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EDITORIAL INTRODUCTION: ORCHESTRATING INQUIRY LEARNING

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There is currently increased recognition amongst researchers that inquiry learning (interpreted as the ability to plan, carry out and interpret novel investigations), particularly when supported by technology, can foster the development of higher order thinking skills and offer learners a meaningful and productive approach to the development of their knowledge of the world. Science educationalists propose that young people need to know how to ‘act like scientists’ if they are to understand and contribute to the major scientific debates that are shaping our world. That said, inquiry learning presents challenges for both teachers and students. For example, pupils may experience difficulties in engaging with inquiry learning, forming appropriate investigations, designing and running experiments, and interpreting data. A key challenge, then, is how to resource and support processes of inquiry learning within and beyond the classroom. Other issues include motivating young people to see their world as a site for scientific investigation, engaging them in scientific discourse, integrating inquiry learning with the teaching of science principles, and designing new tools for investigatory learning. The work being reported in this book is intended to address these challenges.

The volume brings together work on inquiry learning and orchestration of learning, where orchestration is the planning, management and guidance of learning. The contributors are working at the cutting-edge of the field, and they represent a wide range of disciplinary contexts including human-computer interaction, science learning, psychology and education. A central argument is that technological support, when coupled with appropriate design of the activities and learning environment, can enable the orchestration of inquiry learning

experiences that are engaging, authentic and personally relevant. The term ‘orchestration’, as you will see, carries subtle differences in emphasis for each of the teams of contributing authors. That said, this metaphor captures the important sense in which the focus of attention is channelled towards a specific aspect of an ongoing activity - there being shifts between what is fore-grounded and what is back-grounded, taking into consideration the contributions of the learners.

Our authors offer characterisations of the nature of inquiry learning. They attempt to specify the conditions and pedagogic contexts within which such learning can most effectively be promoted and are working to distil the results into concrete messages for practical application. Whilst a key focus for many authors is the inquiry learning that is conducted in and framed by the concerns of formal educational settings, for example schools and colleges. Other learning contexts are also considered, including school grounds, homes, museums and discovery centres, streets and parkland. A theme of the book is how to connect learning within and beyond the classroom.

The volume opens with a review by Eileen Scanlon, Stamatina Anastopoulou and Lucinda Kerawalla (Chapter 1). Focusing particularly on inquiry learning in science, these colleagues are especially concerned to explore: a) how contemporary research can inform the design of inquiry learning experiences and b) the ways in which technologies can be harnessed to resource and support inquiries such that learners come to develop their knowledge and understanding of the world. Two key issues emerge from this exploration. The first concerns the efficacy and value of ‘personalising’ inquiries in ways that make them meaningful to learners – a process that may incorporate elements of personal relevance, choice and learner responsibility. Seen in these terms, personal inquiry cannot simply be equated with ‘personal interest’, rather it is the process of grounding scientific content and process in students’

existing points of view and activities that can enable them to see the intellectual relevance of their learning activities. It is evident, that helping learners reframe their everyday experiences in empirical and scientific terms is a substantive challenge. The simplistic use of the 'everyday' in educational contexts is problematic - not least because it trivialises the complex processes involved in meaning making and falls far short of the authenticity that is essential to engage young people and support learning. It may also be the case that some inquiries are too personal to be explored within an educational context. To explore some issues of personal relevance would be to engage learners in complex processes of negotiating, re-negotiating and managing identity work – processes full of the inherent possibility of invoking 'troubled identities' in relation to one's peers. Even preparing for such an activity might pose problems, for, as Murphy (2000) notes: 'even the imaginary gaze of critical peers is a major threat to [learners'] identities and significantly affects how they learn to position themselves in subjects. Positions that can constrain future learning'. A second substantive focus concerns how educators might harness the pedagogic potential and affordances of representations of the inquiry cycle to resource process of teaching and learning. Scanlon and her colleagues argue that representations of the inquiry cycle can constitute powerful mediating tools that frame teaching-learning interactions in ways that scaffold learners to gain meta-cognitive awareness of inquiry processes. For these authors it is in the creative alignment and interplay of teacher, learner(s), mediating tools/technologies, and activities that efficacious personal inquiry learning is constituted - with orchestration being the process that productively supports interventions across multiple activities and contexts occurring at multiple social levels. Orchestration is thus construed as a process that is necessarily and inherently adaptive to the emergent learning trajectory.

