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A method for teacher inquiry in cross-curricular projects: Lessons from a case study

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Abstract

Many changes in teaching practices (such as introduction of e-assessment) are initiated by school management, or by a lead teacher, but have direct impact on the learning designs of others. However, models of teachers as innovators, conducting evidence-based inquiry into their students' learning, view the teacher as initiator of change in their own practice (normally as individual). This paper addresses the question of whether such models can also be applied to change introduced by top-down processes. In this paper, we examine teacher inquiry in such a context. We discuss a case study in which we worked with the Head of Science (HoS) of a secondary school. The HoS designed a cross-curricular science, technology, engineering and mathematics (STEM) project with 57 STEM teachers and introduced Google Forms as a tool for formative assessment. We supported the HoS to design and conduct an inquiry that involved all teachers. We examine the context and process of inquiry and how it was applied. Our findings provide insight into teachers' use of tools and representations when communicating about learning design, and the implications of this for the development of learning analytics tools. They also inform the development of a method for coordinating teacher inquiry in cross-curricular projects and, more generally, in the context of top-down introduction of change.

Introduction

There is a rich body of research that has investigated the role of teachers as innovators who can influence policy through a process of evidence-driven inquiry into student learning (Banks, Leach & Moon, 1999; Hargreaves, 1999; Thorpe, 2009). The emphasis has been largely on individual teachers conducting inquiry into their practice, but there is also a significant line of research on collaborative inquiry and the factors necessary for collaboration to be successful (eg, Nelson & Slavit, 2008). There is evidence that collaboration is effective in supporting long-term teacher development (Grossman, Wineburg & Woolworth, 2001) and provides an environment that supports long-term change (Giles & Hargreaves, 2006). What all these approaches highlight is the role of teachers, or groups of teachers, as initiators of change.

In existing teacher inquiry methods (eg, evidence-based decision support, the video-based, scaffolded inquiry approach by Rich & Hannafin, 2008), teachers identify questions for inquiry in

their practice and then design a process for collecting evidence about student learning that informs their subsequent learning designs. However, in practice, the school context does not always support this ideal notion of a cyclical process of teacher inquiry informing learning design and learning design triggering teacher inquiry. There are many barriers to teacher-led change, both in terms of conducting inquiries, such as the lack of time and collaborative cultures (Nelson & Slavit, 2008), and acting on the results of the inquiry, such as the lack of a culture of change within the teachers' department (Priestley, Miller, Barrett & Wallace, 2011). In practice, many significant changes to teachers' learning designs are introduced not by individuals or groups of teachers, but by management or lead teachers, such as heads of department. For example, the large-scale introduction of technology in schools tends to be driven from the top (eg, iPads; Clark & Luckin, 2013), as is the drive to evaluate the impact of the change. In such cases, management or lead teachers are not conducting an individual inquiry: they identify the question for inquiry, but the innovation changes all teachers' learning designs. The context is not one of a collaborative inquiry either, because one person (or a small group of people) leads the change and introduces the innovation.

It is generally accepted that successful school leadership does not involve imposition of goals, but the creation of a shared sense of purpose and direction and the distribution of leadership practice throughout the school community (Leithwood & Riehl, 2003). The goal of those in leadership roles is to manage the relationships within the school in order to utilise the expertise that is available in the organisation. Therefore, understanding successful leadership must go beyond head teachers' accounts, to explore the "collective interaction among leaders, followers, and their situation" (Spillane, 2012). However, the literature is less clear on what forms of distributed leadership activity are effective (Harris, 2003). The implication for teacher inquiry is that we need to better understand how to support a distributed process of inquiry that enables management or lead teachers to implement a participatory rather than top-down approach.

An additional factor to take into account, when considering the current context of teacher inquiry, is the increasing expectation from policy makers that decisions will be data driven (eg, Mandinach & Gummer, 2013). This can only be achieved on a large scale if teachers have tools that allow them to collect and analyse large amounts of data. The developing field of learning analytics may provide such tools for improving epistemic and pedagogic practice (Bull & Kay, 2007; van Harmelen & Workman, 2012). Until recently, learning analytics has focused on analysing log data from the use of interactive learning environments by students, and less research has been done on providing analytics to support teachers' needs (Ali, Hatala, Gašević & Jovanović, 2012; Ferguson, 2012). This focus is slowly changing, and researchers are designing tools to meet teachers' requirements (eg, Dyckhoff, Lukarov, Muslim, Chatti & Schroeder, 2013; Vatrapu, Teplovs, Fujita & Bull, 2011). The availability of data on students' learning is obviously a critical point, making online student interactions and high-level data on student performance (eg, submission/non-submission of academic work) primary areas for developing learning analytics tools (eg, Arnold & Pistilli, 2012). The effectiveness of learning analytics tools in a school context depends on the extent to which the tools meet the teachers' inquiry requirements, for example, the usefulness of learning analytics indicators to the teachers' inquiry questions, the data literacy of teachers and the ease of use of the tools (Clow, 2012; Dyckhoff *et al*, 2013; Mandinach & Gummer, 2013). A recent report on teachers' use of data on student learning suggests the need to provide support to develop teachers' data literacy (Means, Chen, DeBarger & Padilla, 2011).

