Participatory Task Science: The reSolve story

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In this paper we introduce the term "task science" to encompass the range of activities involved in designing tasks for school mathematics. We argue that task science is enriched by the participation of teachers, but more particularly that participating in task science is a powerful form of professional learning. We describe the role and design of task science in the reSolve: Maths by Inquiry project, and give examples of how teachers' involvement in each phase of the process was both critical in developing the resources and promoted rich professional learning.

Tasks have long been recognised as central to mathematics teaching (Anthony & Walshaw, 2009; Jones & Pepin, 2016). Just as it is through experiments that students obtain a sense of what it is to do science, it is through tasks that students get their sense of what it is to do mathematics (Henningsen & Stein, 1997). Hence, the tasks in which students engage need to provide opportunities for students to encounter new and challenging ideas, and inquire into and solve meaningful problems.

Well-designed tasks have the potential to fulfil a number of important functions in school mathematics education. These include:

- Shaping students' mathematical understanding (Stein, Grover, & Henningsen, 1996);
- Providing students with opportunities to learn (Goos, 2014);
- Promoting cognitive activation (Russo & Hopkins, 2017);
- Developing students' mathematical reasoning and giving opportunities for students to communicate their reasoning (Choppin, 2011; Choy, 2016);
- Encouraging generalisation (Papadopoulos & Iatridou, 2010);
- Promoting positive dispositions towards mathematics (Attard, 2013);
- Enabling teachers to better understand and act on students' thinking (Didis, Erbas, Cetinkaya, Cakiroglu, & Alacaci, 2016); and
- Prompting students to make inferences and connect ideas (Fielding-Wells, O'Brien, & Makar, 2017)

Using good tasks is therefore critically important if teachers are to help students realise the range of goals for mathematics education described in, for example, the Australian Curriculum: Mathematics (Australian Curriculum Assessment and Reporting Authority, 2018). We suggest that there are two inherent dangers in separating the roles of teaching and task design: the first is that the task designers may lose sight of the perspective of teachers; the second is that teachers may fail to see the intent of the designer. We therefore describe a process in which teachers are involved at all stages of task design and discuss the implications for both task quality and teacher learning.

In the first section we describe the reSolve: Maths by Inquiry project, and particularly the resource development process that we undertook with teachers. We describe this as *task science*

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rather than *task design* in order to emphasise the full range of activities involved in prioritising, conceptualising, selecting, designing, and implementing tasks in the school mathematics classroom. In the second section we focus on the impact that engaging in task science has on the professional learning of teachers. Using data obtained from participant reflections, we describe how the process of engaging in task science impacted on the personal domain, the domain of practice, and the domain of consequence (Clarke and Hollingsworth, 2002). We conclude by suggesting that participatory task science opens up a range of opportunities for improving professional learning at scale and could become a productive field of research in its own right.

Task science in the reSolve: Maths by Inquiry project

The reSolve: Maths by Inquiry project.

reSolve: Maths by Inquiry is an Australian Government funded project designed to promote a spirit of inquiry in students from Foundation to Year 10. The project is managed by the Australian Academy of Science in collaboration with the Australian Association of Mathematics Teachers. It has two specific but overlapping aims: the first is the development of a coherent suite of resources promoting mathematical inquiry; the second is the engagement of the profession. The suite of resources includes professional learning resources focused on important elements of inquiry, highlighted by exemplary classroom resources addressing key components of the Australian Curriculum: Mathematics (ACARA, 2018). Engagement of the profession occurs through a cadre of almost 300 Champions across all states and territories of Australia, each of whom undertakes a 12-month professional learning and networking program.

The project's philosophy is built around what we term the reSolve: Maths by Inquiry Protocol (Thornton, 2017). The Protocol articulates those elements of the mathematics, tasks and learning environment that we believe will promote a spirit of inquiry. The three key elements in the Protocol are:

- reSolve mathematics is purposeful
- reSolve tasks are challenging yet accessible
- reSolve classrooms promote a knowledge-building culture

By *mathematics that is purposeful* we wish to challenge perceptions that mathematics is merely a body of disconnected facts or procedures described in a curriculum document. We highlight connections between mathematical ideas and between mathematics and the real world by focusing on important mathematical ideas that give students power in their lives. We seek to acknowledge mathematics as a creative and imaginative endeavour, continually changing and developing in a technological society.

By *tasks that are challenging yet accessible* we wish to challenge perceptions that mathematics is for the few, and assert that it ought to be both challenging and accessible for all. reSolve tasks seek to activate existing knowledge and to develop new knowledge through the exploration of relationships between key ideas. The tasks are designed to engage students in sustained inquiry, problem solving, decision making and communication with the goal of optimising their mathematical development. They use evidence of students' progress to inform feedback and subsequent teaching action, and provide prompts and activities that meet a range of student capabilities.

