Interactive and Gesture-Based Technologies: The Future For Learning or Merely Tools Used For Entertainment?

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Interactive and gesture-based technologies are becoming increasingly popular within many fields, ranging from interactive art and gaming to education and learning. Interactive technology is an appealing topic for those interested in immersion and interactivity. This is especially true when considering how such technologies can contribute towards and benefit different aspects of daily life. For example, interactive technology may be particularly interesting in the context of learning. Indeed, given that specific learning theories identify active engagement as a key feature for effective learning, the use of these technologies within learning could potentially prove invaluable.

This dissertation aims to examine the potential of interactive and gesture-based technologies within learning. The advantages, disadvantages and potential consequences of integrating these technologies into learning environments will be considered in order to determine the potential impact upon the learning process. A range of interactive and gesture-based modalities are considered, with a particular focus on hand-gesture based interaction. Additionally, this investigation serves as a framework for a hand-gesture recognition project that is situated within a learning context, in the form of teaching and learning the guitar. This project may prove important for identifying the technological and sociological limitations of using interactive and gesture-based technologies within learning.

Overall, this dissertation provides an analytic discussion as to whether gesture-based technologies may potentially enhance current learning practices by providing an effective, enjoyable, transferrable and interactive method of learning. It therefore contributes to the ongoing discussion as to whether or not the use of such technologies could be the future of learning. It is concluded that while such technologies may potentially be advantageous within learning environments, further technological developments are required before this potential is realised.
Chapter 1 - Introduction

‘If knowledge comes from the impressions made upon us by natural objects, it is impossible to procure knowledge without the use of objects which impress the mind.’ (John Dewey, 1916, p. 217)

Interactive and gesture-based technologies are becoming increasingly popular due to significant developments within both fields. Such technologies are also becoming increasingly prevalent within learning and are often considered an aid to the learning process. The term interactive technologies can have multiple meanings, but in a general sense the term refers to technologies that the user can interact with such as touch-screens, smart boards, webcams, standard controllers and projectors.

The concept of interactivity is often strongly associated with interactive technologies and derives from the adjective interactive. According to the Collins English Dictionary (2003), the term interactive relates to a ‘continuous two-way transfer of information between the user and the central point of a communication system, such as a computer or television.’ Many philosophers, psychologists and theorists have attempted to define the term interactivity over the years. Jonathon Steuer (1992, p. 84) has defined the term as ‘the extent to which users can participate in modifying the form and content of a mediated environment in real time.’ Frank Biocca (1998, p. 5) defines the term in a similar fashion stating that interactivity is ‘the name given to properties of a medium that stimulate properties of human interaction with the physical world and/or other humans (intelligent beings).’

Lev Manovich (2001, p. 59) defines interactivity in terms of how it affects the user. He refers to menu interactivity as ‘closed interactivity’ where the user determines which elements are accessed and states that this is ‘the simplest kind of interactivity’. On the other hand, he refers to 'implementations' such as computer programming and developing interactive systems as 'open interactivity', where the user's interactions determine how elements are generated (Manovich, 2001, p. 59). This dissertation primarily focuses on interactive and gesture-based technologies that are based on this ‘open interactivity’ (Manovich, 2001, p. 59) concept, where such systems require the user's input and interaction in order to generate content and provide feedback.
Interactive multimedia is another concept that can be closely linked with interactive technologies. Robin Phillips (1997) defines this concept:

> The term interactive multimedia is a catchall phrase to describe the new wave of computer software that primarily deals with the provision of information. The multimedia component is characterised by the presence of text, pictures, sound, animation and video; some or all of which are organised into some coherent program. The interactive component refers to the process of empowering the user to control the environment usually by a computer. (Phillips, 1997, p. 8)

The Greek philosopher, Aristotle, once said, 'For the things we have to learn before we can do them, we learn by doing them.' (Aristotle, cited in Bynum et al., 2005, p. 21:9). Indeed, a favoured teaching method is learning by doing and this is best associated with the term interaction. Interaction, in its simplest form, can be described as the act between two objects, people or living things. When related to the use of interactive technologies within learning, the term interaction can be defined as an individual using such technology in order to learn. Many people argue that learning by doing is the most effective way to learn; this dissertation aims to explore that argument. As the old Chinese proverb goes: 'Tell me and I'll forget; show me and I may remember; involve me and I'll understand.' (Chinese Proverb, N.D).

The learning by doing method is strongly associated with active learning. Active learning, popularised by Charles Bonwell and James Eison (1991), builds upon this approach and involves educating the learner by means of active participation. This involves the learner becoming engaged in the learning process by participating in some form of activity. This learning method will be discussed further in forthcoming chapters.