In this paper, we test the application of a model for teacher inquiry in a context of top-down introduction of change, with the characteristics we discussed above. The case study involved the introduction of a new form of assessment in a cross-curricular science, technology, engineering and mathematics (STEM) project. Our work contributes insight into teachers' use of tools and

representations when communicating about learning design and teacher requirements for the development of learning analytics tools, and informs a revised method for teacher inquiry in cross-curricular projects, and, more generally, in the context of top-down introduction of change to teachers' learning designs.

A model for teacher inquiry

The present study is part of the NEXT-TELL project (http://www.next-tell.eu/). The project aims to provide a platform, for use within schools, to continuously and collaboratively innovate information and communication technology (ICT)-enhanced formative classroom assessment, with an emphasis on formative assessment enabled by learning analytics. The work we report on here centres on developing a method to support individuals and groups of teachers to conduct data-driven inquiries into students' learning with the aim being to improve pedagogy and use of ICT in their learning designs.

In practice, the literature has shown that in order to pursue inquiries, teachers often require guidance and support (Ingram, Seashore Louis & Schroeder, 2004; Nelson & Slavit, 2008). From our perspective, such guidance and support must be developed in collaboration with teachers. It is necessary to work closely with teachers to understand the complexity of their working contexts and the difficulties they can experience in embedding new technologies into their everyday pedagogic practices. The increased possibility for new forms of data capture, such as capture through handheld devices (Bennett & Cunningham, 2009), combined with learning analytics (van Harmelen & Workman, 2012), offers promise for supporting a more in-depth inquiry process into student learning. However, the rich data on students' learning have been difficult for teachers to capture and evaluate (Means *et al*, 2011; Scheuermann & Pedro 2010). Therefore, teachers' and schools' existing skills and prospective strategies have guided our introduction of ICT to contexts of inquiry.

The initial teacher-led inquiry method we applied, Teacher Inquiry into Student Learning (henceforth TISL), was guided by the theoretical framework of Teacher Design Research (Bannan-Ritland, 2008), then developed in several cycles during workshops with teachers. Table 1 shows the method steps. The inquiry begins with a trigger, which could be a question arising from teaching practice. This question is then refined into a research question that identifies an aspect of student learning. The following steps involve planning and carrying out data collection, analysing the data and establishing specific changes that are informed by the results of the analysis. Figure 1 shows the TISL method as a set of guiding questions, which were found to be easier for teachers to work with than the description of activities in Table 1. In alignment with teachers' professional

Table 1: Five steps to systematising teacher inquiry with TISL

TISL method	*Description of activities*
Step 1: trigger	Establishing a question that leads to the inquiry. This can be formalised as a research question
Step 2: refine question	Identifying what aspect of the learning experience is examined (eg, using new technology to support collaboration)
Step 3: collect data	Determining what data will be collected and which technology tools will aid this process
Step 4: analyse	Examining and evaluating the data. Reflecting upon students' learning and practitioners' teaching
Step 5: enact change	Deciding upon and undertaking any changes in practice that may result from new knowledge gained

TISL, Teacher Inquiry into Student Learning.

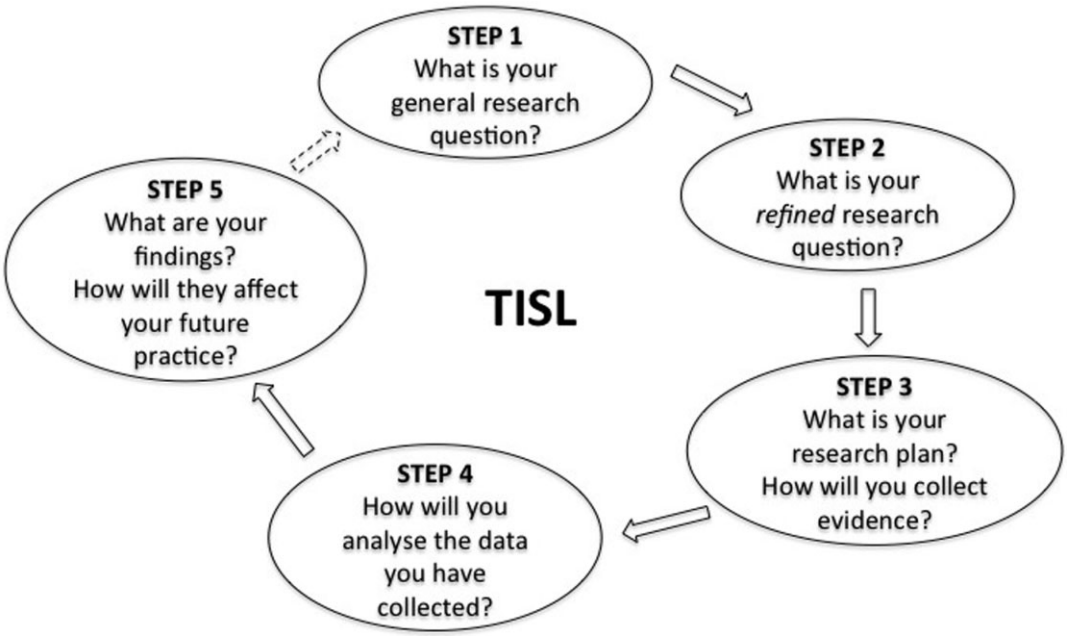

Figure 1: The Teacher Inquiry into Student Learning (TISL) method as a set of guiding questions

development, TISL aims to enable teachers to conduct a sustainable and relevant inquiry into students' learning and related school-based practices (eg, teaching, assessment, etc).