By *knowledge-building culture* we wish to challenge a view that mathematics is best learnt through demonstration, reproduction and repetition. We seek to promote environments that sustain higher order thinking through the active role of both teachers and students and that build success through collaborative inquiry, action and reflection. We seek to challenge existing student ideas or misconceptions and use mistakes as opportunities for learning. We seek to build positive dispositions such as productive struggle and the confidence to take risks.

The reSolve resource development process.

The resource development process employed in the reSolve project follows a five-stage design thinking process (Figure 1), which we refer to as *task science*. The process of task science is actualised on two levels. The first is the level of the reSolve Design Team (RDT) comprising writers employed to oversee the process and to prepare resources to publication standard. The second level is the Collaborative Design Team (CDT), which includes up to 15 invited teachers and one or two invited academics. At least one CDT has been established in each Australian state and territory.

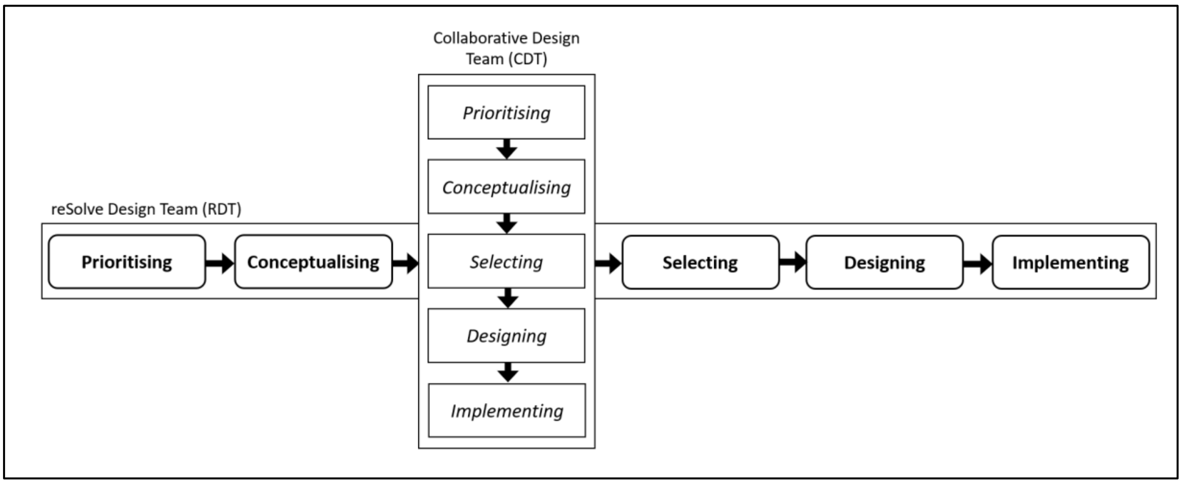

Figure 1. The reSolve: Maths by Inquiry task science process.

The first stage of the process, which occurs at the design level, is *prioritising* a particular mathematical focus for the tasks. The RDT identifies areas of the Australian Curriculum: Mathematics that may be underserved in currently available resources or for which we see a strong need for elaboration. For example, we identified multiplicative thinking as a topic that was well researched (e.g. Siemon, Breed, Dole, Izard, & Virgona, 2006), but for which good resources were not widely available. From here, we *conceptualise* a learning progression for the topic which aligns with the curriculum and draws from relevant research. The learning progression attempts to articulate the key developmental growth points for students, which then provides a focus for the collaborative design process to follow.

Each member of the CDT is then sent a paper outlining the thinking of the RDT, along with the proposed learning progression and accompanying research articles. The RDT, teachers and invited academics then meet for a two-day workshop where the process of design commences on the second level with the CDT.

On the first day, the teachers use the learning progressions to *prioritise* a focus for resources for the given topic. They are specifically asked to consider three questions:

- What do students experience in this topic?
- What is missing?
- What is there too much of?

For multiplicative thinking, the CDT felt that there was a large selection of resources developing the idea of the array, but that the idea of *for each* (Cartesian product) was not well resourced. The CDT is then asked to *conceptualise* by brainstorming ideas that might bring these priorities into sharp focus. The group then *selects* a number of these that show particular promise in terms of their capacity to address the needs identified in the prioritisation exercise.

The second day is focused on the process of developing ideas and *designing* tasks that build on these ideas. Prototype tasks are developed that attempt to capture the reSolve spirit of inquiry and that enact the three central elements of the Protocol. Teachers then take these tasks back to their own classrooms to *implement* them as a proof of concept. For multiplicative thinking, a sequence of resources developing the 'for each' idea was conceptualised for Year 2 and then Year 4. In year 2 students play a version of "Go fish" in which they find robots that have unique combinations of heads, bodies and legs, leading to an investigation of how many are possible. In year 4 the ideas are extended to a more formalised notion of Cartesian product in which students are challenged to design their own avatar and represent Cartesian product as a tree diagram.

