Paper: An Investigation of Secondary Students' Engagement in a Science Inquiry through a Student–Scientist Partnership

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Keywords: student–scientist partnership, scientific inquiry, secondary school science

Abstract: In 2011, Year 9 science extension students at a regional Queensland secondary school participated in a 'full' scientific inquiry (US National Academy of Sciences, 2000), wherein they undertook plant growth trials to investigate the capacity of biochar, a fine-grained charcoal, to enhance the nutrient quality of compost. The inquiry was planned and guided by their teacher and a scientist, who aimed to afford high-performing, junior secondary students an opportunity to work alongside a 'real scientist' and experience the 'thinking and doing of science' (Hume & Coll, 2010). Qualitative data emanating from semi-structured interviews with nine students, as well as the teacher and scientist, revealed high levels of student engagement in the inquiry focus, given potential benefits of biochar as a combined system for soil improvement and carbon sequestration. Students reported working with greater accuracy and purposefulness as inquiry results were not predetermined and were to inform pilot research for the scientist's doctorate. Quantitative data analysis revealed that students who participated in the biochar inquiry outperformed their science extension-level peers who did not participate in the inquiry, in both a state-wide science test and overall science grades. Findings of this study highlight positive outcomes to have resulted from the student–scientist partnership. At a time when the school science curriculum is failing to engage the majority of young people (Lyons, 2006), there is need for further research to evaluate the effectiveness of this strategy in enhancing student engagement and achievement in science in the compulsory years of schooling.

Goals and objectives: The purpose of this study was to investigate the level of student engagement in a science inquiry, which aimed to afford high-performing science students the opportunity to participate in the "thinking and doing of science", through processes that "more realistically mirrored the practice of scientific communities" (Hume & Coll, 2010, p. 43). This aim was consistent with emphases on science inquiry skills in the Australian national science curriculum (Australian Curriculum, Assessment and Reporting Authority, n.d.) and on the science 'ways of working' in the Queensland Comparable Assessment Task (Queensland Studies Authority [QSA], 2009). To a lesser extent, the study sought to explore possible impact of students' participation in the inquiry upon their achievement in science. The research questions guiding this study were:

1. What was the level of student engagement in and understanding of the inquiry focus and inquiry processes?
2. How did participants reflect upon the challenges of and their engagement in the inquiry and the student–scientist partnership?

3. What indication is there that student achievement was impacted as a result of participation in the inquiry and the student–scientist partnership?

Theoretical frame: Effective science teaching and learning has been increasingly associated with inquiry over recent decades (Abd-El-Khalick et al., 2004). Nonetheless, research evidence has revealed that, “what is enacted in classrooms is mostly incommensurate with visions of inquiry put forth in reform documents” (Abd-El-Khalick et al., 2004, p. 398). There is growing awareness that the way science is experienced in the classroom by students is substantively different from that, by practicing scientists (Harnik & Ross, 2003). Recipe-type experiments undertaken for purposes of illustrating and verifying scientific concepts covered in lessons are most common in secondary science programming (Hackling, 2005; Hume & Coll, 2010; QSA, 2010). However, if students are to develop the investigative skills, including critical thinking and reasoning, that are emphasised in curricula and integral in promoting a scientifically literate citizenry, they need opportunity to participate in “more authentic, inquiry-based investigations” (Hackling, 2005; QSA, 2010, p. 3). According to Hume and Coll (2010), “authentic scientific inquiry encourages the thinking and doing of science where students have opportunity to experience the procedural and conceptual knowledge required to carry out investigation in a manner that more realistically mirrors the practice of scientific communities” (p. 43).