Methodology

The aim of this study was to explore how an existing method for supporting teacher inquiry in individual or collaborative contexts could be adapted to support inquiry in contexts where teachers' pedagogy is directed by a top-down process. As this was an exploratory question, a case study methodology was adopted. We were interested in capturing the context of: (1) the design and implementation of an inquiry into the learning design of the cross-curricular project, as well as (2) teachers' implementation of the learning design; both were directed by a lead teacher. We examined the process of implementing the inquiry, with a particular focus on data collection (Step 3, see Table 1), which was the step in which the lead teacher who designed the inquiry involved the other teachers. We also focused on teachers' communication about practice and how this was facilitated. In other words, teachers' discussions about the implementation of their learning design, and the tools and representations used to facilitate these discussions. This collection of data would inform our understanding of this type of inquiry context where one teacher leads the inquiry, and learning design is largely directed. Consequently, the data would lead to appropriate adaptation of the TISL method. These data would also inform our understanding of the kind of data teachers chose to collect and how this might align with the development of learning analytics tools.

Case context

We worked with an academy school in the UK. Academy schools are funded by central government and are independent of direct control by the local authority. The primary contact was the school's Head of Science (HoS), who was the key coordinator for a cross-curricular STEM project. It is the fourth time this type of project has been run at the school. The project ran over 4 weeks, with 57 teachers responsible for 364 learners. Its aim was to develop and consolidate learners'

STEM skills. The project involved the introduction of e-assessment using Google Forms. Pedagogically, cross-curricular projects are significant because they try to integrate students' knowledge from separate disciplines, such as science, technology, engineering and math, and follow an inquiry-based pedagogy. Logistically, the project involves the coordination of work between many teachers who collaboratively supervise student projects.

Method

We interviewed 13 teachers, including the HoS and 2 teachers who were also part of the school's management team, the Head of Design Technology and the Head of Mathematics (identified in quotes as "Management"). The teachers interviewed ranged from those working on their first STEM project at the school to those who had already assisted in the facilitation of previous projects. The interviews were not part of the TISL inquiry, but part of our research on the use of the TISL method. Interviews were semi-structured, conducted face-to-face over 2 days, one at the beginning of the project and one at the end. The interviews were audio recorded and lasted approximately 30 minutes. The questions were focused on the processes involved in delivering the project, the tools used, teachers' perspectives on the effectiveness of processes and tools, the challenges that were encountered and how these challenges were addressed. The interview questions are included in the Appendix. We also collected data from our email communication with the HoS, which occurred on an as needed basis, and from a staff survey that was set up by the HoS as part of the inquiry. This survey was anonymous and was administered online using Google Forms. The HoS sent an email to teachers asking them to complete the survey. The survey questions are included in the Appendix. The research procedure followed British Educational Research Association ethics guidelines (BERA, 2011) and was approved by our institution.

Analysis

The interviews and email communication with the HoS were analysed by two researchers using NVivo (QSR international) to identify themes relating to the inquiry process. Note that our focus was on the inquiry process, not the use of Google Forms, which was the focus of the HoS's inquiry. The coding began with a process of interpreting the data and identifying units of analysis in relation to teachers' perspectives and actions. As new themes emerged during this process, themes were constantly compared following the process of open-coding (Strauss & Corbin, 1990), resulting in a set of 32 initial themes. Further analysis explored connections between the initial themes, resulting in their integration into nine higher level themes. For example, the higher level theme *teacher discomfort* is analysed further into subcategories, for example, *teacher confidence in teaching outside of their specialist subject*. The themes resulting from our analysis are included in the Appendix (Table A1).

The survey set up by the HoS (see Appendix) received only 15 responses, and the answers to the 4 open questions were 1–2 sentences long. We therefore summarised the closed questions and extracted the issues raised in the open questions.

Case study

The project set-up

The project was coordinated by the HoS; it involved three departments (Science, Technology, which incorporates Design Technology and ICT, and Math) and ran over 4 weeks. Fifty-seven teachers were responsible for 364 learners. Students worked in small groups of approximately four learners. Each group was supported by at least four subject teachers, with one each from Science, Design Technology (including teachers with expertise in engineering), ICT and Maths. Some classes received support from additional teachers if they were in classes that were normally "shared" by teachers. Therefore, each teacher was allocated to co-supervise (with other subject teachers) one to five student groups from the classes they taught.

Table 2: The TISL inquiry

Step 1: trigger	Improve STEM project design, particularly formative assessment. The aim is to further develop student engagement and autonomy, with learners being given increased responsibility for tracking their own learning using assessment phases (similar to a learning diary).
Step 2: refine question	Is Google Forms a useful tool to track, formatively assess and monitor student learning? How can it best be used?
Step 3: collect data	Do teachers use the forms? Do students fill in the forms? Survey from teachers: feedback on project process. Are the forms useful in assessing student progress? Are they easy to use?
Step 4: analyse	Collate information on use of forms. Collate information from teacher survey.
Step 5: enact change	Use Google Forms on next project? Make changes to project process?