At this stage the tasks are then passed back to the RDT who make decisions on which of the prototype resources should be selected for further development and refinement. They are then carefully documented and designed, paying particular attention to the choice of contexts, choice of examples, and optimal sequencing to best enact the student learning progression. They are also put into a form that is consistent with other reSolve resources, and made available for implementation through widespread trialling and focused feedback designed to capture teachers' views on how the resources enhance students' engagement and understanding. The design and implementation are repeated as often as necessary to take account of feedback from the field.

While the primary goal of the process described above is to enhance the quality of resources, informal comments from participating teachers highlighted the value of the process in their own professional learning. Accordingly, we designed a small-scale qualitative study to examine the impact of the process on teacher learning.

The impact on teacher learning

Theoretical background

We used the Clarke-Hollingsworth interconnected model of professional growth (Clarke & Hollingsworth, 2002) as a framework for structuring our thinking and methodology. The model identifies four domains that encompass the professional world of teachers: the personal domain (teacher knowledge, beliefs and attitudes), the domain of practice (professional experimentation), the domain of consequence (salient outcomes) and the external domain (sources of information, stimulus or support) (see Figure 2). These four domains of the model are *change* domains, that is, any professional change observed can be located within one or more of these domains. For example, a teacher who tries a new pedagogical strategy is engaging in a form of professional experimentation and so this change is located within the domain of practice. Changed expectations of students is a change in beliefs and attitudes and will therefore be situated in the personal domain.

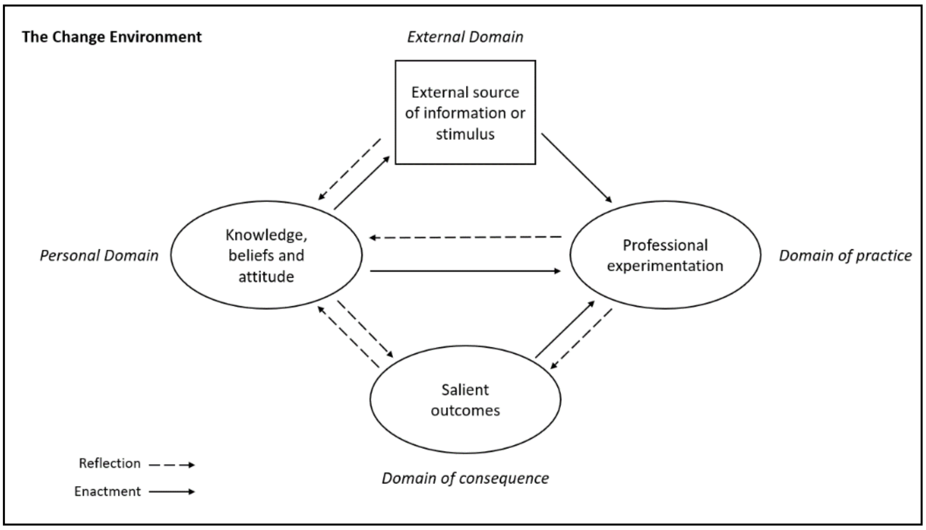

Figure 2. The Clarke-Hollingsworth interconnected model of professional growth

For the purposes of this study we interpreted these change domains as:

External Domain: The reSolve Protocol, and teachers' collaboration with other members of the CDT, (Wilkie & Clarke, 2015) informed by the documentation prepared by the reSolve team and invited academics.

Personal Domain: The reported impact on teachers' knowledge, attitudes and understanding towards inquiry.

Domain of Practice: Teachers' reporting of their experimenting with ideas and developing tasks in collaboration with others in the workshop; their feedback on how they modified tasks based on trialling in classrooms.

Domain of Consequence: The value of the process in developing reSolve resources; the impact of the process on teachers' self-efficacy and observations of students' engagement and understanding.

Methodology

We designed a survey around the change domains identified above. Teachers were asked to comment on how they were professionally challenged and affirmed within each domain, and were then asked whether they had noted changes in the domains or if they anticipated future changes to surface. Teachers were also asked to comment on the value of their participation in the workshop as professional learning and if they would look for further opportunities to participate in similar experiences in the future. The survey was sent to 84 teachers and 29 responses were received. These responses were collated and summaries were sent to the original 84 teachers for confirmation. The teachers were asked to add further comments if they believed the summaries missed information that they believed to be important.

