The Use of Multiple Cameras to Capture Students' Virtual & Real Actions

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This paper explores the value of multiple video sources to capture both the real (i.e. physical/concrete) and virtual actions of science students as they interacted with computer models to reason about natural selection in an informal learning environment. The study involved the use of two tripod cameras filming students working in pairs, web cameras attached to each pair's computer that also filmed the pairs, and Camtasia Studio (screencasting software) installed on the computers, which recorded what took place on screen. We propose that the different video data generated using these different video sources afforded the opportunity to investigate the action-based nature of student reasoning in science; specifically the way in which students executed both real and virtual actions as they interacted with computer models to reason. We suggest that current understandings of real and virtual actions, particularly in regards to students' reasoning in science, must be reconsidered in light of the distributed nature of this process.

Exploring students' reasoning in science

This paper emerges from research conducted at a science education centre, in Melbourne, Australia. The authors worked with staff at the science education centre to develop a new one-day program designed to enable students to explore natural selection. One of the sessions involved students interacting with a suite of computer models (specifically NetLogo models) in order to explore the relationships between malaria and the hbb gene.[1] The goal was to support and encourage students to reason about natural selection.

The researchers were interested in the way in which the students interacted with the computer models, each other and more knowledgeable others (demonstrators and education officers) as they reasoned about natural selection. Reasoning has long been recognised as a central part of teaching and learning science, particularly in the context of inquiry-based approaches to science education (Lehrer & Schauble 2006; Tytler & Peterson 2005; Vosniadou, Skopeliti & Ikospentaki 2005). Yet the precise meaning of reasoning and its manifestation in the science classroom is far from determined.

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[1] The hbb gene is involved in the regulation of beta-globin, a protein integral to haemoglobin that transports oxygen around the body.

[2] This is not in anyway a criticism of this research, but rather a statement about the primary focus to

The focus of this research was not students' deductions and inductions, which we suggest are often the focus of educational research exploring reasoning,[2] but rather the way students created their own ideas (i.e. hypotheses) to explain the relationships between malaria and the hbb gene (and by extension natural selection). This is what Magnani (2001, 2009), building on the seminal work of Peirce (1998a, 1998b), refers to as abduction. It is the most generative aspect of reasoning and arguably the most important because it leads to genuinely new insights (i.e. discoveries). While creativity in the science classroom has long been valued, evident in the plethora of literature on the topic, it is poorly understood. We propose that it is often (but not always, see the vast literature on authentic scientific inquiry, e.g. Hume 2009, and the use of representations to creatively reason in science, e.g. Tytler, Prain, Hubber & Waldrop 2013) black boxed as an illogical process that is mostly unconscious and unintentional. In this way it mirrors the mystification of discovery in the world of science (as opposed to school science), which Latour (1986) and more recently Magnani (2001, 2009) have attempted to deconstruct. We propose, however, extending Magnani's work to the educational context, that students' creative reasoning can be logically understood as abduction and as such can be systematically explored (and demystified).

But where to start, particularly in regards to this research? Magnani (2001, 2009) proposes that perhaps the most important component of abduction is its manipulative nature. He argues that much creative reasoning involves the individual interacting with what he calls "epistemic mediators" (Magnani 2004, p. 440) (i.e. tools). He conceptualises this reasoning as "manipulative abduction" (Magnani 2004, p. 440). By extension we propose that the students' interactions with the computer models, and their interactions with other students and more knowledgeable others, can be understood as manipulative model-based abduction. Magnani (2001, 2009) suggests that most creative reasoning is model-based. This gives us a clear starting point for exploring students' abductions; we need to focus on their manipulations, in other words their actions. But how can students' actions be captured in such a way that their reasoning is made amendable to logical analysis?