Key impediments to the implementation of inquiry in school science programs, especially ‘more open’ inquiry (US National Academy of Sciences, 2000), include inadequate teacher knowledge and methodological expertise, access to professional scientific support and modern instrumentation, and time in light of crowded curricula (Harnik & Ross, 2003; Symington & Tytler, 2011). In the face of such constraints, one strategy is to link students directly with scientists. There are two types of arrangements that connect students and scientists: research apprenticeships, which create opportunities for students to work directly with scientists outside the regular classroom setting, most typically involving access to scientific research laboratories, and classroom-based research or student–scientist partnerships, a model that has the potential to engage a much wider student population in science inquiry (Sadler, Burgin, McKinner, & Ponjuan, 2010; Tinker, 1997). Student–scientist partnerships are promoted in Australian primary and secondary schools through a number of initiatives, including the *Scientists in Schools* program (Howitt, Rennie, Heard, & Yuncken, 2009). In their scientist partners, teachers potentially have access to someone with deep understanding of science concepts, current knowledge of scientific developments, expertise in planning and conducting scientific inquiry, as well as a positive role model for students (Pegg, Schmoock, & Gummer, 2010; Rennie & Howitt, 2009). Research studies have indicated potential for enhanced student engagement and learning of inquiry skills, science content and real world applicability of concepts through student–scientist partnerships (Harnik & Ross, 2003; Moebius-Clune et al., 2011; Oliver et al., 2011).

Methodology: The biochar inquiry informed a second action research cycle in an action research project designed to enhance Year 9 student engagement and achievement in science. The project and its first action cycle were initiated in 2010 in response to poor performance of Northern High’s 2009 cohort on the Year 9 Queensland Comparable Assessment Task for science. In a 2010 paper, the authors (Authors) reported on some of the key actions and outcomes of the first action research cycle. In the second cycle, the intent was to shift focus from faculty-level initiatives to those at the classroom level. In 2011, Northern High had two Year 9 science extension classes, comprising high-achieving students who had attained an A or B grade in Year 8 science. All aspects of the Year 9 science program were the same for the two extension classes, which for the purposes of this study are referred to as Class A and

Class B, with exception of the inquiry component for Term 2. While the 22 students of Class B engaged in a teacher-guided research project, the 26 students comprising Class A participated in the biochar inquiry with the scientist and teacher.

This study employed mixed methods. The lead researcher interviewed nine students, who participated in the biochar inquiry—three females and six males—in three groups, each of three participants, utilising a semi-structured interview technique (Parker & Tritter, 2006). The three group interviews, of 30-minute average duration, were held during school hours at Northern High. Individual interviews were also held with the scientist and the teacher (20-minute average duration). In part, student responses informed development of the interview schedule for the scientist, and responses from all prior interviews informed the teacher-interview schedule. Semi-structured individual and group interview techniques "have long since featured as fundamental components of qualitative research" (Parker & Tritter, 2006, p. 25). Interviews were transcribed for purposes of content analysis and data were organised into categories related to the central questions of the research (Fereday & Muir-Cochrane, 2006). To a lesser extent, the paper draws upon quantitative data. Year 9 science achievement results for 2011 were compared for Class A (biochar inquiry) and Class B (no biochar inquiry) on: (1) a start-of-year, researcher-designed baseline test (Authors, 2010) that was formative in nature; (2) the Queensland Comparable Assessment Task undertaken in Term 3; and (3) overall end-of-year science grades. The significance of any difference in results between the two extension classes was calculated using IBM SPSS Statistics for Windows Version 20.0.

Results and discussion: The literature suggests that engagement in science learning is enhanced through opportunity for students to have direct contact with scientists and assume an active role in inquiry, involving hands-on experimentation, input into experimental design, literature searches and computer work (Dijkstra & Goedhart, 2011; Moss, Abrams, & Kull, 1998). In the whole-of-class biochar inquiry, students participated in review of the literature, field experimentation, data collection and analysis, and report writing. As an individual preliminary activity, they drew upon prior knowledge from a Year 8 fast plants experiment to formulate a hypothesis and design a fair test, relating to biochar as an agricultural amendment. One student felt that the overall aim of the inquiry and associated activities was to build student capacity in "how to set up an experiment by ourselves". Another student reflected that working alongside the scientist provided "the motivation to apply ourselves more, concentrate more, to get us to be more accurate with our results".

