Interdisciplinary Modelling in the Primary Mathematics Curriculum

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This paper examines one approach to promoting creative and flexible use of mathematical ideas within an interdisciplinary context in the primary curriculum, namely, through modelling. Three classes of fifth-grade children worked on a modelling problem (Australia's settlement) situated within the curriculum domains of science and studies of society and environment. Reported here are the cycles of development displayed by one group of children as they worked the problem, together with the range of models created across the classes. Children developed mathematisation processes that extended beyond their regular curriculum, including identifying and prioritising key problem elements, exploring relationships among elements, quantifying qualitative data, ranking and aggregating data, and creating and working with weighted scores.

Numerous researchers and employer groups have expressed concerns that schools are not giving adequate attention to the understandings and abilities that are needed for success beyond school. Research suggests that although professionals in mathematics-related fields draw upon their school learning, they do so in a flexible and creative manner, unlike the way in which they experienced mathematics in their school days (Gainsburg, 2006; Hall, 1999; Hamilton, in press; Noss, Hoyles, & Pozzi, 2002; Zawojewski & McCarthy, 2007). Furthermore, this research has indicated that such professionals draw upon interdisciplinary knowledge in solving problems and communicating their findings.

The challenge then is how to promote creative and flexible use of mathematical ideas within an interdisciplinary context where students solve substantive, authentic problems that address multiple core learnings. One approach is through mathematical modelling involving cycles of model construction, evaluation, and revision, which is fundamental to mathematical and scientific understanding and to the professional practice of mathematicians and scientists (Lesh & Zawojewski, 2007; Romberg, Carpenter, & Kwako, 2005). Modelling is not just confined to mathematics and science, however. Other disciplines including economics, information systems, social and environmental science, and the arts have also contributed in large part to the powerful mathematical models we have in place for dealing with a range of complex problems (Lesh & Sriraman, 2005; Sriraman & Dahl, in press). Unfortunately, our mathematics curricula do not capitalize on the contributions of other disciplines. A more interdisciplinary and unifying model-based approach to students' mathematics learning could go some way towards alleviating the well-known "one inch deep and one mile wide" problem in many of our curricula (Sabelli, 2006, p. 7; Sriraman & Dahl, in press; Sriraman & Steinthorsdottir, in press). There is limited research, however, on ways in which we might incorporate other disciplines within the mathematics curriculum.

The study reported here represents one attempt to link children's mathematical learning with their learning in other curriculum areas; in the present instance, the focus is on fifth-grade children's developments in solving a modelling problem situated within the curriculum domains of science and studies of society and environment (SOSE). The problem was created in collaboration with the classroom teachers to tie in with the

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children's learning of Australia's settlement. The problem differed from the children's modelling experiences in the previous year of the study in that it comprised mostly qualitative, rather than quantitative, data (see Appendix). Hence one of the research goals was to explore how the children dealt with data of this nature, for example, whether they quantified and/or transformed the data in some way to solve the problem. Another goal was to document the developments in the children's mathematical thinking and learning as they interacted with the problem and with each other in small-group situations. Given that previous research has highlighted the multiple cycles of interpretation that children display in solving such problems (Doerr & English, 2003; English, 2006), it was anticipated that the children would display a diversity of approaches in solving the problem. Finally of interest, were variations in the models the children created with respect to the mathematical ideas constructed and the mathematisation processes applied.

Mathematical Modelling for the Primary School

Modelling is increasingly recognized as a powerful vehicle not only for promoting students' understanding of a wide range of key mathematical and scientific concepts, but also for helping them appreciate the potential of mathematics as a critical tool for analyzing important issues in their lives, communities, and society in general (Greer, Verschaffel, & Mukhopadhyay, in press; Romberg et al., 2005). Students' development of powerful models should be regarded as among the most significant goals of mathematics education (Lesh & Sriraman, 2005). Importantly, modelling needs to be integrated within the primary school curriculum and not reserved for the secondary school years and beyond as it has been traditionally. Recent research has shown that primary school children are indeed capable of developing their own models and sense-making systems for dealing with complex problem situations (e.g., English, 2006; English & Watters, 2005).