The value of video to capture students' manipulative abductions

The answer may be video. It was mentioned earlier that this research was conducted in an informal learning environment, specifically a science education centre. There is an existing body of literature in which video has been used to record various aspects of visitors' behaviours and actions as they visited various informal learning environments. Moss, Essen and Bazley (2010) employed video cameras to record the attentiveness of visitors as they attended a particular zoo exhibit. Research has also been conducted in science museums: Hohenstein and Tran (2007) used cameras to record and explore the conversations stimulated by exhibit labels; Tulley and Lucas (1991) utilised video data to capture and investigate patterns in visitors' behaviour as they interacted with a problem-solving exhibit; while von Lehn, Heath

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and Hindmarsh (2002) provide a comprehensive overview of the history of video-based field studies conducted to explore visitors' behaviour in science museums.

The research that is the focus of this paper, however, was conducted in a science education centre and not a science museum or zoo. In this context visitors are primarily school students and their learning experiences are determined (or perhaps carefully shaped is a better description) to a significant degree by the staff at the centre. This is not to say that students are not encouraged and supported to explore science; in fact the science education centre that was the location for this research promotes and practices an inquiry-based approach to learning. But the behaviour and activity of the visitors (i.e. students) is directed towards specific educational ends. In this way the research of Martin, Brown and Russell (1991) is particularly relevant. They used video cameras in a natural history science education centre to record, and then analyse, the interactions between students and teachers as they attended to a particular exhibit.

These examples of video-based methodologies used in informal learning environments suggest that the reasoning of the students in this study, more specifically their abductions, could potentially be captured, and subsequently analysed, using cameras. This includes their interactions with the more knowledgeable others and perhaps more importantly their interactions with the computer models. While the abovementioned studies used video data to primarily explore visitors' social interactions as they attended to particular exhibits, in contrast to this study which focuses on students' reasoning, it is the case that this literature demonstrates that video-based methodologies can provide the opportunity to explore complex and dynamic aspects of human action and behaviour. In this way it seems reasonable to suggest that a similar methodology might illuminate the students' reasoning that is at the centre of this research.

And indeed this is what we did. But this was far from straightforward. The challenge was to design and implement a video-based methodology that would allow the recording of not just the most obvious aspects of students' manipulative abductions (i.e. what the students did as individuals), but also the interactions between the students, more knowledgeable others and computer models. In this way the manipulative model-based abductions seemed not to be restricted to the students; they appeared to be distributed between the students, more knowledgeable others and the computer models. More will be said on the importance of the distributed nature of this reasoning in a later part of the paper.

The camera set up and its affordances

The set up of the cameras used in this study is shown in Figure 1. Each of the three different types of video recording equipment was paired with a specific audio source. The two tripod cameras were linked with lapel microphones. The web cameras were linked with in-built microphones, while the screencastings (provided by