Gesture-based technologies can be classified as a specialist subtype of interactive technologies. They can be defined as systems that are purely based on the user’s movements; requiring them to move their hands, fingers, or body in order to interact. Examples of gesture-based technologies include data and gesture gloves, key gloves, motion tracking, heads-up-displays (HUDs), advanced controllers, biofeedback and even gesture-recognition software for facial expression and eye tracking. Such technologies can be incorporated into learning to form a gestural learning experience that may prove to be more effective than an unaided learning experience.
The term *gestural learning* can be defined as the use of gesture-based technologies within learning environments that essentially assist in the learning process itself. Such technologies currently exist and are in use today. For example, advanced controllers such as the *'Nintendo Wii-mote'* (Nintendo, 2006) are becoming common in modern society and are being used in many areas of education, including medicine. There are a number of studies supporting the use of such technologies within education (Institute of Medicine, 2002; Oka et al., 2002; Lee et al., 2005; National Public Radio, 2008; BrainLAB, 2008; Wachs et al., 2011). Such studies signify the potential impact that these technologies can have on education and learning. These studies will be analysed in the forthcoming chapters.

A wealth of research has focused on how such technologies may serve as an aid to the learning process (Chickering and Gamson, 1987; Bonwell and Eison, 1991; Lee et al., 2005; Izadi et al., 2007). In particular, two psychologists, Jean Piaget (1967) and Lev Vygotsky (1978) have been hugely influential in informing research and application design for interactive learning methods. Both are known for the *constructivism* learning theory with Vygotsky (1978) focusing more on *social constructivism*. Constructivism is one of three main perspectives in educational psychology, along with *cognitivism* and *behaviourism*. Constructivism can be defined as a dynamic process in which the learner constructs new ideas or concepts themselves, using their current and past knowledge (Learning with Frontiers, 1999). This learning theory will be examined in detail in the forthcoming chapter.

This dissertation will first outline learning theories and foundation principals that are embedded in everyday teaching practices. These include Dewey's (1938) ‘*experiential learning*’, Jerome Bruner's (1961) ‘*discovery learning*’, Piaget's (1967) ‘*constructivism*’, Vygotsky's (1978) ‘*social constructivism*’ and more recent theories including Bonwell and Eison's (1991) ‘*active learning*’ and Richard Mayer's (1998) ‘*multimedia learning*’. This will provide a foundation for an in-depth analysis of the argument in question; that is, whether interactive and gesture-based technologies can significantly enhance the learning experience. A successful learning experience in this case would be one that is effective, efficient, enjoyable, transferable, interactive and in line with constructivist principals. Relevant learning theories and research will be examined and existing interactive and gesture-based technology systems will be also be considered and critiqued.
The second chapter investigates the foundations of learning and consequent concepts. Learning models such as active, social and situated, experiential, discovery, interactive and gestural learning, and learning and play will be examined whilst foundation theories such as constructivism will also be considered. This chapter will also discuss major philosophers and psychologists and their respective theories relevant to the subject area. Consequently, situated, distributed and embodied cognition will also be examined. The argument will then be raised as to whether or not the use of interactive and gesture-based technologies can be advantageous within learning. This forms the basis of this paper and leads onto subsequent chapters detailing the use of such systems in modern society.

The third chapter serves as the main analysis of the use of such technologies within learning. This chapter explores the subject area by examining key terms such as interactive and gesture-based technologies, with a specific focus on hand gesture-based technologies such as the data glove, coinciding with the concept of hand-gesture recognition. The background history of interactive and gesture-based technologies will also be discussed, along with the major proponents in those fields. Finally, foundation learning theories and research established in the previous chapter will be drawn upon to examine and critique existing systems and the advantages or disadvantages such systems possess. This chapter seeks to construct a clearer view on the argument as to whether the use of such technologies within learning can be advantageous and therefore, whether learning is more effective and efficient using gesture-based systems.

The fourth and final chapter aims to provide a justified conclusion in answer to the original question as to whether the use of interactive and gesture-based technologies in learning can be beneficial to the learner.
Chapter 2 – Theoretical Foundations

‘Knowledge can be defined as providing self-regulating symbolic structures, developed by processes of assimilation and accommodation.’ (Gregory, 1987, p. 621-622)

This chapter focuses on the foundations of learning and consequent concepts ranging from constructivism, active learning and embodied cognition, to interactive and gestural learning. It aims to provide a solid framework for analysing the potential impact of the use of interactive and gesture-based technologies within learning in the forthcoming chapters.