The terms, models and modelling, have been used variously in the literature, including in reference to solving word problems, conducting mathematical simulations, creating representations of problem situations (including constructing explanations of natural phenomena), and creating internal, psychological representations while solving a particular problem (e.g., Doerr & Tripp, 1999; English & Halford, 1995; Gravemeijer, 1999; Greer, 1997; Lesh & Doerr, 2003; Romberg et al., 2005). As used in the present study, models are "systems of elements, operations, relationships, and rules that can be used to describe, explain, or predict the behavior of some other familiar system" (Doerr & English, 2003, p. 112). From this perspective, modelling problems are realistically complex situations where the problem solver engages in mathematical thinking beyond the usual school experience and where the products to be generated often include complex artifacts or conceptual tools that are needed for some purpose, or to accomplish some goal (Lesh & Zawojewski, 2007).

Mathematical modelling in the primary school presents children with a future-oriented approach to learning. The mathematics they experience differs from what is taught traditionally in the curriculum for their grade level, because different types of quantities and operations are needed to mathematise realistic situations. The types of quantities needed in these situations include accumulations, probabilities, frequencies, ranks, and vectors, whereas the operations needed include sorting, organizing, selecting, quantifying, weighting, and transforming large data sets (Doerr & English, 2003; English, 2006; Lesh, Zawojewski, & Carmona, 2003). Modelling problems thus offer richer learning experiences than the standard classroom word problems ("concept-then-word problem", Hamilton, in press). In solving such word problems, children generally engage in a one- or two-step process of mapping problem information onto arithmetic quantities and operations. In most cases, the problem information has already been carefully mathematised for the children. Their goal is to unmask the mathematics by mapping the problem information in such a way as to produce an answer using familiar quantities and basic operations. These traditional word problems restrict problem-solving contexts to those that often artificially house and highlight the relevant concept (Hamilton, in press). They thus preclude children from creating their own mathematical constructs.

In contrast, modelling provides opportunities for children to elicit their own mathematics as they work the problem. That is, the problems require children to make sense of the situation so that they can mathematize it themselves in ways that are meaningful to them. This involves a cyclic process of interpreting the problem information, selecting relevant quantities, identifying operations that may lead to new quantities, and creating meaningful representations (Lesh & Doerr, 2003). Because children's final products embody the factors, relationships, and operations that they considered important in creating their model, powerful insights can be gained into the growth of their mathematical thinking.

As previously noted, mathematical modelling provides an ideal vehicle for interdisciplinary learning as the problems draw on contexts and data from other domains (English, in press). The problem addressed in this paper, *The First Fleet*, complemented the children's study of Australia's settlement and incorporated ideas from science and the SOSE curriculum. Dealing with "experientially real" contexts such as the nature of community living, the ecology of the local creek, and the selection of national swimming teams provides a platform for the growth of children's mathematisation skills, thus enabling them to use mathematics as a "generative resource" in life beyond the classroom (Freudenthal, 1973).

Finally, modelling problems support recent studies of peer-directed group work (e.g., Web, Nemer, & Ing, 2006), which have demonstrated the importance of implementing activities that inherently develop students' discourse in cooperative groups. The problems are designed for small-group collaborative work where children are motivated to challenge one another's thinking, and to explain and justify their ideas and actions.

Design and Methodology

This study adopted a multilevel collaborative design (English, 2003), which employs the structure of the multitiered teaching experiments of Lesh and Kelly (2000). Such a design focuses on the developing knowledge of participants at different levels of learning, including the classroom teachers whose participation is an essential factor. At the first level of collaboration (the focus of this paper), children work in small groups to solve the modelling problems. At the second level, their teachers work collaboratively with the researchers in preparing and implementing the activities. At the third level, the researchers observe, interpret, and document the growth of all participants.

Participants and Procedures

Three classes of fourth-grade children (8-9 years) and their teachers took part in the first year of this 3-year study; the children participated again in the second year, along with their new classroom teachers. The classes represented the entire cohorts of fourth and fifth graders from a private K-12 college situated in a regional Queensland suburb.