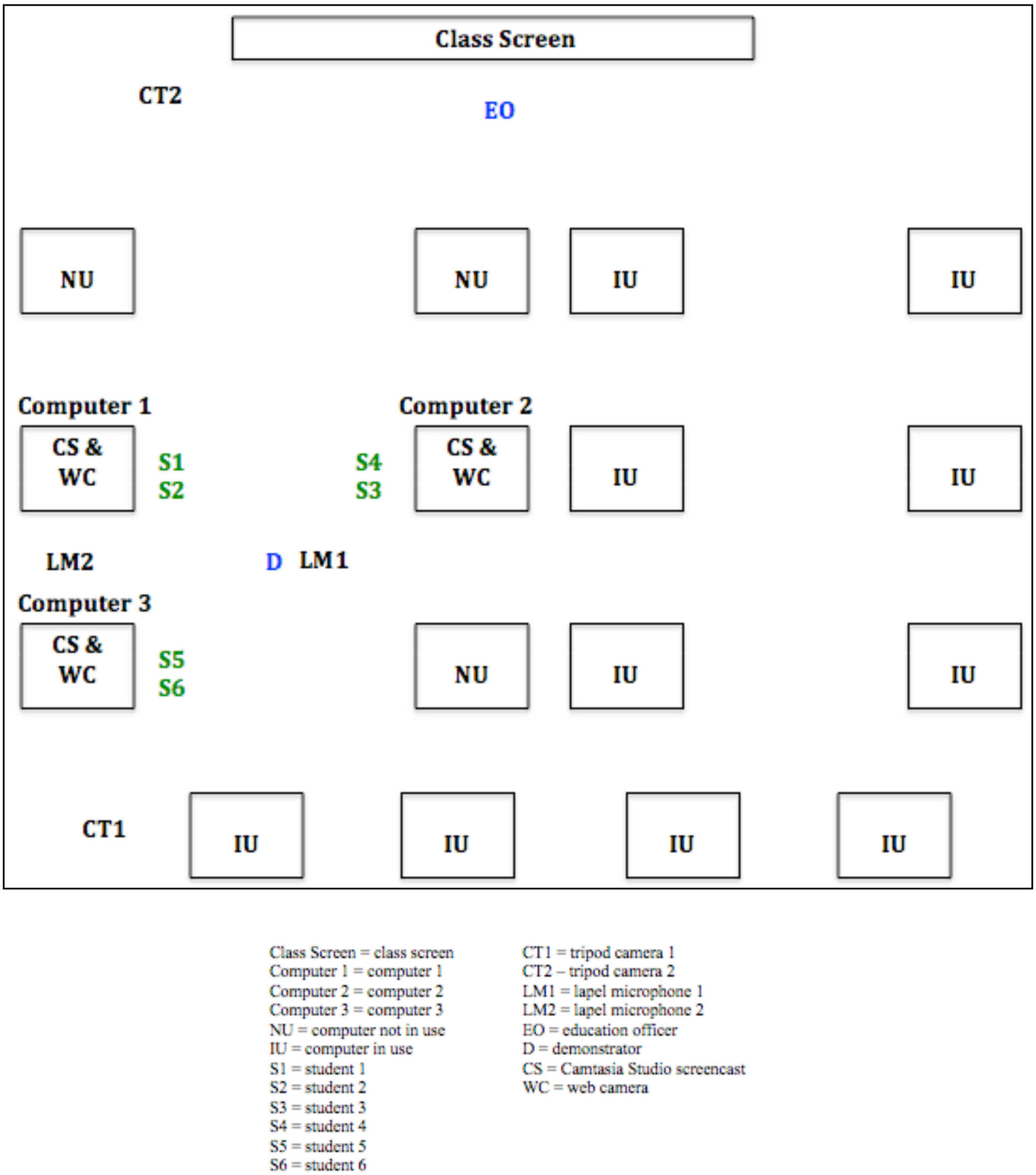

Figure 1: The camera set up (with associated microphones) in the computer room

Camtasia Studio) were also linked with the microphones built into the web cameras. While there were three different types of video recording equipment, it is the case that the total number of recording devices was greater than this due to the need to record the participation of six students (three pairs), a demonstrator and an education officer. In total there were: two tripod cameras (and two lapel microphones); three web cameras (each with a built-in microphone and attached to a computer); and three computers running Camtasia Studio (to record screencasts).

As can be seen this particular camera set up utilised multiple video sources in order to (try) to capture the reasoning emerging from the students' interactions with each other, the more knowledgeable others and the computer models. Each of these different types of video recoding equipment (and the associated audio equipment) enabled a different aspect of manipulative abduction to be captured. The two tripod cameras captured, from a distance (with some scope for close-ups), the students interacting with the computer models, the computer models playing out on screen as well as the students interacting with each other and with the more knowledgeable others. The web cameras also captured the students interacting with the computer models, as well as the students interacting with each other and with the more knowledgeable others. But this was from a much more intimate perspective (with the students' faces at the centre of vision). Finally the screencasts (generated using Camtasia Studio) recorded what was taking place on screen. But unlike the tripod cameras, which recorded the computer models on screen from a distance, the screencasts recorded the computer models directly from the computers. The screencasts were unique in this way because they focused solely on the computer models, unlike the tripod cameras and the web cameras that mainly focused on the human agents (i.e. students and more knowledgeable others) in the reasoning process.