Constructivism, Social Constructivism and Radical Constructivism

Constructivism has significant roots in education and is the driving force behind many teaching styles such as active learning, discovery learning and experiential learning. There are innumerable definitions for constructivism but most commonly associate the learning theory with Piaget (1967). Some even suggest that Piaget was the ‘most prolific constructivist in our century’ (Glasersfeld, 1996, p. 6) and that he is the ‘great pioneer of the constructivist theory of knowing’ (Glasersfeld, 1990). Constructivism is a conceptual framework in the philosophy of learning that stresses that an individual constructs knowledge by building upon his or her own experiences. It is important to note that constructivism is a learning theory and not a particular pedagogy. Ernst Von Glasersfeld (1996) provided an interesting definition for constructivism:

Indeed, constructivism is a theory of active knowing, not a conventional epistemology that treats knowledge as an embodiment of Truth that reflects the world “in itself”, independent of the knower. (Glasersfeld, 1996, p. 2)

The foundations of constructivism may be traced back to Piaget (1967). However, unbeknownst to Piaget, the Italian philosopher Giambattista Vico (1710) had previously formulated key ideas that provide the basis for key principles of the constructivist theory in his epistemological treatise. One of Vico’s key ideas revolved around the concept that knowledge of a ‘thing’ is only truly gained if one knows the components that it consists of, stressing that ‘to know means to know how we make’ (Vico, 1710 cited in Glasersfeld, 1996, p. 4). Furthermore, despite Piaget being commonly acknowledged as the source of constructivism, it is worth noting that Piaget was heavily influenced by the ideas of Immanuel Kant (1724-1804).
Constructivism has its roots in the cognitive theories of Piaget (1967) and Vygotsky (1978), with Piaget discussing active learning, assimilation and accommodation and Vygotsky considering group work and social constructivism. Piaget saw knowledge as a composition of schemas (Piaget, 1971), which consist of past experiences and serve as a basis for understanding new ones. These schemas may be modified by the complementary processes of assimilation and accommodation. Assimilation involves modification of perceptual inputs by existing knowledge-structures, while accommodation embraces modification of those knowledge-structures to adapt to the input (Gregory, 1987, p. 622).

Piaget's theory on constructivism (1967) emphasises that in order for knowledge and understanding to be achieved, the learner must be active in their environment and learn not through direct instruction, but from opportunities in which they can discover and invent themselves (Gregory, 1987, p. 622). Consequently, Piaget views the construction of knowledge by a cognising subject as a process in which distinctions and coordinations are established in the individual’s own perceptual field (Piaget, 1937).

Vygotsky (1978) takes a slightly different approach to constructivism and is largely credited for the development of social constructivism. Social constructivism is a learning theory strongly associated with constructivism, but differs in that it focuses primarily on social learning experiences that promote group construction of knowledge. Thus, Vygotsky views knowledge as not individually constructed, but rather co-constructed from interaction with other people (Meece, 2002). Indeed, Vygotsky saw ‘tool and sign-using behaviour as essential for all higher forms of psychological processes’ (Gregory, 1987, p. 805). Vygotsky emphasises this point in his book Mind in Society (1978) where he details the process of a child’s cultural development as being primarily social:

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\text{Every function in the child's cultural development appears twice: first, on the social level, and later on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formulation of concepts. All the higher functions originate as actual relations between human individuals. (Vygotsky, 1978, p. 57)}
\]
Another constructivist approach is that of radical constructivism, popularised by Glasersfeld (1996). According to Glasersfeld (1996), the origins of the term radical constructivism can be traced back to the philosopher George Berkeley (1710). Glasersfeld (1996) outlines two basic principles of radical constructivism:

1. Knowledge is not passively received either through the senses or by way of communication, but it is actively built up by the cognising subject.
2. The function of cognition is adaptive and serves the subject’s organisation of the experiential world, not the discovery of an objective ontological reality. (Glasersfeld, 1996, p. 2)

Specifically, the meaning of knowledge is defined by the individual and corresponds to reality as they experience it. Furthermore, Glasersfeld (1996, p. 5) suggests that radical constructivism shares key concepts with pragmatism, stating that both have shared attitudes toward knowledge and truth. Pragmatism, a term coined by philosopher Charles S. Peirce in 1878 (cited in Gregory, 1987, p. 631), suggests that the knowledge or meaning of an object or idea, can only be found in its practical consequences. This therefore highlights the importance of experimental methods in learning, hence offering support for pedagogical approaches that promote active learning. Additionally, pragmatism appears to be a central element to most theories associated with the constructivist approach.

In sum, the constructivist theories outlined above emphasise the importance of active engagement in promoting successful learning. Thus, it may be argued that these constructivist approaches support the use of interactive and gesture-based technologies within learning, given that they promote a more active learning experience.