At the beginning of each year, the teachers participated in half-day workshops on mathematical modelling and its implementation in the classroom. Meetings during the first term of each year were held to plan the three modelling problems to be implemented in the year, and, in the case of the first year of the study, some preliminary modelling activities (e.g., interpreting and using visual representations; conventionalising representations; explaining and justifying mathematical ideas). Each modelling problem was implemented in four 50-minute sessions per remaining term. Where possible, the four sessions were conducted in the same week so that the children did not lose track of their ideas. Planning and debriefing meetings were held with the teachers prior to and following the implementation of each problem.

The present modelling problem, the First Fleet, was implemented at the beginning of the second year of the study and comprised several components. First, the children were presented with background information on the problem context, namely, the British government's commissioning of 11 ships in May, 1787 to sail to "the land beyond the seas". The children answered a number of "readiness questions" to ensure they had understood this background information. After responding to these questions, the children were presented with the problem itself, together with a table of data listing 13 key environmental elements to be considered in determining the suitability of each of five given sites (see Appendix). The children were also provided with a comprehensive list of the tools and equipment, plants and seeds, and livestock that were on board the First Fleet. The problem text explained that, on his return from Australia to the United Kingdom in 1770, Captain James Cook reported that Botany Bay had lush pastures and well watered and fertile ground suitable for crops and for the grazing of cattle. But when Captain Phillip arrived in Botany Bay in January 1788 he thought it was unsuitable for the new settlement. Captain Phillip headed north in search of a better place for settlement. The children's task was as follows.

> Where to locate the first settlement was a difficult decision to make for Captain Phillip as there were so many factors to consider. If you could turn a time machine back to 1788, how would you advise Captain Phillip? Was Botany Bay a poor choice or not? Early settlements occurred in Sydney Cove Port Jackson, at Rose Hill along the Parramatta River, on Norfolk Island, Port Hacking, and in Botany Bay. Which of these five sites would have been Captain Phillip's best choice? Your job is to create a system or model that could be used to help decide where it was best to anchor their boats and settle. Use the data given in the table and the list of provisions on board to determine which location was best for settlement. Whilst Captain Phillip was the first commander to settle in Australia many more ships were planning to make the journey and settle on the shores of Australia. Your system or model should be able to assist future settlers make informed decisions about where to locate their townships.

The children worked the problem in groups of three to four with no direct teaching from the teachers or researchers. In the final session, the children presented group reports on their models to their peers, who, in turn, asked questions about the models and gave constructive feedback.

Data Collection and Analysis

In each classroom, one group of children was video-taped and audio-taped and another group was audio-taped in each session, with all data subsequently transcribed. All of the children's group reports to the class and their responses to their peers' comments were also video-taped and transcribed. Other data sources included classroom field notes and all of the children's artefacts. All of the data were reviewed several times for evidence of: (a) children's initial interpretation and re-interpretations of the problem components; (b) cycles of mathematical development as the children created their models, including how the children operationalised the given data and ways in which they documented their actions; and (c) diversity in their approaches and model creation. This paper addresses the cycles of mathematical development displayed by one group of children (Mac's group) in working the problem and then summarises the range of models developed across the three classes.

Results

Cycles of Development Displayed by one Group of Children

Cycle 1: Prioritising and assessing elements. Mac's group commenced the problem with Mac stating, "So, to find out, OK, if we're going to find the best place I think the most important thing would be that people need to stay alive." The group then proceeded to make a prioritised list of the elements that would be most needed. There was substantial debate over which elements to select, with fresh water, food (fishing and animals), protective bays, and soil and land being chosen. However, the group did not remain with this selection and switched to a focus on all 13 elements listed in the table of data.

The children began to assess the elements for the first couple of sites by placing a tick if they considered a site featured the element adequately and a cross otherwise. The group then began to aggregrate the number of ticks for each site but subsequently reverted to their initial decision to focus just on the most essential elements ("the best living conditions to keep the people alive"). Still unable to reach a consensus on this issue, the group continued to consider all of the elements for the remaining sites and rated them as "good" and "not so good". The children explained that they were looking for the site that had "the most good things and the least bad things".