Students were aware of the novel nature of the scientific application of biochar with compost to soils and that, in terms of the findings, there were no foregone conclusions. They attributed high engagement levels to "the unpredictability of results", with one student explaining that, unlike the fast plants experiment, where "Ms Reynolds knew the results—she knew what the average was, and what the results should be—with the biochar she has no idea". The openness of the findings was a leveller, positioning students, teacher and scientist as co-inquirers in what was perceived by another student as "completely new science". The taking of non-traditional roles (Crawford, 2000) served to promote teacher–students relations – an unintended outcome of the inquiry.

Hubber, Darby, and Tytler (2010) found that student involvement in more open science investigations not only enhanced their engagement in science but disrupted "standard expectations of science and what it is to do science" (p. 11). Such disruption is captured poignantly by a student of this study, when reflecting that, "it felt like we were working towards a point, rather than just sort of a school assignment that gets forgotten after five minutes". For another student, the inquiry promoted a sharper focus on science learning: "I think this semester, where we are doing our own experiments, has motivated us to learn more about science. I can't wait for Year 10 extension science". These student sentiments resonate with what Hubber et al. (2010) described as "an opening of possibilities for envisaging what science can be both in school and beyond" (p. 11). The teacher perceived the broader focus on biochar's potential role in carbon sequestration and climate change mitigation to be especially relevant for students, given ongoing media attention relating to Australia's carbon tax legislation. One student communicated a sense of global connectedness through her participation in the biochar inquiry. Another student perceived the scientist's research focus as "really interesting. It builds your hope that you know there are people who are very proficient at science, who do care about the environment". Gough (2008) argued that "rather than accepting that science education is something static and in its traditional form incompatible with—or at least a limited vehicle for—environmental education", students' declining interest in science despite increasing levels of environmental concern provides an obvious rationale for developing a different relationship between the learning areas (p. 44).

Quantitative data analysis revealed that students of Class A, who had participated in the science inquiry in Term 2 facilitated through the student–scientist partnership, outperformed their science extension-level peers in Class B on the 2011 Queensland Comparable Assessment Task and in terms of overall science grades. While there was no significant difference in performance on the baseline science test at the start of the year, there was a significant difference between the classes in student achievement by Term 3. We acknowledge the limitation of the quantitative data drawn upon in this paper, given that Class A and Class B had different science teachers and that it is not possible to separate the influence of the scientist-guided inquiry from individual teacher qualities and pedagogies.

Conclusions and significance: Research is needed to provide further empirical support to the largely qualitative research studies that have found positive outcomes for students participating in scientific inquiry through student–scientist partnerships. In Sadler and colleagues' (2010) critical review of the literature on arrangements that connected students and scientists, only five of the 20 articles pertaining to secondary school studies detailed scientist–student partnerships; of which, four were descriptive accounts. The one systematic investigation of a student–scientist partnership, reviewed by Sadler et al. (2010), revealed inherent tensions between scientists' needs for high-quality data and student expectations across three overlapping partnerships. It is important to note that in the context of the present study, the success of the scientist's doctoral research was in no way contingent on the quality of the students' field experimentation or the data emanating from it, even though the biochar inquiry was to potentially serve as a pilot for the scientist.

This study found high levels of engagement on account of students' active participation with a scientist in a full inquiry (US National Academy of Sciences, 2000) wherein they discovered new knowledge with potential societal and environmental benefits. For McWilliam, Poronnik, and Taylor (2008), the difference is between static and dynamic sources of knowledge. The latter is associated with intellectual challenge, stimulation, exploration, questioning and discussion of ideas and, importantly, the production of knowledge – characteristic of what Tinker (1997) refers to as the "scientific high adventure" (p. 111). Many science teachers themselves have never engaged in scientific inquiry and, as a consequence, teach mainly from textbooks and other static sources (Dresner & Starvel, 2004). Findings suggest that there are rewards to be had, in terms of both student and professional outcomes, for teachers who are prepared to relinquish the safe role of textbook expert, be creative and flexile in their planning, and pursue partnerships, resources and professional development so that their students can actively engage in science inquiry as part of their class programs.

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