The significance of learning trajectories is explored in Chapter 2, by Karen Littleton and Lucinda Kerawalla, who focus specifically on the challenge educators confront in ensuring

that young people have a coherent, cumulative experience of the diverse activities, ideas and settings that are implicated in the process of inquiry learning. These authors suggest that a crucial educational challenge facing teachers working on inquiry projects is how to ensure that the overall educational experience for the students is one that is genuinely *cumulative and reciprocal*, rather than simply extended in time. The work they present highlights how the affordances of the technologies in play distinctively enter into, and resource, the processes of *connection building* across phases of activity – such that from the learner’s perspective, the work they are undertaking begins to develop a cumulative quality in which specific activities, and their goals, begin to form part of a greater whole - a purposeful educational ‘journey’ through which they come to understand the nature and processes of inquiry learning. The metaphor of ‘orchestration’ sits crucially at the heart of Littleton and Kerawalla’s exploration, and for these authors the metaphor draws attention to the subtle interweaving of activities, ideas and resources and the ways in which a teacher may make (what are often moment-by-moment) shifts between what is fore-grounded and what is back-grounded in an ongoing inquiry. It also captures the sense in which a teacher encourages, and works with, learners’ contributions in the context and pursuit of overall goals as part of a longer trajectory of meaning-making.

The necessity of working with learner’s contributions is further underscored by Kevin W. McElhaney and Marcia C. Linn who, in Chapter 3, describe how their knowledge integration framework can strengthen inquiry instruction. Crucially, they argue that centring inquiry investigations on ‘realistic and relevant’ contexts encourages students to take advantage of their knowledge in designing experiments and in reasoning about their findings. Returning to the significance of personalisation (introduced earlier by Scanlon and colleagues) and the imperative to help learners build connections (Littleton and Kerawalla), McElhaney and Linn

also underscore the efficacy of students testing *their* ideas rather than following a ‘recipe’ that may not *connect* to their prior conceptions or relevant everyday ideas. That said, they also caution that prevailing canonical notions of classroom science and what it entails may preclude authentic interpretations of inquiry investigations. Young people’s: ‘interpretations of experience, the meanings they attach to their learning - will, in part, be determined by their involvement with schools and other institutions of their society ... schools have their own body of cultural knowledge, and their own ways of communicating and legitimising knowledge’ (Mercer, 1992, p.31). Learners’ interactions and experiences are thus framed by, and therefore can only ever be fully understood within, their specific cultural niches. Different contexts will afford different opportunities for, and place different constraints upon, learning. According to McElhaney and Linn the implication of all this is that students need to ‘let go’ of their positioning as science student to assume the role of science investigator. Their work with the distinguishing task of *Airbags* exemplifies the substantial effect that subtle changes in framing of inquiry tasks can have on student’s insights. This in turn underscores that whilst meaning is not a tangible or fixed commodity, in practice it is often assumed that educational ‘tasks are given’ (Murphy, 2000). The work reported in this chapter, however, reminds us that inquiry tasks are constructed through a complex process of interpretation and re-interpretation, emerging as a consequence of mediated action and interaction.

The complexity of the pedagogic challenges and the dilemmas facing teachers committed to inquiry learning are thrown into further relief by Sharples and Anastopoulou (Chapter 4). These authors underscore the delicate balance between the need to teach the fundamentals of a science topic in a well-structured way and the value of open ended inquiry (where students may conduct investigations that yield inconclusive results, for instance). They also draw

attention to the ways in which the teacher must be able to initiate and guide activities that take place beyond the classroom. Organising inquiry learning for the home, or other sites where the teacher is not present is a compelling pedagogic challenge and the authors detail the work of the Personal Inquiry project designed to address this challenge through the development of a mobile toolkit specifically designed to support the orchestration of teaching activities across formal and non-formal settings. As the authors explain the intention is: 'to provide a seamless handover from teacher orchestration supported by the technology to technology guided personal inquiry'. The ways in which one can 'script' such technologically-mediated support for personal inquiry is the focus of Chapter 5.