STEM, science, technology, engineering and mathematics; TISL, Teacher Inquiry into Student Learning.

Students chose their own project titles, in some cases with guidance from their teachers. All titles had to be approved before students started work on their projects. Projects varied, for example, one group explored the use of solar panels, while another developed an edible pen.

Students followed their usual school timetable during the project. They continued to work on their projects in each subject class, receiving supervision from each subject teacher on different aspects of their project. However, there was evidence of increased flexibility. Groups were allowed to work on specialist resources in other classrooms (such as the lathe located in the technology workshop), as well as work informally on their projects outside of school time, at lunchtime or after school.

The inquiry

The HoS investigated the use of Google Forms for formative assessment. Learners were set questions as part of weekly assessment phases (a screenshot is included in Appendix; Figure A1). Because this required access to a computer, students filled out the form either during a lesson that occurred in a computer lab or they were sent in small groups to the library during a lesson (while the other students worked on their projects). The purpose of using Google Forms was to allow teachers to review and formatively assess student progress on their projects.

Table 2 presents an overview of the inquiry. The focus of the inquiry is on assessing student learning during a cross-curricular STEM project. Google Forms is used for the first time in the implementation of cross-curricular projects as a tool for formative assessment.

Findings

First, we discuss our findings on the inquiry process. We then discuss communication about the learning design: what teachers communicated about and what tools and representations they used. At the beginning of each section, we indicate the data source from which we draw our findings.

Context of inquiry

Interviews and email communication with the HoS

The trigger for the inquiry was to find a new formative assessment method. The cross-curricular structure of the project is a relatively new pedagogic approach and previous assessment methods had not been entirely successful. For example, in a previous project, they used audio for formative assessment. While there were some positive outcomes (eg, it was easier for lower ability students to reflect on their work), there were also negative ones (eg, it was time-consuming to review effectively).

It is interesting to note that both the audio assessment method, used in the previous project, and the choice of Google Forms in the present project are qualitative representations, rather than quantitative data. This is intentional for the HoS: "qualitative can be so useful in terms of discussion . . . because there is a record of a way they [the students] *perceive* their skills, not so much the actual skills" (HoS, emphasis added). Additionally, one of the main criteria was to choose a method that would increase learner autonomy and responsibility: "it's going to . . . put the students in the driving seat and the teachers . . . review it" (HoS). The choice of formative assessment method was also based on ease of use and ease of sharing: "I like the ease of using [Google Forms], and . . . didn't take me long to use it and figure that out. And I'm not the best technical person in the world" (HoS).

One source of evidence for the inquiry was straightforward: whether teachers use Google Forms. The HoS monitored this on a weekly basis. However, the HoS was also interested in finding a method of data collection that would provide constructive feedback from teachers. This feedback did not arise spontaneously: "Absolutely no idea. How can I tell? They are all being very nice to me. . . . I have a lot of positive feedback saying this is great" (HoS). Therefore, an online survey was set up to collect teacher feedback on: "how they found the process, in a practical way and in an educational perspective way" (HoS). The survey was short (it included nine closed and four open questions, see Appendix) in order to encourage response given the constraints on teachers' time. We note again that the HoS is seeking qualitative data, in the form of teachers' self-report, to evaluate the formative assessment method.

Survey and interviews with teachers

The request for feedback on the project and use of Google Forms (via the survey) was sent to teachers during the last week of the project (teachers were not asked in advance to gather data about the use of Google Forms). The choice of a survey did not prove successful, as only 15 out of 57 teachers responded. The survey responses that were submitted also indicated that this method missed important feedback on learning design and pedagogic practice. The interviews led to in-depth insights from the teachers on how the project implementation could be improved, which did not make it into the survey. For example, a teacher commented on the survey: "consider involving the English department." In contrast, during an interview, they discussed in depth the issue of supporting low-ability students to express themselves: "the high ability students tend to be more comprehensive in what they write, it is just teaching those lower ability students to try and avoid one word descriptions . . ." (teacher).

Context of learning design

Interviews with all teachers

Teachers worked in groups during the project. Teacher communication was facilitated through three face-to-face meetings, a blog and email. The meetings were arranged at the beginning of the year. The management's intention was to provide several forms of communication: "I don't mind if people are using the blogs, or using email, or going and speaking to each other, it's about providing people with ways of communicating with each other and finding what works for them" (Management).

The project structure was communicated to teachers by the HoS through email and staff meetings. In order to ensure that teachers were using the chosen method of formative assessment, the HoS sent weekly summaries of who had used Google Forms that week. This monitoring appears to have been necessary for many teachers, who did not initially use the assessment method. This indicates the difficulties in implementing a particular learning design with many teachers and that some form of monitoring may be necessary: "[The HoS] has been checking each week, goes into all 16 [groups] and does it periodically sends out a matrix of YESs and NOs . . . staff know [the

HoS] is chasing up . . . each week there are some NOs, the following week the NOs had become YESs" (Management).

There may be several reasons for non-compliance. In this case, one reason was that several teachers did not initially understand how to use Google Forms: "That is the thing, sometimes the staff were like how do I use Google Forms . . . by now I'm sure they have got into it" (Management). There may also be confusion over implementation of the learning design: "in fact we had to deal with a few members of staff, in terms of talking to them about what they had done, and how they would need to put this right and sort it out. And you know, I think we observed from a distance in a managerial sense, that something had gone on" (Management).