**Active, Experiential and Discovery Learning**

Active learning derives from the concept that students who are actively engaged in the learning process are far more likely to recall the knowledge they have constructed later (Bruner, 1961). Active learning is commonly associated with Piaget (1967) and his cognitive theories. It is evident that he was a firm believer of the active approach to learning, even for adults: ‘Experience is always necessary for intellectual development... the subject must be active...’ (Piaget, 1980). Furthermore, according to Mayer (2004, p. 14), individuals learn most effectively not by being behaviourally active during learning, but rather cognitively active, thus emphasising Piaget’s cognitive theories. Conversely, it could be argued that Edward Thorndike was the pioneer of active learning, especially when
examining his *law of exercise* theory which states that individuals *learn by doing* and *forget by not doing* (Thorndike, 1905, 1911).

Active learning is a term that was popularised by Bonwell and Eison (1991) in their text *Active Learning: Creating Excitement in the Classroom*, which focused primarily on an instructional approach to active learning methods within a classroom context. Bonwell and Eison (1991) highlight cognitive research, which has revealed that individuals learn most effectively by using pedagogical techniques, rather than standard lecturing. They also cite a significant number of other research studies, which have shown that active learning is far more superior to lectures, in terms of promoting the development of the student’s skills in higher-order processes such as analysis and evaluation (Bonwell and Eison, 1991).

Despite most of Piaget’s research (1937, 1967) being focused primarily on children, an increasing body of research also indicates the effectiveness of active learning for older learners (Chickering and Gamson, 1987). Analysis of the research literature by Arthur Chickering and Zelda Gamson (1987, p. 2) suggests that students must be *engaged* and, more importantly, take an active role in their learning in order to construct knowledge most effectively. Chickering and Gamson (1987, p. 2) stress that the learner must ‘*make what they learn part of themselves*’ by using past experiences to construct new knowledge, building upon existing knowledge and then applying it to their daily lives. They believe that students learn very little if there is no active participation and that tactics which promote active learning benefit the students significantly more than less active strategies (Chickering and Gamson, 1987).

However, as with most learning methods, certain challenges and obstacles must be surmounted in order for active learning to be successful. For example, within a classroom context there are specific challenges that active learning methods face (Bonwell and Eison, 1991). Such challenges include limited class time, the potential difficulty of incorporating active learning with large numbers of students and, according to Bonwell and Eison (1991), the greatest challenge of all; the risk that students will not participate in such active learning methods (1991). However, despite the challenges of active learning methods, it is clear that interactive and gesture-based technologies are consistent with the key principles of active learning theories. Thus, interactive and gesture-based technologies promote both
interaction and active engagement, processes that are emphasised by active learning theorists to enhance learning.

Experiential learning is yet another method based upon constructivist views and relates to the construction of knowledge through practical and hands-on learning approaches (Kearsely, 2011). The term experiential learning is often used interchangeably with active learning. Experiential learning can be defined as the process of making meaning from direct experience (Itin, 1999) and according to David Kolb (1984); knowledge is continuously gained through both personal and environmental experience (cited in Merriam et al., 2007). Dewey (1916) was a major proponent of experiential learning and stressed that knowledge was best achieved as part of an interactive and practical process. Therefore, one could argue that experiential learning methods also support the use of gesture-based technologies within learning, given that they emphasise a predominantly hands-on interactive approach.

Similarly, discovery learning requires the learner to discover new rules and ideas, rather than just reiterating material provided by the teacher (Mayer, 2004, p. 15). Discovery learning methods differ from constructivist principles in that the learner does not construct knowledge purely alone, rather they construct knowledge with guidance from others; namely the teacher. According to Mayer (2004, p. 15) there are three types of discovery learning: pure discovery, where students receive problems to solve with no assistance from the teacher; guided discovery, where students receive problems with moderate assistance from the teacher; and expository discovery, where students receive problems along with the correct answers.

Several studies have assessed the effectiveness of the three discovery methods. For example, Robert Gagné and Larry Brown (1961) found that guided discovery methods provided the most effective results. Consequently, one could argue that in terms of discovery learning, individuals learn most effectively when they are given feedback and assistance when trying to solve problems and construct knowledge. Indeed, Mayer (2004, p. 15) suggests that guided discovery methods may complement constructivist learning. It is important to note that discovery learning, as well as the previously mentioned learning theories, are all essentially pedagogically equivalent approaches (Kirschner et al., 2006, p. 75). Importantly, a key strength of gesture-based technologies is that they offer continuous
real-time feedback to the learner. Thus, discovery learning methods strongly support the use of gesture-based technologies within learning.

