often they run into technical problems and how they handle them, how often they use technology in

their lessons and how these choices are made. This will allow the researcher to interpret the teachers' interactions

- The TPACK framework presented in Section 5 is premised on the idea that technology use should reflect pedagogic considerations specific to the subject being taught; Harris *et al.* (2009) propose using 'content-based activity types' (p. 403) to address this, and identify 42 indicative activities (such as reading texts, group discussions, debates, writing an essay, making an artefact, and so on) derived from studies of teaching practice as a way of indexing different technologies that can support specific educational intentions. There are, of course, limits to this: "reading texts" may become quite different activities depending on whether the text in question is a YouTube video or a medieval Latin manuscript, and this need to situate practice is acknowledged. However, such indicative lists of activity types may provide useful sources of inspiration or points of departure for development and design. Before the workshop, the teacher will be asked to design a learning activity capitalising on web resources to be used in the workshop
- Teachers will be asked to design their learning activity using the low fidelity prototype of the app and to run a 'simulated' activity with the Spiral researchers. The simulated activity will be done with a set of students in mind to help envision how the app would benefit or harm specific students
- The simulated activity will present the entire app workflow from the collaboration processes involved to the application of formative assessment
- When the teacher finds it difficult to accomplish their goals or has a critique, the researcher will probe this further – what did they expect to find and why is the design inadequate? what could be done to improve the problem?
- Process: the researcher is taking an objective perspective to understand human or design barriers to using the Spiral app
- Interpretation: ideas for improving the app's flexibility and ease of use will be collected from observations/discussions around teachers' interaction with the low fidelity prototype

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7. Design Research to ensure the apps are socially appropriate for students (builds upon Sections 3 and 4)

Goals

- Revised high fidelity prototype to accommodate student concerns

Methods/Process

- Participants: Students, Spiral team
- Workshops will be held with students. Key points to understand: (1) if the formative assessment and collaboration design (tension between teacher directed and student directed interaction) is balanced and socially appropriate and (2) if the look and feel is appropriate
- A simulated activity will be run with students (similar to step 6) that presents the entire app workflow from the collaboration processes involved to the application of formative assessment
- When the student finds it difficult to accomplish their goals or has a critique, the researcher will probe this further – what did they expect to find and why is the design inadequate? what could be done to improve the problem?

- Interpretation: Incidents of key social barriers (e.g. making one's response visible to others) to the use of the apps will be noted and triangulated with earlier workshops. Students' proposed solutions to problems they identify will be considered in light of the theoretical knowledge underpinning Spiral to make decisions as to whether students' suggestions align with and serve the longer term learning vision of Spiral.

9. Formative evaluation of a working prototype

Goals

- Identify usability problems and evaluate pedagogical design decisions made in previous stages by testing a high fidelity working prototype with students and teachers

Methods/Process

- Participants: Students, Teachers, Spiral team
- Two schools will take part: one that participated in the design and one that is new to Spiral
- Two sets of sessions will be held at each school, one with teachers and one with teachers and students. The goal will be to incrementally improve interaction design decisions by observing the prototype's usability and pedagogical use
    - Teacher session: teachers will be involved in a one to one basis using the software to plan a session. Spiral researchers will observe how teachers are interacting with Spiral probing teachers to discuss perceived problems. After the interaction has been completed, teachers will be interviewed in an open format
    - Student/teacher session: this will involve a small group of students using the app under the supervision of a teacher (with an activity designed in the teacher session). Usability problems and challenges in running the pedagogical activity will be captured unobtrusively. After the interaction has been completed, the teacher will be interviewed separately and a focus group will be run with the students
- Interpretation: User feedback at this stage will be based on experience. It will be important to compare what students and teachers express with concerns and priorities highlighted in previous stages. Similar to earlier stages, students' and teachers' proposed solutions to problems they identify will be considered in light of the theoretical knowledge underpinning Spiral to make decisions as to whether these suggestions align with and serve the longer term learning vision of Spiral.

5.2. Research Questions and Methodological Implications

In this literature review we have argued that technology needs to be understood in the context of real world practice and the messiness this involves (*Section 3.4*). Moreover, we have covered theoretical issues with variable 'units of analysis' ranging from individuals (e.g. teachers, students; *Sections 3 and 4*) to institutions (e.g. schools; *Section 5*). Additionally, whereas in collaborative learning there is reasonable evidence with regards to the mechanisms to learning, in reviewing the literature on formative assessment a need was identified for exploratory research in which a deeper understanding of the different types of formative assessment would be first attained. Finally, it is noted that the key concern in collaborative learning is to understand the evolution of cognitive and social skills, necessitating that the researcher looks at the phenomenon in-depth over time.

These characteristics suggest case study research as a most likely candidate for the Spiral evaluation. In case study research, the researcher has *no control* over events that shape researchers' understanding (Yin, 2014). The unit of analysis can be the *individual, group or institution*. Case study research is often *qualitative*, but can include *quantitative* methods. Its aim is to illuminate a set of decisions, exploring why they were taken, how they were implemented and with what result (Flyvbjerg, 2006). Thus, depending on the goals of the research, it can be exploratory (e.g. seeking to develop new propositions and hypotheses), descriptive (e.g. describes the characteristics of a situation) or explanatory (e.g. attempting to explain human behaviour on the basis of previous theory).