The implementation of the cross-curricular project, more generally, created some challenges for the teachers we interviewed. They identified three specific issues: difficulty in teaching outside of their specialist subject, giving up control to students (as this was a student-led project) and sharing control with other teachers (as the projects were supervised collaboratively). For example, a Math teacher discussed their discomfort with teaching effectively on the STEM project: "when [the students are] working on their own project, I have to try and offer an extension to it, or suggest when to do something else, which when it is not just Maths I find difficult" (teacher). They also reported that student motivation was sometimes low and that low-ability students lacked the skills to develop their own ideas and work in groups effectively.

Overall, the HoS perceived a change in patterns of communication between teachers during the project: "The biggest change I have seen is that staff are talking, and the downside, the only downside is they are not talking enough. What can I say? We have improved, we are on that continuum of improvement, we're working our way up to good teamwork but we aren't there yet by any means" (HoS).

There was an issue on what communication between teachers should be private (by email to a subset of teachers) and what should be shared (via the blog to all teachers). There was a case where the teachers were discussing something via email, but then were told the issue was relevant to all teachers. For example: "someone said oh well the kids keep saying . . . that they have already done something, and I messaged the teacher back and I said, yeah they are saying that in mine too . . . but there was some communication through email about that, but not through the blog. And then [the HoS] said, you need to put that on the blog so that everybody can see . . ." (teacher).

According to the HoS, most, but not all teachers, attended the face-to-face meetings. There was no data on use of email, as this is private, but all interviewed teachers used it. The HoS reported that most teachers used the blog (only two groups did not use it) during the initial stages, but its use diminished over time. All interviewed teachers also reported that it was often most effective to find and speak to another teacher in person. For example: "I whizzed across to see, I can't explain something on an email sometimes, a blog doesn't tell me the whole story, so you whizz across to a certain to say look you finished that off . . ." (teacher). Overall, all the teachers we interviewed reported that each of the three communication channels (blog, email, face to face) had advantages over the others. The blog enabled teachers to keep track of what their student group had done with other teachers, email allowed targeted communication with specific teachers and face-to-face meetings were necessary for the resolution of immediate questions and for when a teacher was not responding to emails. The barriers to communication that teachers identified were time (particularly when they were supervising many groups) and not having an existing relationship with their colleagues (this was especially the case across departments).

Survey

The survey responses indicated that all 15 respondents attended the staff meetings, though three of them did not find it useful because there was insufficient time. They found the materials

produced by the HoS about the project useful, though six thought it included too much written information. In terms of the project process, five teachers identified a need to improve collaboration between teachers and coordination of teaching across STEM subjects. The other issues that were raised related to the difficulty of the process for many students who lack skills and motivation to engage effectively. Only one teacher did not use the blog, while eight used it regularly. Twelve teachers thought the use of Google Forms for formative assessment was useful, but they felt the students had to fill them in too often during the project (this was done weekly).

Discussion

Our findings identify key elements in the inquiry process that need to be integrated into the TISL method in order to make it fit for use in the kinds of school contexts where many teachers are working. First, our application of an individual/collaborative TISL method to this context identified an important limitation of the method. The lead teacher, the HoS, carries out the first steps in the inquiry: the question and refining the question, and planning the data collection. The HoS also analyses the data at a high level, but, effectively, his analysis is a meta-analysis of the analysis carried out by the teachers who are providing feedback. This is not made explicit in the inquiry method and the HoS, therefore, does not consider how to support teachers more effectively (see the TISL plan, Table 2). The teachers are asked to provide feedback on the use of Google Forms via a survey. However, they are not given explicit direction or support to collect evidence about it, both in terms of motivating them to participate and supporting them in doing so.

Second, there appears to be a preference for qualitative data, both for formative assessment (evaluating epistemic practice) and for assessing methods of formative assessment (evaluating pedagogic practice). This preference has implications for the development of learning analytics tools. Typically, such tools make use of quantitative data that are available without additional interpretive work by teachers. It may be that, in contexts such as this one, teachers translate qualitative data on student learning into quantitative indicators that are then analysed by a tool. However, this would be a time-consuming process. For quantitative data to be more readily available, changes would need to be made to the context of interaction between students, for example, include some elements of online communication. This might be problematic in current classrooms, in terms of availability of technology, and student and teacher skills. Indeed as we discussed, it was reported that many teachers found Google Forms, a relatively simple technology, difficult to use at first. Teachers' difficulties echo findings from other studies (Means *et al*, 2011; Scheuermann & Pedro, 2010) who have found evidence that teachers lack the skills to use new technology to capture data on student learning. An additional challenge for learning analytics researchers is to understand how we can assess complex skills, such as students' metacognitive assessments of their own learning (this was the focus of the formative assessment in our case study). One of the challenges of learning analytics is to create strong connections with learning theory (Ferguson, 2012).

These findings suggest that introduction of learning analytics in schools may not immediately align with teachers' current preferences and skills. Working with teachers to develop learning analytics tools may not be a case of fulfilling an existing need. Initial collaboration between researchers and teachers may require work on understanding how learning experiences can be designed to collect relevant data, which can then feed into learning analytics tools. The challenge is not only to understand what indicators to search for in the data (Dyckhoff *et al*, 2013) but how to collect relevant data in the first place.