**Social and Situated learning**

The term *social learning* can be attributed to Albert Bandura (1977). According to Bandura’s Social Learning Theory (1977, cited in Kearsley, 2011), most human behaviour may be defined in terms of continual interaction between cognitive, behavioural, and environmental influences. Bandura (1977, cited in Kearsley, 2011) argues that the majority of human behaviour is learned through modelling; that is, observing the behaviours, attitudes, and learning styles of others in order to direct one’s own behaviour. This theory draws upon the work of Vygotsky (1978) and Jean Lave (1991), both of whom emphasise social learning as playing a fundamental role in the learning process.

*Situated learning* is a term often credited to Lave and Etienne Wenger (1991) and is strongly related to the *social development* work of Vygotsky (1978), which states that social interaction plays a vital role in the process of cognitive development (Vygotsky, 1978). Lave and Wenger (1991) argue that learning is *situated* due to the activity, context and culture in which it occurs, with social interaction being a fundamental component in order to create an active and engaging environment (Lave and Wenger, 1991). These ideas are part of what Lave and Wenger (1991) call the process of *'legitimate peripheral participation’*. Lave and Wenger (1991) believe that two key principles define *situated learning*; firstly, that knowledge must be presented in a specific context; secondly, that learning requires social interaction in order to be truly effective.

According to John Anderson et al., (2000), there are multiple arguments against situated learning from a cognitivist perspective. Firstly, supporters of situated learning believe that activity and learning are embedded into the specific situations in which they occur. However, in contradiction to that, some argue that learning being embedded into specific contexts depends on both the type of learning and the method in which it is learned (Anderson et al., 2000). Secondly, while situated learning theorists claim that knowledge does not transfer between activities, others argue that it depends solely on the extent to which a task is completed (Anderson et al., 2000). Conversely, despite these arguments, one could argue that social and situated learning theories support gestural learning, in that learning is *situated* due to the activity in which it occurs (Lave and Wenger, 1991).
However, in contradiction to this, one could also argue that social learning theories do not support gestural learning, given that some gesture-based systems are aimed at individual use. However, this is not true for those gestural learning systems that implement multi-user aspects.

**Situated, Distributed and Embodied Cognition**

Situated cognition is often associated with situated learning and stresses that knowledge is best achieved through social, cultural and physical activity (Greeno and Moore, 1993). Situated cognition and *situated learning* were both developed by Lave and Wenger (1991), who were influenced by many philosophers including Dewey (1938), Piaget (1967), and Vygotsky (1978). The term, *situated cognition* was popularised by John Brown, Allan Collins and Paul Duguid (Brown et al., 1989). They suggest that situated cognition refers to the process by which concepts or ideas continually evolve with each new occasion of use and that meanings are continually being constructed (Brown et al., 1989). Furthermore, they suggest that situated cognition emphasises *immersive learning*, in that an individual will learn far more effectively if they are physically and mentally immersed in the context about which they are learning.

* Distributed cognition is a psychological theory that can be credited to Edwin Hutchins (1995), who suggested that knowledge not only lies within the individual, but also in the individual’s social and physical environment. Thus, distributed cognition revolves around the idea that cognitive activity provides a system for thinking and constructing knowledge. This essentially allows the individual to offload information into the environment to *free up their mind* for other incoming information. Distributed cognition focuses on defining the mechanisms of cognitive processes by examining how knowledge is distributed across objects, individuals, and the environment (Hutchins, 1995). The concept of distributed cognition is worth noting for its acknowledgement of interaction between humans, machines and environments and could prove useful when examining the effectiveness of interactive and gesture-based technologies within learning.

Embodied cognition entails the single, unified interaction of the mind and body, where movements are based on the immediate interaction with one’s current environment. Embodied cognition focuses on the idea that cognition is embodied, situated, body and movement-based, environmentally based, and action-orientated (Wilson, 2002, p. 625).
George Lakoff and Mark Johnson (1999) draw upon a wealth of research and evidence from cognitive theories and embodiment effects to support their theory of embodied cognition. For example, they draw upon research including mental imagery, image schemas, gestures and colour concepts (Lakoff and Johnson, 1999). From this evidence, they suggest that an individual’s conceptual and linguistic structures are shaped by the peculiarities of their own perceptual structures (Lakoff and Johnson, 1999).

Importantly, situated, distributed and embodied cognition all emphasise the importance of the interaction between the user and the system. Therefore, all three of these theories must be considered when designing gesture-based systems to be used within learning.