We propose that this video-based methodology afforded the opportunity to record, and subsequently analyse, manipulative abduction as it played out across the students, more knowledgeable others and computer models. Specifically, not only were the real (i.e. concrete/physical) actions captured (such as students pointing to something taking place on screen), but the actions occurring on screen, within the computer models, were also captured (such as students using the cursor to point to something taking place on screen). We call these 'virtual actions'. More than this the camera set up allowed the relationship between these different forms of action to be captured; the way in which virtual actions followed real actions (and vice-versa) or most interestingly when real and virtual actions took place simultaneously. In this way we suggest that the use of multiple cameras, including video from two perspectives and screen capture, is necessary in order to capture the distributed nature of reasoning that involves the interaction between physical and virtual actions (e.g. physical gestures, virtual alteration of computer models).

The role of real actions is established in the literature on abduction, in particular Magnani (2001, 2004) who proposes a central role for these actions in the process of working with epistemic mediators to conduct reasoning. However the latter type of action, what we call virtual action, is less well understood in regards to reasoning. Virtual actions in the literature have commonly been referred to as actions performed in a 'virtual reality' space; whether in a space created by Oculus Rift-type devices or via augmented reality programs where an aspect of visual computing interface is overlaid onto 'reality' via a computer screen, tablet or smartphone. Dezuanni (2015), for example, examined how students interacted with computer devices as part of their media literacy training. The students interacted with the digital technology to create digital materials using their own knowledge about how to use the digital technological systems as an extension of the human body. This is consistent with Hayles (1999) notions of *inscription* and *incorporated* habits as types of *bodily writing* within the digital media space. Inscription practice refers to "systems of signs operating independently of any particular manifestation" (Hayles, 1999, p. 198). These might refer to the students using the computer mouse to point to, or circle points of interest to communicate meaning to their partner. The use of incorporated practices refers to "an action that is encoded into bodily memory by repeated performances until it becomes habitual" (Hayles, 1999, p. 199-200), suggesting that a practice used in everyday life may be an embodied action that is enacted in a digital space via the digital tools available.

We propose that this common understanding of virtual actions as fundamentally the virtual manifestation of physical actions may be overlooking the contribution that these actions make to students' reasoning, in particular abduction (not that we doubt the important link between physical and virtual actions). We suggest that there is more to virtual actions than the virtual inscription of physical actions; and we are exploring whether they have their own affordances or are modified by the design of the computer models when it comes to reasoning. But we are unsure of the precise nature of this virtual component of reasoning; hence the need for further research in this area. However we do know that a more refined understanding of this aspect of manipulative abduction is only possible if the distributed nature of students' reasoning is acknowledged. In this way we put forward the use of multiple video cameras as an effective means to capture and explore the distributed, and hence physical and virtual, nature of the actions that underpin students' abductions involving computer models.

The way in which this camera set up afforded an investigation of the physical and virtual nature of students' abductions was a result of the intimate, yet surprisingly unobtrusive, and naturalistic nature of the video data collected. The set up of the cameras in this study, as described above, might seem to the reader to be intrusive for the students and more knowledgeable others. However, due to the fact that the environment at the science education centre was novel for the students even without the cameras, it is likely that the presence of the cameras did not significantly impact their behaviour. Even when the students did respond directly to the cameras this was intermittent and short lived. The more knowledgeable others seemed similarly unperturbed by the cameras.

We propose, as a result of this non-intrusive camera set up, that the video data collected can be seen as a naturalistic representation of what took place. In other words the video recordings show how abduction plays out when students work with more knowledgeable others to reason with computer models. However, we are not suggesting that the video data equates to the realities of the classroom; rather the use of video cameras enabled a representation of the participants' realities that can be considered a valid and reliable basis for exploring reasoning in action.

Underpinning the natural nature of this video data was the intimate footage captured by the web cameras. While the students' facial expressions captured by the web cameras were not directly analysed as a part of reasoning, it is the case that the facial expressions informed the analysis of abduction. In many cases the students' facial expressions indicated when abduction was, or was about, to take place. This is because abduction normally follows the noticing of anomalies (Magnani 2001, 2009) and when students notice anomalies their surprise is expressed in their faces. And the computer models presented students with many anomalies. In addition this intimate footage, in conjunction with the varied footage from the other cameras, provided the researchers with a 'feel' for the video data. This provided an important context for the analysis of specific subsets of data (so much video data was generated that only certain carefully selected sections could be analysed in relation to investigating reasoning).