Cycle 2: Ranking elements across sites. Next, the group attempted a new method: they switched to ranking each element, from 1 ("best") to 5, across the five sites, questioning the meaning of some of the terminology in doing so. The children also questioned the number of floods listed for each site, querying whether it represented the number of floods per year or over several years. As the children were ranking the first few elements, they examined the additional sheet of equipment etc. on board the First Fleet to determine if a given site could accommodate all of the provisions and whether anything else would be needed for the settlement. The group did not proceed with this particular ranking system, however, beyond the first few elements.

Cycle 3: Proposing conditions for settlement and attempting to operationalise data. The children next turned to making some tentative recommendations for the best sites, with Mac suggesting they create conditions for settlement.

> …like if you had not much food and not as many people you should go to Norfolk Island; if you had a lot of people and a lot of food you should go to Sydney Cove or um Rosehill, Parramatta.

The group then reverted to their initial assessment of the elements for each site, totalling the number of ticks ("good") and crosses ("bad") for each site. In doing so, the children again proposed suggested conditions for settlement.

> And this one with the zero floods (Norfolk Island), if you don't have many people that's a good one cause that's small but because there's no floods it's also a very protected area. Obviously, so maybe you should just make it (Norfolk Island) the best area.

The group devoted considerable time to debating conditions for settlement and then made tentative suggestions as to how to operationalise the "good" and the "bad". One child suggested finding an average of "good" and "bad" for each site but his thinking here was not entirely clear and the group did not take up his suggestion.

> We could find the average, I mean as in like, combine what's bad, we add them together; we can combine how good we think it might be out of 10. Then we um, could divide it by how many good things there is [sic] and we could divide it by how many bad things there is [sic].

Finding themselves bogged down here, the group turned to a new approach.

Cycle 4: Weighting elements and aggregating scores. This new cycle saw the introduction of a weighting system, with the children assigning 2 points to those elements they considered important and 1 point to those elements of lesser importance ("We've valued them into points of 1 and 2 depending on how important they are"). Each site was then awarded the relevant points for each element if the group considered the site displayed the element; if the site did not display the element, the relevant number of points was subtracted. As the group explained,

> The ones (elements) that are more important are worth 2 points and the ones that aren't are 1. So if they (a given site) have it you add 2 or 1, depending on how important it is, or you subtract 2 or 1, if they don't have it.

The children totalled the scores mentally and documented their results as follows (1 refers to Botany Bay, 2 to Port Jackson, and so on):

1 -12 + 10 = -2
2 - 9 + 13 = 4
3 - 5 + 17 = 12
4 - 7 + 15 = 8
5 - 9 + 13 = 4

Cycle 5: Reviewing methods and finalising site selection. The group commenced the third session the next morning by reflecting on the two main methods they had employed to determine the best site, namely, the use of ticks ("good") and crosses ("bad") in assessing elements for each site and trying to operationalise these data, and the weighting of elements and aggregating of scores. Mac commenced by reminding his group of what they had found to date.

> Yesterday we, um, OK, the first thing we did yesterday showed us that the fifth one (Norfolk Island) was the best place, second one (weighting of elements) we did told us … showed us that number three (Rosehill, Parramatta) was the best. So it's a tie between number three and number five. So it's limited down to them, work it out. Hey guys, are you even listening?

After bringing the group back on task, Mac stated, "OK, we're doing a tie-breaker for number three and number five." The group proceeded to revisit their first method, assigning each tick one point and ignoring the crosses. However, on totalling the points, Mac claimed that Rosehill, Parramatta, was the winning site. Bill expressed concern over the site's record of 40 floods and this resulted in subsequent discussion as to whether

Parramatta should be the favoured site. The children finally decided on Norfolk Island because it was flood-free and because it was their choice using their first main method.

Diversity of Models Created Across all Groups

The children's models varied in mathematical sophistication, from limited use of mathematisation processes through to various scoring and ranking systems that included the use of weighted scores as above. Other models across the classes included the following.