**Interactive and Gestural Learning**

Interactive learning is a term that builds upon constructivist principles and stresses the need for active participation in the learning process (Sessoms, 2008, p. 91). Interactive learning is often used interchangeably with *multimedia learning*, which details that individuals learn by using both auditory and visual stimuli (Mayer, 2001). Buckminster Fuller (1962) provides an interesting view on the use and effectiveness of computers within learning:

> Computers, suddenly making human beings obsolete as specialists, force them back into comprehensively functioning… and computers as learning tools can take over much of the “educational metabolics”, freeing us to really put our brains and wisdom to work. (Fuller, 1962, p. 117-118)

According to Diallo Sessoms (2008), creating interactive learning environments are paramount for improving learning as learners change and technology advances. Alfred Bork (1980) also suggested that students should use technology as a tool to aid learning, which in turn would benefit the learning process by providing them with, arguably, more effective methods of learning.

Consequently, Sessoms (2008) provides a framework, which can be applied to interactive learning and teaching. This consists of a constructivist approach in theoretical terms, interactive tools, interactive learning and teaching and ‘interaction between students and teachers’ (Sessoms, 2008, p. 88).
This *interactive teaching and learning* framework highlights the processes required to effectively implement an interactive learning environment (Sessoms, 2008, p. 88). However, as technology continuously evolves, a sophisticated *interactive learning system* could potentially replace the role of the teacher, by providing both tasks to complete and continuous real-time feedback. In this respect, interactive and gesture-based systems and the extent to which they could potentially fulfil this role in providing effective and educative learning tools will be discussed in the next chapter.

*Gestural learning* is closely related to *interactive learning* but with a particular focus on the use of gesture-based technologies and gesture-recognition that act as learning tools. As mentioned in the introduction, gestural learning involves technologies that require the learner to take an active role when interacting with material, with a specific focus on hand,
finger, and body movement. Such technologies include data gloves, head-mounted displays, advanced controllers (Wii-mote), as well as motion-tracking and gesture-recognition software. As outlined above, an important aspect of gestural learning is the ability to receive constant feedback throughout the learning process. Marcy Driscoll (2002) states that learning is best achieved when students receive feedback about their learning, especially when combined with the opportunity for reflection. Thus, technology that incorporates constant feedback and promotes time for reflection could potentially provide a viable solution for improving the learning experience (Driscoll, 2002).

Gestural movements are predominantly learnt with gestural learning technologies. Such gestural movements are particularly important within certain fields. For example, within the medical field, surgeons must learn specific hand movements required to complete surgery successfully (Institute of Medicine, 2000; National Public Radio, 2008). Furthermore, gestural learning experiences may prove particularly effective given that they require the learner to be an active participant in the learning process, the benefits of which were discussed above. Thus, one could argue that the use of such systems to aid learning could prove invaluable within certain fields such as medicine. Gestural learning and gesture-based technologies will be examined and discussed further in the forthcoming chapter.

Another important aspect is learning and play. Play is an underrated, yet extremely important, promoter of learning throughout life. Kenneth Eble (1968) poses the question as to whether education begins in play and continues in play for the rest of our lives. Bork (1980) defines a critical aspect of play and how it is always an active process, therefore promoting constructivist principles and active learning:

One critical aspect of play is that it is always an active process. The child, or the adult, engaging in games for learning or for pleasure, is playing an active role, constantly interacting with the environment and manipulating the environment. (Bork, 1980, p. 3)

Mitchel Resnick (2004), a professor for learning research at MIT, also argues for a playful learning experience. Resnick (2004, p. 1) argues against the term ‘edutainment’ and states that he prefers the term playful learning. Playful learning is an example of the active pedagogic approach to learning. Therefore, playful learning can also be linked with other pedagogical approaches such as experiential learning, interactive learning, and even the
foundation constructivist approach. Playful learning is consistent with these theories as they stress that the most effective form of learning is achieved when the individual is an active participant and fully engaged in the learning process (Resnick, 2004, p. 1). However, caution is warranted given the danger that students could become too engaged with the playful aspect, losing focus on the learning process itself. Indeed, it may be argued that there is a fine line between learning whilst playing and playing simply for fun. This must be taken into account when designing interactive and gesture-based systems for learning, particularly for those which incorporate games.

Despite these caveats, it is evident that play is indeed an important aspect in the learning process, especially when examining Piaget’s research on children’s learning processes (Piaget, 1967). One could argue that through play we gain most of our experiences, which in turn provides a basis for how we construct knowledge in the future. Therefore, play appears to be an important aspect in how individuals construct knowledge and is consistent with constructivist approaches to learning. Arguably, gesture-based technologies used within learning build upon this by incorporating this playful aspect and active engagement into the learning process itself. By promoting play and active engagement, such systems may potentially provide a more effective and efficient method of learning.