Results

Each of the three authors independently read the teachers' responses and suggested how they might be categorised. Further discussion led to the development of five locations in which changes might be observed: personal, teaching, students, community and resources. These were combined with the domains identified by Clarke and Hollingsworth to construct a two-dimensional model through which we summarised the key observations from the teachers' responses to the survey. The model is shown in Table 1, along with indicative quotes to illustrate the changes in the domains.

Table 1
Categorisation of Teacher Responses with Indicative Quotes

	Personal Domain	**Domain of Practice**	**Domain of Consequence**
Personal	"I though maths was black and white as there was one answer for each question. It opened my mind to open-ended questions and the endless amount of thinking a question can generate."	"…successful mathematics learning requires a pedagogical shift from transmissive to challenging teaching where students are active (not passive) in their learning."	"It made me think deeply about the different aspects of teaching multiplications and ways to develop rich tasks."
Teaching	"It encouraged me to deepen my content-knowledge and pedagogical content knowledge in early years foundational maths skills."	"The importance of developing a culture of learning where ideas are challenged (not people)."	"…inspired! The ideas shared at the workshop were so great and creative and fun. That's what I want to see for my students."
Students	"The expectation of the students and how I have to challenge the more capable ones."	"Constantly pushing students outside of their comfort zones in mathematics."	"The students engage in mathematics to a greater extent. They are confident to take risks and enjoy the activities."
Community	"Continuing to hold myself and colleagues to a high standard."	"I have created a sequence of lessons myself for my teaching and colleagues."	"We changed the way we planned and taught maths in Prep."
Resources	"Quality maths lessons/investigations take a while to develop."	"I now will incorporate all the reSolve resources for my students and I will share them with colleagues."	"We have continued our work of designing rich mathematical tasks for students ensuring they have opportunity to explore, engage and experiment with mathematical concepts."

Discussion

Table 1 shows that teachers' involvement in the process of task science did not just achieve one goal, but many. In the personal domain, it impacted on: their sense of efficacy as a teacher; their mathematical and pedagogical content knowledge; the expectations they had of their students and colleagues, and; their understanding of the complexity of task science. In the domain of practice, it impacted on: their approach to teaching; the culture of the classroom, including challenging students to take risks, and; their commitment to work with colleagues to design tasks and to select and use rich tasks in their own teaching. Finally, in the domain of consequence, it: provoked deep thinking about mathematics and teaching; inspired creativity; engaged students cognitively and affectively; challenged teachers in their school context, and; stimulated ongoing task design among colleagues.

Three things stood out in the intensity and frequency of the teachers' responses.

1. The power of the external domain

While the value of high quality professional learning opportunities, often conducted by externally sourced experts, is well documented in the literature, the importance of professional collaboration and collegiality in the external domain (Wilkie & Clarke, 2015) is less frequently described. Almost every participant in this study commented on the value of this collegiality, and described how the process of participatory task science positioned them as designers and developers of tasks, rather than as merely consumers and implementers.

2. The extent to which participatory task science affirmed and challenged already expert teachers

Although the teachers invited to participate in the workshops were already highly regarded and knowledgeable, many commented quite animatedly about the extent to which they were affirmed in their existing practice. Their self-efficacy was enhanced as they saw their ideas valued and shared in a national project. They expressed a deep commitment and desire to be involved in professional learning and to share the experience with their colleagues.

3. Participants' knowledge of the big picture

Participants frequently referred to their increased knowledge of how students develop understanding of particular aspects of mathematics. They commented that they saw more clearly how mathematical ideas were connected across grade levels as well as across content strands. The process of prioritising and conceptualising drew into sharp focus the stages of the learning progression, highlighting the gaps and excesses in existing resources.

Conclusions

We have described the process of participatory task science as enacted in the reSolve: Maths by Inquiry project. We suggest that the active involvement of teachers at all stages of task design is essential if we are to realise the full range of potential outcomes of well-designed tasks. This helps avoid the parallel dangers that task designers may lose sight of the perspective of teachers, and that teachers may fail to see the intent of the designer.

Equally significantly the act of participating in the workshops had a profound impact on participants' knowledge, practice and self-efficacy. Participants' reflections on their involvement in the process highlighted their enhanced sense of worth as a teacher, their increased knowledge of student learning progressions and their increased commitment to work with colleagues in a similar process. Indeed, a common response at the end of each two-day workshop was that this was the best professional learning they had ever done.

We have termed the process described in the paper *task science*. By using this term, we have tried to capture both the rigour and richness of the process. We suggest that this is much more than task design, a term which fails to capture the subtleties arising when tasks are enacted by expert teachers in the classroom. We suggest that this conception of participatory task science opens up a range of possibilities for further research into its impact on teacher learning, particularly into how it might be implemented at scale for sustained improvements in mathematics education.

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