Third, related again to the applicability of quantitative data and learning analytics during TISL, the interviews revealed more than the survey in terms of the detail of teachers' feedback. As discussed in our findings, the brevity of the survey responses did not communicate the detailed thinking behind a suggestion (for example, the suggestion to involve the English department) or

Table 3: A modified method for distributed TISL (additional steps in italics)

TISL method		*Description of activities*
Question	Step 1: trigger	Establishing a question that leads to the inquiry. This can be formalised as a research question (eg, is introduction of new technology improving learning?).
	Step 2: refine question	Identifying what aspect of the learning experience is examined (eg, using new technology to support collaboration).
	Step 3: identify teacher ownership	*Identify the scope for teachers to take ownership of the inquiry (eg, new technology to support collaboration in various contexts of learning: inquiry based, subject specific, etc). Identify collaborative tools to aid this process.*
Data collection	Step 4: collect data	Determine what data will be collected and which technology tools will aid this process.
	Step 5: support data collection	*Determine who else will be collecting data and how to provide support for them. Identify strategy to support and monitor communication.*
Analysis	Step 6: overall analysis	Examining and evaluating the data. Reflecting upon students' learning and practitioners' teaching. Revise based on Step 7.
	Step 7: synthesis	*Examine and evaluate teachers' data. What question have they addressed? Can their findings be combined?*
Change	*Step 8: new inquiries*	*Can teachers' questions lead to new inquiries?*
	Step 9: enact change	Deciding upon and undertaking any changes in practice that may result from new knowledge gained.

TISL, Teacher Inquiry into Student Learning.

the depth of an issue (whereas in the survey teachers suggested better collaboration was needed, in the interviews they talked specifically about the difficulties they experienced in collaboration: being involved in teaching other STEM subjects and sharing control of the project process with other teachers). Obviously, interviews are time-consuming. However, time-consuming methods of data collection may be necessary in addition to quantitative approaches.

Fourth, there appear to have been many preferences in teachers' choice of tools and representations to support communication during their implementation of the project's learning design. Online tools were used: (1) blogs, where information was permanently available and visible to many and (2) email, where information was visible only to recipients. However, brief face-to-face discussions were often preferred.

Fifth, there is a fine balance to be struck between controlling what teachers do and maintaining cohesion. Some form of management, both of communication and implementation of learning design, appears to have been necessary. However, teachers had their own ideas about the learning design (for example, the teacher who queried its effectiveness for low-ability students). Existing teacher inquiry methods, applied to the context of one teacher directing many, do not support a process for identifying and integrating variations in the inquiry by participating teachers. Implicitly, they assume the lead teacher will have control of the inquiry. The methods do not allow for the introduction of some form of collaboration at a later stage.

Based on the above insights, we revised the TISL method for lead teachers, shown in Table 3. Figure 2 shows the process of inquiry and associated guiding questions for each step. The method follows the original steps of inquiry (Steps 1–5 of the original method correspond to Steps 1, 2, 4, 6 and 9), but introduces appropriate guidance for the lead teacher to work with teachers in the collection of evidence, taking into account the need to reduce the lead teachers' control over the inquiry and the possibility of variations in the TISL question.