**Chapter Summary**

This chapter has established a solid foundation that outlines effective methods of learning whilst also exploring the potential of interactive and gestural learning methods. This provides a framework for analysing and critiquing the use of interactive and gesture-based technologies within learning. The next chapter will build upon the theories discussed here to analyse these technologies and consider whether they can provide an effective, efficient, enjoyable, transferable and interactive way of learning. The use of technology within education is vastly increasing with gesture-based technologies becoming increasingly popular. Thus, the important question is how effective are these technologies when used within learning?
Chapter 3 – Analysis of Interactive and Gesture-Based Technologies within Learning

‘Any sufficiently advanced technology is indistinguishable from magic.’ (Arthur C. Clarke, cited in Bynum et al., 2005, p. 125)

Technology has advanced exponentially over the past decade and most significantly in the past ten years, especially in relation to interactive and gesture-based technologies. The previous chapter established the theoretical foundations, most of which point toward an active learning process as being the most effective and efficient method of learning. This chapter draws upon these foundations in order to analyse how interactive and gesture-based technologies can potentially be beneficial to the learner. A range of interactive and gesture-based modalities will be covered, with a specific focus on the advantages and disadvantages of using gesture-based technologies within learning.

History of Interactive Technologies

The study of user-to-system interactivity derives from research into human factors that details the way in which humans respond to information presented to them by a computer or an interactive system (Guedj et al., 1980). Biocca (1993, p. 63) wrote that the term ‘human factors’ refers to fundamental characteristics of human performance and behaviours that must be considered when designing and implementing any form of interactive system. Thus, human factors critically influence the design of such systems. Ben Shneiderman (1998) stresses that designers of user interfaces should plan to accommodate human diversity by focusing on five human factors (Shneiderman, 1998; Turk and Kolsch, 2003, p. 4):

1. ‘Time to learn’
2. ‘Speed of performance’
3. ‘Rate of errors over time’
4. ‘Retention over time’
5. ‘Subjective satisfaction’

These factors must therefore be considered when designing interactive and gesture-based systems for use within learning.
Embodied interaction also plays a significant role in the design of interactive systems. Embodied interaction can be defined as the study or analysis of how users interact with computer systems that occupy our world (Dourish, 2001, p. 3). Such information is key to the development of an effective interactive system.

According to Sessoms (2008), an interactive learning system must be supported by teacher development programs in order to be effective. These programs must emphasise interactive pedagogies that promote the implementation of interactive teaching and learning with interactive tools (Sessoms, 2008, p. 86). It is also evident in Sessoms’ text (2008, p. 87) that if interactive tools are to be truly effective we need to educate and encourage teachers to treat learning as an interactive process with the aid of interactive tools.

Interactive technologies have developed significantly over the past century and range from interactive boards and crickets, to more complex systems such as flight training simulators and medical simulations. One of the most common types of interactive technology currently used in education is the interactive board. These emphasise the fundamental notion of constructivist approaches to learning. Thus, they promote active participation and stress that individuals learn effectively by being challenged through ‘technology based interactive learning environments’ (Sessoms, 2008, p. 89). The effectiveness of interactive boards has been discussed by Sessoms (2008). He argued that interactive boards facilitate learning by providing the student with the opportunity to engage with content in multiple ways (Sessoms, 2008). For example, he argued that the visual nature of interactive boards allows students to develop the schemata required for new learning (Sessoms, 2008). Furthermore, interactive boards encourage students to learn by doing (Sessoms, 2008, p. 89), a concept which is in line with the constructivist theories outlined previously in Chapter 2. However, it is important to distinguish the differences between learning with interactive boards compared to specialist gesture-based systems. For example, interactive boards focus predominantly on the individual learning content that is visible on the screen, whereas gesture-based systems focus more on learning specific physical movements; this is especially evident in medical simulators (BrainLAB, 2008; National Public Radio, 2008; Solomon et al., 2011; Wachs et al, 2011). Gesture-based systems will be further discussed later in the chapter.
Finally, Crickets are tiny interactive computers which can be programmed to perform multiple tasks such as the control of motors and lights, to receive information from sensors and to communicate with other crickets via infrared light (Resnick, 2004, 2007). Research has revealed (Resnick, 2004, 2007) that children who use crickets learn more effectively and have more enjoyment whilst learning when using these interactive tools, due to being actively involved and learning whilst they are playing (Resnick, 2004, 2007). Such findings suggest that interactive tools can have a significant impact upon an individual’s learning process, resulting in a far more effective and enjoyable experience for the learner. Interactive technologies appear to provide an effective and efficient learning aid within a wide range of fields. However, can gesture-based technologies provide the same benefits?