Model 1. This was the most common model that was generated across the classes. It entailed taking each site in turn and assessing whether it adequately displayed all or a selection of the elements. Children used ticks, crosses, and highlighting on the given table of data and took a subsequent tally of each site. The site with the highest tally was selected as the place for settlement. As one group explained, “We’re just highlighting the best and then we’re going to see how many highlighted ones there are (for each site).” Another group explained, “The least bad and the highest good is the best.”

Model 2. Here, children selected and prioritized elements to consider for each site (“We chose six things that we thought were important and made a graph”). The children in one group ranked “accessible by sea” as no. 1, “fresh water” as no. 2, “soil quality” as no. 3, “bush tucker” as no. 4, “land available” as no. 5, and “land suitable for livestock” as no. 6. Each site was then assessed in terms of these elements. The site that displayed the most favoured of these elements was chosen (the site that had the “best out of these categories”).

Model 3. The third model was an advance on the previous models. Children rated selected elements (accessible by sea, fresh water, soil quality, trees and plants, and local bush tucker) for each site as “very good”, “good”, “OK”, and “bad”. The number of times each category appeared for each site was tallied and the site that had the highest tally for the “very good” category was chosen.

Model 4. This model extended model 3. Each of the 13 elements was ranked in turn from 1 to 5 across the five sites (1 = best). The site with the highest number of ranks of one was chosen as the most suitable site.

Model 5. The fifth model extended the previous two models by awarding 3 ticks for “very good”, 2 ticks for “good”, 1 tick for “average”, and a cross for “bad”. The site with the highest number of ticks was the chosen site. On totalling the number of ticks, one group claimed the score was “out of 13”.

Model 6. This model incorporated a scoring system where each element for each site was assessed and given a score out of 10 or out of 13. The group that used the 10-point system reported to the class as follows.

> Our strategy was using a point score. We did a rating out of 10 for the data headlines, in the importance of, like 10 out of 10. And down the scale we went. We then rated the answers, like accessible by sea, we rated like, accessible by sea, we rated 9 out of 10 for importance. The answer going down the column would only go up to the highest of 9, because it was 9 out of 10. We did this for the whole graph (table), then for the 5 places here we added up the total scores. We ended up with 39 for Botany Bay, 62 for Sydney Cove, Port Jackson, 77 for Rosehill, Parramatta, 66 for Port Hacking and 70 for Norfolk Island. We chose the highest rating; it was Rosehill.

Discussion and Concluding Points

This study represents one approach to introducing interdisciplinary modelling problems into the primary mathematics curriculum. Mathematical modelling has traditionally been confined to the secondary school and beyond, yet this study and other research have shown that such problems contribute effectively to primary school children's learning in several domains. Such problems allow for a diversity of solution approaches and enable children of all achievement levels to participate in, and benefit from, these experiences. In contrast to traditional classroom problem solving, these modelling problems facilitate different trajectories of learning, with children's mathematical understandings developing along multiple pathways. Importantly, children direct their own mathematical learning. That is, they elicit key ideas and processes from the problem as they work towards model construction. In the present case, the children identified and prioritized key problem elements, explored relationships between elements, quantified qualitative data, ranked and aggregated data, and created and worked with weighted scores—before being formally introduced to mathematisation processes of this nature.

Modelling problems engage children in multiple cycles of interpretations and approaches, suggesting that real-world, complex problem solving goes beyond a single mapping from givens to goals. Rather, such problem solving involves multiple cycles of interpretation and re-interpretation where conceptual tools evolve to become increasingly powerful in describing, explaining, and making decisions about the phenomena in question (Doerr & English, 2003). Furthermore, these phenomena can be drawn from a wide range of disciplines.

The interdisciplinary nature of mathematical modelling means that we can create problems that can help unify some of the myriad core ideas within the primary curriculum. For example, problems that incorporate key concepts from science (English, in press) and SOSE can help children appreciate the dynamic nature of environments and how living and non-living components interact, the ways in which living organisms depend on others and the environment for survival, and how the activities of people can change the balance of nature. The First Fleet problem can also lead nicely into a more in-depth study of the interrelationship between ecological systems and economies, and a consideration of ways to promote and attain ecologically sustainable development.