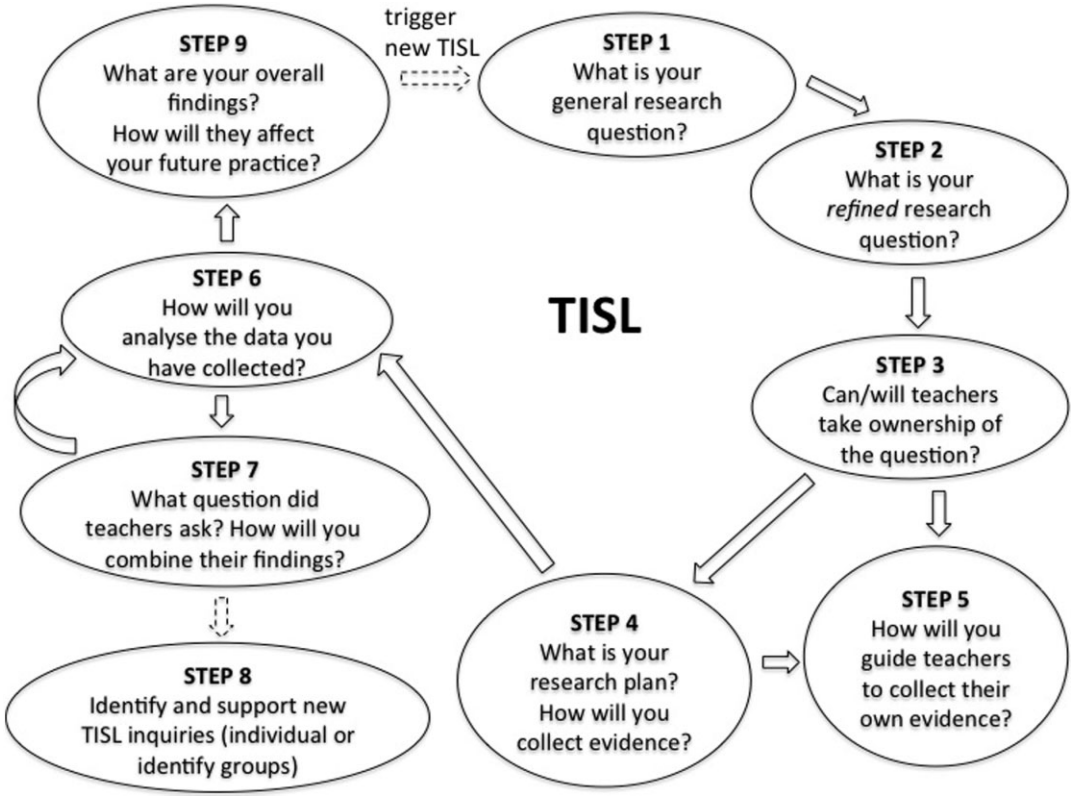

Figure 2: Process of the modified Teacher Inquiry into Student Learning (TISL) method

The modified method for distributed TISL also identifies the opportunity to identify and support new inquiries that are considered important, either on a level of individual teachers or identifying groups of teachers who have similar interests and can work collaboratively. As such, the refined method is powerful in that it can provide the structure for a lead teacher to trigger smaller scale inquiries that are focused on broadly the same question and have school-wide or department-wide relevance.

Conclusions

Teacher inquiry offers a powerful, participatory and evidence-based approach to innovation in schools. However, these models presume that teachers are able to operate autonomously. This is not the case in many schools, where teachers' practice is influenced in powerful ways by the context in which they work, and particularly by school management, as demonstrated in the case study presented here.

Studying this case of distributed teacher inquiry enabled us to identify a series of places in which the conventional model failed to support the planning process. To address these shortcomings, we have developed a model designed to support teachers trying to undertake such inquiries while working in teams, or even simply in a coordinated way. In doing so, we have highlighted that teacher inquiry is not simply a matter of evidence or analysis, but is dictated by context, and that this needs to be recognised in the methods and processes we offer to teachers.

Learning analytics may potentially inform teacher inquiry by enhancing teachers' use of data on student learning. However, we need a better understanding of what data to collect and what they

tell us about the learning process. Teachers will require training and support to develop learning designs that increase the availability of data on student learning and to participate in the development of learning analytics tools and adopt them in their practice.