Most importantly, case studies align with approaches used to study the phenomena covered in this report. For instance, the complexity of technology integration lends itself to such approaches, although these are often complemented by surveys that seek to establish broader patterns of success or failure. In particular, case studies involving interviews are widespread. For example, Zhao *et al.* (2002) developed their account of technology integration whilst evaluating projects funded by a U.S. state's technology innovation grants scheme. This included surveys (to establish broad patterns) and interviews (to understand the specific reasons for the success or failure of implementation). Their analysis used specific individuals as case studies to illustrate the interplay of the conditions they identified on the process of technology integration. Similarly, Howard & Gigliotti (2015) followed one teacher (selected from a larger cohort), providing a longitudinal case study built on online surveys, interviews and focus groups. The longitudinal element allowed them to explore changes in experience over time, and the qualitative approach allowed the reasons for these changes to be identified.

Our review has highlighted a number of possible research questions which we tentatively present in Table 1, in line with their expected outcomes:

Table 1 – Possible research questions, outcomes and methodologies

Possible Research Questions	**Outcomes**	**Methodology**

Possible Research Questions	Outcomes	Methodology
What is the technological pedagogical content (TPC) knowledge supported by Spiral?	Will yield examples of use provided alongside the technology to help Spiral teachers imagine ways of using it. Examples will be cross subject and curriculum	• Descriptive case study in schools to capture TPC • Methods: system logs capturing four TPC uses per teacher followed by a survey or Skype interview • Up to 20 teachers, distributed across schools in the UK and abroad • The unit of analysis are the teachers
What are the opportunities provided by Spiral for formative assessment?	Examples and new hypotheses as to how different types of formative assessment provided in Spiral may support learning	• Exploratory case study aiming at developing new propositions with regards to how technology employed for formative assessment supports learning • The unit of analysis is the teacher/student pair • A minimum of 5 observations in schools per teacher/student pair across 2-4 schools • 30 minute interviews with teachers and students in part drawing on incidents from the observations
What are the collaboration processes encouraged through the use of Spiral and how do these facilitate learning over time?	Evidence and examples of how Spiral benefits the learning process	• Explanatory case study research aiming to explain collaborative learning with a focus on how this changes over time • The unit of analysis is the student group • A minimum of 5 observations per group across 2-4 schools • 30 minute interviews with students in part drawing on incidents from the observations

Possible Research Questions	Outcomes	Methodology
How successful is the integration of Spiral in schools?	Knowledge of what BYOD models are best suited to the integration of Spiral An understanding of the barriers and enablers to technology integration for Spiral	• Exploratory/explanatory case study research using predictions from the technology integration theory but also identifying new conditions specific to BYOD • The unit of analysis is the school • A minimum of 2 observations per school across 4 schools (selected due to their differences in implementing BYOD) • 30 minute interviews with teachers, students, head teachers and technical support

5.3. Implementation Implications

Technology integration in schools is challenging and BYOD poses a varied and unique set of considerations. We summarise *Section 5* in Table 1 by mapping conditions or processes for technology integration to the case of BYOD. It is suggested that without an effective BYOD policy, the use of Spiral in the classroom will not be sustainable. Therefore, Table 2 offers some criteria for targeting future Spiral clients who are most likely to recognise the value of collaborative learning and engage in sustainable technological practices. It is noted however that it is unlikely that any school will fulfil all of the conditions to BYOD technology integration. The Spiral team may thus want proactively seek to support integration processes through a community of practice where teachers share pedagogical uses of Spiral across different content areas *and* where teachers and schools are supported to discuss barriers and solutions around broader BYOD issues; for example, information about the kind of infrastructure that a school would need to have in place to support use of the technology, or advice about the kinds of questions and concerns a school network manager might have when thinking about implementing the technology. Prompts to the teacher could also be provided, to help them think about the wider network of people they might need to involve when working towards integration of the technology.

Table 2 – Summary of technology integration implications for Spiral

Conditions/Processes of Technology Integration	Considerations for BYOD and Spiral
(1) Teachers' technology proficiency	• Teachers must understand how to use varied tablet and mobile devices, and operating systems

Conditions/Processes of Technology Integration	**Considerations for BYOD and Spiral**
(2) Compatibility between a teacher's pedagogical beliefs and the technology	• Teachers must believe in collaborative learning
(3) Social awareness	• Exam pressures must be aligned with what the apps offer; one solution to this, is to align summative with formative assessment (see Section 4)
(4) Nature of the innovation	• Schools with tested and long running BYOD policies are more likely to buy into Spiral • Teachers who have successfully used mobile devices in the classroom will be more likely to buy into Spiral • BYOD introduces a dependence on technical support from the school and thus a firm commitment is needed by the school
(5) Teacher beliefs	• Teacher beliefs need to be supported by the school and the community with a commitment to BYOD and collaborative learning
(6) Teacher knowledge	• It is necessary to provide evidence of technological pedagogical content knowledge across a variety of content areas

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