Finally, the inherent requirement that children communicate and share their mathematical ideas and understandings, both within a small-group setting and in a whole-class context, further promotes the development of interdisciplinary learning. The problems engage children in describing, explaining, debating, justifying, predicting, listening critically, and questioning constructively—which are essential to all discipline areas.

References

Doerr, H. M., & English, L. D. (2003). A modeling perspective on students' mathematical reasoning about data. *Journal for Research in Mathematics Education, 34*(2), 110-137.

Doerr, H. M., & Tripp, J. S. (1999). Understanding how students develop mathematical models. *Mathematical Thinking and Learning, 1*(3), 231-254.

English, L. D. (in press). Mathematical modelling: Linking Mathematics, Science, and the Arts in the Elementary Curriculum. In A. Beckmann, C. Michelsen, & B. Sriraman (Eds.), *Proceedings of The Second International Symposium of Mathematics and its Connections to the Arts and Sciences*. University of Southern Denmark.

English, L. D. (2003). Reconciling theory, research, and practice: A models and modeling perspective. *Educational Studies in Mathematics, 54(*2 & 3), 225-248.

English, L. D. (2006). Mathematical modeling in the primary school: Children's construction of a consumer guide. *Educational Studies in Mathematics, 62*(3), 303-323.

English, L. D., & Halford, G. S. (1995). *Mathematics education: Models and processes*. Mahwah, NJ: Lawrence Erlbaum Associates.

English, L. D., & Watters, J. J. (2005). Mathematical modeling in the early school years. *Mathematics Education Research Journal*, 16(3), 58-79.

Freudenthal, H. (1973). *Didactical phenomenology of mathematical structures*, Boston: Kluwer.

Gainsburg, J. (2006). The mathematical modeling of structural engineers. *Mathematical Thinking and Learning, 8*(1), 3-36.

Gravemeijer, K. (1999). How emergent models may foster the construction of formal mathematics. *Mathematical Thinking and Learning, 1*, 155-177.

Greer, B. (1997.) Modeling reality in mathematics classroom: The case of word problems. *Learning and Instruction 7*, 293-307.

Greer, B., Verschaffel, L., & Mukhopadhyay, S. (in press). Modelling for life: Mathematics and children's experience. In W. Blum, W. Henne, & M. Niss (Eds.), *Applications and modelling in mathematics education* (*ICMI Study 14*). Dordrecht: Kluwer.

Hall, R. (1999). *Case studies of math at work: Exploring design-oriented mathematical practices in school and work settings* (NSF Rep. No. RED-9553648), Arlington, VA: National Science Foundation.

Hamilton, E. (in press). What changes are needed in the kind of problem solving situations where mathematical thinking is needed beyond school? In R. Lesh, E. Hamilton, & J. Kaput (Eds.), *Modeling as foundations for the future in mathematics education*. Mahwah, NJ: Lawrence Erlbaum.

Lesh, R., & Doerr, H. M. (Eds.). (2003). *Beyond constructivism: Models and modeling perspectives on mathematic problem solving, learning and teaching*. Mahwah, NJ: Lawrence Erlbaum.

Lesh, R. A., & Kelly, A. E. (2000). Multi-tiered teaching experiments. In R. A. Lesh & A. Kelly (Eds.), Handbook of research design in mathematics and science education (pp. 197-230). Mahwah, NJ: Lawrence Erlbaum.

Lesh, R. A., & Sriraman, B. (2005). John Dewey revisited—pragmatisim and the models-modeling perspective on mathematical learning. In A. Beckmann, C. Michelsen, & B. Sriraman (Eds.). *Proceedings of the 1st international symposium of mathematics and its connections to the arts and sciences* (pp. 7-31). Schwöbisch Gmund, Germany: The University of Education.

Lesh, R., & Zawojewski, J. S. (2007). Problem solving and modeling. In F. Lester (Ed.), *Second handbook of research on mathematics teaching and learning*. Greenwich, CT: Information Age Publishing.