Collins, Mullholland and Gaved (Chapter 5) argue that scripting support for personal inquiry necessarily entails an open approach that enables teachers and students to author or customise inquiries on personally relevant topics, which may span, for example, home, school and field trip contexts. Based on a theatrical metaphor, scripts characterise a set of activities which both engineer and harness differences between students' opinions or knowledge in order to foster effective learning. Crucially, students' actions and decisions can be reified through the tools they use to support their inquiry and the chapter explores five aspects of personal inquiry that can be addressed through scripting support: personal choice; collaboration, regulatory process support, transformative process support and orchestration. The suggestion is that scripting provides a set of representations that are used for orchestration and involves the identification and co-ordination of students' activities, their learning process, and the technological support used. It is clear that scripting enables teachers to specify the overall structure of an inquiry and the options available to students. Both the activities undertaken and the students' progress through them can be shown in a scripting application. A crucial affordance here, then, is the potential of the technology to resource the linking of activities in

meaningful ways which help lend cohesion and coherence to learners' experience of inquiry-based activities, especially those which extend over lengthy periods of time. The experienced and anticipated learning trajectory becomes rendered visible in ways intended to foster purposeful understanding. Given that changes to a script can be made at any time by a teacher in response to student progress or to follow up issues of particular interest, significance or consequence it is clear that, far from being prescriptive, scripts can flexibly support the more 'improvisational' elements of inquiry learning, where students and their teachers can explore and interrogate emerging questions and issues.

A commitment to participatory design is shared by many of the authors in the book and it is clear how researchers are increasingly undertaking work *with* teachers and other education professionals and students, rather than conducting research *on* them, thereby recognizing them as people with concerns rather than treating them as objects of concern. This process of participatory design is in evidence in Chapter 6 where Roy Pea, Marcelo Milrad, Heidy Maldonado, Bahtijar Vogel, Arianit Kurti and Daniel Spikol discuss learning and technological designs for mobile science inquiry collaboratories. The chapter explores how this team moved from visions of mobile science inquiry, to co-design activities with educators, to system architecture and technical developments to the instantiation of mobile science collaboratories. Aiming to afford the seamless integration of, for example, data coming from multiple devices, Pea and colleagues' work carries important implications for enhancing the orchestration of inquiry-based learning activities. Moreover, the significance of representations as objects to think with and 'interthink' with (Mercer and Littleton 2007) is once again underscored.

The focus on collaborative inquiry that sits at the heart of Chapter 6 also assumes prominence in Chapter 7 where Marjut Villo, Pirta Seitmaa-Hakkarainen and Kai Hakkarainen examine the practices of supporting collaborative inquiry. Their analyses of an elementary school teacher's practices and efforts to support pupils' cognitive responsibility for their advancing their own collaborative oriented inquiry process highlights how the epistemic, social, technological and cognitive infrastructure of the class are all implicated in ensuring the efficacy of students' experience of inquiry. It is also evident from these authors' work that the orchestration of inquiry learning necessitates efforts that are strategically oriented at multiple levels (characterized here as the micro, macro and meso level) if serious inquiry is to be object-oriented.

At this point in the book the vexed issue of assessment is raised. The chapters presented thus far yield substantial evidence of creative and innovative approaches to the design of inquiry learning experiences. Yet assessment practices, often shaped by statutory imperatives, remain somewhat conservative and heavily reliant on individual testing methods. In Chapter 8 Daniel T. Hickey and Michael Filsecker summarise a comprehensive approach to instruction and assessment that uses situative theories of cognition, participatory views of learning and design-based methods to transform classroom assessment and educational testing. Adopting a broad view of assessment and testing, learning is aligned within embedded assessments of communal discourse to classroom assessments of individual understanding. This focus on the orchestration of assessment is taken up by Barbara Wasson, Vibeke Vold and Ton de Jong in Chapter 9. Wasson and colleagues argue that the orchestration of assessment in inquiry learning environments requires the careful design of mechanisms for both formative and summative assessment. Rooted in the learning by design literature, the work by these

authors work also shows the centrality of designed artifacts and emerging learning objects in both learning and assessment processes.

The volume ends with a contribution from Ann Jones, Marilena Petrou and Canan Blake whose research addresses the issue of how to support inquiry learning in non-formal contexts. They suggest that given the increasing rise and importance of science inquiry learning in a range of less formal settings, it is imperative that we develop our understandings of how students learn in these settings and how such learning might be supported and resourced by technologies. The Sustainability Squad investigation they report here represents an important contribution to this emerging field.

This is a book about multiplicity, plurality and complexity. The scholars who have contributed are engaged in a dynamic process of inquiry into inquiry learning. Through their work, involving committed engagement with teachers, learners and other education professionals, they are participating in an iterative research process that is producing invaluable support for theoretically-informed ways of promoting productive inquiry learning. And now the inquiry continues ...

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