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Appendix

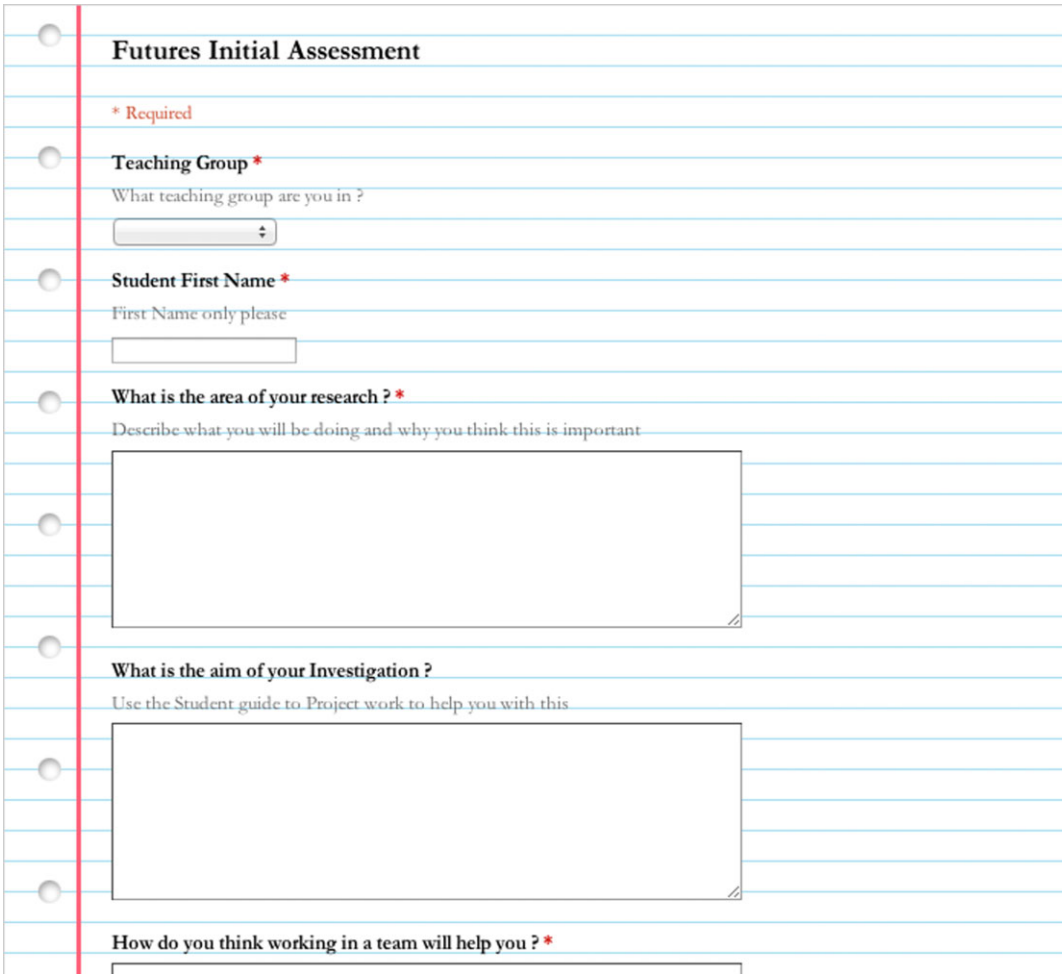
Semi-structured interview questions

1. Status of STEM project and use of Google Forms
   - How has the STEM project been going so far?
   - (If they have participated in previous projects) What are the main changes from the last STEM project?
   - Could you talk me through your activities on the STEM project?
   - Have there been any challenges? Have you overcome them? How?
   - How have students responded to the use of Google Forms?
   - How will you assess the work which the students have done using Google Forms?
   - What do you think of using Google Forms for tracking students' learning?
     - What, if anything, did the Google Forms tell you about the effectiveness of the STEM project?
     - Is there anything about the project process that you want to know more about?
     - How might Google Forms change teaching during the project?
   - How have other teachers responded to the use of Google Forms?
2. Teacher collaboration
   - How often are your meetings on the STEM projects?
   - Could you describe how you normally collaborate with colleagues on projects, such as this? (ask about tools)
   - Has the use of Google Forms assisted this collaboration in any way?
   - What would you say were the key challenges in achieving successful collaboration between teachers? How were these issues overcome?

Survey questions (created by the lead teacher conducting the inquiry)

1. What is your subject specialism?
   Choose: Science, technology, engineering, mathematics, ICT
2. How many project groups did you teach this year?
   Choose: 1, 2, 3, 4, 5, more
3. Did you attend the initial staff meeting?
   Choose: Yes/no
4. Did you find that meeting useful and relevant to you?
   - I was unable to attend that meeting.
   - I found the meeting useful.
   - I did not find the meeting useful.
5. Please comment on your previous response.
   Open question

6. Please comment on the resources made available to you.
   - The information sheets were useful and relevant.
   - The information sheets were fairly useful but I did not use them.
   - There was too much written information.
   - The information sheets were not relevant or useful.
7. The project process
   How would you rate the student experience?
   - The pupils had an enjoyable and useful experience.
   - The project process was good and delivered useful skill development.
   - Students were able to develop some skills and made progress.
   - The skill development process was minimal and needs development.
8. What aspects of the project process do we need to develop?
   Open question
9. Did you enjoy the process and find it challenging and interesting?
   - Excellent
   - Good
   - Generally yes
   - Yes with reservations
   - No
10. Please enlarge on this last response.
    Open question
11. Staff used a blog to communicate progress during the project
    How did this process work for you? Choose the best response for you.
    - Used the blog regularly
    - Used the blog occasionally
    - Read the blog but did not use it
    - Did not used it—ignored it
    - Was not aware of it
12. Formative assessment was tracked using Google tools forms and spreadsheets
    How did you find this process?
    - The spreadsheets were informative, useful and interesting.
    - The spreadsheets were useful but I was unable to use them fully.
    - Students were able to record their views and self-assess but I was unable to use the information fully.
    - I did not use this system as a formative document.
13. Any feedback on this process would be valued. Please comment here.
    Open question



Futures Initial Assessment

* Required

Teaching Group *

What teaching group are you in ?

Student First Name *

First Name only please

What is the area of your research ? *

Describe what you will be doing and why you think this is important

What is the aim of your Investigation ?

Use the Student guide to Project work to help you with this

How do you think working in a team will help you ? *

Figure A1: Google Form for student assessment

Table A1: Analysis: themes resulting from analysis of interviews and email communication

Design of inquiry by the Head of Science (HoS)	Motivation to try new approach
	Criteria for choosing Google Forms
	Expectations on teacher adoption of Google Forms
	Preference for qualitative data
	Desire for constructive feedback from teachers
The role of the HoS and other management in cross-curricular project implementation	Creation of materials to inform teachers about the project implementation
	Mandatory meetings to facilitate teacher collaboration
	Provision of tools to support collaboration
	Informal monitoring of collaboration between teachers (speaking with teachers)
	Formal monitoring of teacher use of Google Forms for student assessment
	Intervention in teachers' practice
Challenges for management implementing cross-curricular project	Communicate project implementation to teachers
	Ensure collaboration between teachers
	Facilitate adoption of new approaches by teachers
Teacher discomfort	Teacher's confidence teaching outside of their specialist subject
	Teacher's difficulty giving up control in *student*-led project
	Teacher's difficulty sharing control when supervising project *collaboratively*
	Teacher's difficulty taking initiative to try Google Forms
Teaching challenges	Student's lack of motivation
	Student's lack of skills
Barriers to teacher collaboration	Teacher time
	Teachers not knowing each other
	Number of student groups teachers are supervising
Use of tools to support collaboration between teachers	Advantage of blog over email and face-to-face meetings for communication
	Advantage of email over blog and face-to-face meetings for communication
	Advantage of face-to-face meetings over blog and email for communication
Use of Google Forms for formative assessment	Google Forms facilitates collaborative supervision of project groups
	Teacher uptake of Google Forms is easy when shown how it works
	Google Forms is easy to use for students
	Students are comfortable feeding back problems through Google Forms
Teacher initiatives	Teacher's adaptation of project materials to own teaching style
	Teacher's ideas for improving project implementation