Lesh, R., Zawojewski, J. S., & Carmona, G. (2003). What mathematical abilities are needed for success beyond school in a technology-based age of information? In R. Lesh & H. Doerr (Eds.)., *Beyond constructivism: Models and modeling perspectives on mathematic problem solving, learning and teaching* (pp. 205-222). Mahwah, NJ: Lawrence Erlbaum.

Noss, R., Hoyles, C., & Pozzi, S. (2002). Abstraction in expertise: A study of nurses' conceptions of concentration. *Journal for Research in Mathematics Education, 33*(3), 204-229.

Romberg, T. A., Carpenter, T. P., & Kwako, J. (2005). Standards-based reform and teaching for understanding. In T. A. Romberg, T. P. Carpenter, & F. Dremock (Eds.), *Understanding mathematics and science matters* (pp. 3-28). Mahwah, NJ: Lawrence Erlbaum.

Sabelli, N. H. (2006). Complexity, technology, science, and education. *The Journal of the Learning Sciences, 15*(1), 5-9.

Sriraman, B., & Dhal, B. (in press). On bringing interdisciplinary ideas to gifted education. In L.V. Shavinina (Ed), *The International Handbook of Giftedness*. Springer Science.

Sriraman, B., & Steinthorsdottir (2007, in press). Implications of research on mathematics gifted education for the secondary curriculum. In C. Callahan & J. Plucker (Eds.), *What research says: Encyclopedia on research in gifted education.* Austin, TX: Prufrock Press.

Web, N. M., Nemer, K. M., & Ing, M. (2006). Small-group reflections: Parallels between teacher discourse and student behaviour in peer-directed groups. *The Journal of the Learning Sciences, 15*(1), 63-120.

Zawojewski, J., & McCarthy, L. (2007). Numeracy in practice. *Principal Leadership, 7*(5), 32-38.

Appendix: First Fleet Activity Data Table

First Fleet Activity Data Table

	Accessible by sea	Shark infested waters	Land available for future growth	Able to transport harvested or manufactured items from site	Soil quality	Land suitable for livestock	Trees & plants	Local bush tucker	Fresh water availability	Fishing	Ave temp	Ave monthly rainfall	Records of floods
Botany Bay, NSW	Sea coast over 47km long, open and unprotected	Yes	Yes	Yes by boat & land	Damp, swampy land, may lead to disease, mud flats	Dry	Very large hardwood trees, can't cut down with basic tools	Emu, kangaroo, cassowary, opossum, birds	Small creek to north but low swamp land near it	Yes but unskilled men can only fish from a boat	18°	98mm	3
Sydney Cove, Port Jackson, NSW	Deep water close to shore, sheltered	Yes	Yes	Yes by boat & land	Unfertile, hot, dry even sandy in parts	Rank grass fatal to sheep & hogs, good for cattle & horses	Very large hardwood trees, Red & Yellow Gum, can't cut down with basic tools	Emu, kangaroo, cassowary, opossum, birds, wild ducks	Tank Stream flowing & several springs	Yes but unskilled men can only fish from a boat	18°	98mm	7
Rosehill, Parramatta, NSW	Yes 25km inland up the Parramatta River	No	Yes	By land only	Rich, fertile, produces luxuriant grass	Good for all	Smaller more manageable trunks, hoop & bunya pines – softwood	Plentiful, including eels	On the Parramatta River	Yes but unskilled men can only fish from a boat	18°	98mm	40
Port Hacking, NSW	35km south of Sydney, sheltered port	Yes	Yes	Yes by boat & land	Able to support a variety of natural vegetation	Good for all	Abundant eucalypt trees, ficus, mangroves	Plentiful	On Port Hacking River	Yes but unskilled men can only fish from a boat	18°	133mm	8
Norfolk Island	32km of coastline inaccessible by sea except one small cove, extremely rocky shore and cliffs	Yes	3,455 hectares in total	Only crops not wood due to small cove	Far superior to others, suitable for grain & seed	Good for goats, sheep, cattle & poultry	Yes, pines and flax plant	Green turtles, petrel birds, guinea fowl, flying squirrel, wild ducks, pelican & hooded gull	Exceedingly well watered	Yes but unskilled men can only fish from a boat	19°	110mm	0