The distributed nature of students' manipulative abductions

The interactive nature of the task, with exchanges between the students, the more knowledgeable others and the computer models is consistent with the idea of distributed cognition (Hutchins 1995; Zhang & Norman, 1994). Zhang and Norman (1994, p. 87) define distributed cognition as "tasks that require the processing of information distributed across the internal mind and the external environment." In terms of the current study this allows us to explore the external representations embedded within the computer models and the internal representations communicated by the students verbally to each other and via their physical and virtual actions. It also allows us to examine the construction of the computer models and how their representations of various phenomena may facilitate the internal representations developed by the students. Similarly, it allows us to examine the internal representations constructed by the students and how they are facilitated by virtual and physical interactions with the computer models and verbally between themselves.

However, the above is a description of the students' abductions according to the traditional approach to distributed cognition. We suggest that while the notions of external representations and internal representations are useful for discussing the distributed nature of cognition, in this case reasoning, they do not adequately capture the complexity of reasoning on the ground (i.e. in the reality of the science classroom). We argue that when the students interacted with the computer models, in conjunction with the more knowledgeable others, that representations emerged from these interactions. As opposed to representations residing in the minds of the students and within the digital space of the computers, we propose that the representations did not have a location (internal or external) but rather were an emergent property of the distributed system. In this way the distinction between internal and external representations becomes meaningless, beyond acting as a way to initially engage with the idea of distributed cognition.

The ability to examine the interactions between the students and the computer models was only possible because of the sophisticated arrangement of video and screen-capture technology. Without capturing how students were interacting with the computers on-screen we would typically be limited to understanding their cognition as presented verbally or by their gestures. Indeed we would be limited to the traditional notion of distributed cognition. But by capturing the on-screen information, as well as that taking place in the off-screen environment, we are able to examine how the students' interactions with the computer models formed a distributed representational system (including the contribution of more knowledgeable others) from which emerged abductions in various representational forms.

Video as a way to begin reconceptualising students' actions in the context of computer-based manipulative abduction

We conclude by suggesting that the current understanding of real and virtual actions in the context of learning science needs to be reconsidered. In particular in the context of reasoning and specifically when abduction involves both the physical and virtual worlds. But we argue that this is only possible if video is used to inform research.

As mentioned earlier, while the existing notion of real action in regards to reasoning is most enlightening, this needs to be reconsidered in the light of reasoning that also involves the virtual realm. Manipulative abduction, we suggest, involves more than the physical when computer models are involved; it becomes *computer-based manipulative abduction*. The current understanding of virtual action does not adequately capture the nature of abduction that plays out in the virtual world (for example in computer models). Virtual action, when it comes to reasoning with computer models, is more than just the virtual manifestation of the physical (which is the dominant understanding of virtual action). These virtual actions make a unique contribution to reasoning. But they are also intimately linked to real actions, such that computer-based manipulative abduction is simultaneously physical and virtual.

We propose that a new understanding of real and virtual actions, one that will enable the further exploration of abduction involving students and more knowledgeable others working with digital technology, is only possible if reasoning is considered a distributed phenomenon. Distributed across students, more knowledgeable others and computer models. However this distributed nature of reasoning only becomes evident through the spatial and temporal power of video.

The key idea we present in this paper is that none of this is possible without the use of a video-based methodology that utilises multiple cameras to capture not only the individual components of this network, but also the relations among its parts and the reasoning that emerges. Reasoning dynamically unfolds across time and space; video is our best chance to capture this. In this way video-based methodologies must underpin the investigation of computer-based manipulative abduction, in particular our efforts to understand the role of real and virtual actions.

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Acknowledgements

We thank Simon Lynch from Teesside University and the staff at the science education centre for their invaluable contributions to this research. We also acknowledge the tremendous support of the Video-based Research in Education (VRiE) working group at Deakin University.