**History of Gesture-Based Technologies and Gesture Recognition Systems**

Gesture-based technologies are becoming increasingly prevalent within many aspects of life, ranging from pleasure and gaming, to medical and educational. Educational gesture-based technologies remain to be fully integrated; however, they have proven effective in several areas thus far. For example, a study carried out by researchers at the Banner Good Samaritan Medical Centre in Phoenix, Arizona in 2008, revealed that ‘trainee surgeons who played the Nintendo Wii before going into a virtual surgery training test performed almost 50 percent better on the exam’ (National Public Radio, 2008). Similarly, Wachs et al., (2011) found that gesture-based systems, which offer virtual surgeries, allowed surgeons to learn and train most effectively before performing the surgery itself. Such evidence therefore demonstrates the potential of using such technologies to aid and improve learning.

It is important to note direct manipulation when discussing gesture-based technologies, especially gestural interfaces. The term direct manipulation was coined by Shneiderman (1983). Direct manipulation refers to the study of human-computer interaction, which revolves around allowing the user to directly manipulate objects and the menu interfaces with which they are interacting. This is especially important in gesture-based systems. An example of direct manipulation in a gesture-based system could involve the user resizing a graphical shape, such as a square, by dragging its corners or edges with their fingers. This form of interaction is evident in multiple technologies, including Jeff Han’s Multi-touch Screen (Han, 2006) and the hugely popular iPhone (Apple, 2007) and iPad (Apple, 2010).
Consequently, this has generated a wealth of research and development focusing on activities and devices that involve natural user interaction (Paul, 2004; Han, 2006; BrainLAB, 2008; Microsoft, 2010; Oblong Industries, 2011). These primarily aim to achieve and sustain natural interaction between the system and the user.

**Examples of Gesture-Based Systems and Gestural Interfaces**

Flight training and medical simulators have also been developed as interactive systems over the years. The use of computers and digital technology in flight simulators began in the early 1960s. They usually consisted of TV screens in front of a replica cockpit that displayed the computer generated imagery such as the landscape and airports. By the late 1970s, several companies had begun developing flight simulators all over the world. Trainee pilots were trained to a required standard in these simulators before they were allowed to fly the real plane. The use of flight simulators to train pilots is incredibly beneficial. Firstly, flying is particularly dangerous; the simulators allow pilots to practice emergency procedures and extreme manoeuvres without endangering lives. Furthermore, they also provide a cost-effective method of tuition. In both respects, flight simulators have proved extremely effective over the years and the complexity and realism of such systems are constantly improving (Halldale Media Group, 2010).

Interactive systems have also been implemented to develop medical simulators for use in medical training. These simulators can consist of a variety of technology including data gloves, gestural interfaces, augmented reality and even full-size human body dummies that act as patients. Medical simulators have been used worldwide for many years and have also proven effective, much like flight simulators. According to the Institute of Medicine (2000), there are between 44,000 and 98,000 deaths annually due to medication errors and medical mistakes during treatment. Consequently, many have argued in support of medical simulators, stating that the use of such technology will improve the education of medical students and therefore reduce patient risk and the number of deaths due to medical mistakes (Solomon et al., 2011). Furthermore, medical simulators eliminate the requirement for one-on-one continuous instructor observation by providing real-time feedback (Solomon et al., 2011). Not only does this improve the learning process but it would significantly reduce the time and cost of expert instructors (Solomon et al., 2011).
However, although the potential benefits of medical simulators are clear, they are perhaps not used widely to their full potential. As they are a relatively new and emerging technology, they are limited by both expensive purchase and running costs. Nevertheless, as technological advancements occur, these limitations should resolve over time. Furthermore, although initial costs are high, such systems eliminate the use of both cadavers and animal models. Therefore, not only may such systems prove more ethically acceptable but they also significantly reduce costs in this respect (Solomon et al., 2011).

Another example of an interactive, gesture-based work that incorporates a gestural interface to create an interactive environment is A-Volve, by Christa Sommerer and Laurent Mignonneau (cited in Paul, 2004, p. 141). This work integrates direct manipulation and embraces gesture-based technology to identify and track the user's hand and finger movements on a touch-screen. This allows users to produce three-dimensional creatures that then begin living in the water, which is encompassed by the interactive environment. These creatures then evolve and reproduce in reaction to the user's hand movements. It could be argued that A-Volve is actually an effective learning tool that enables users to keep active by interacting with the work, yet also learn about the basics of evolution and survival at the same time.

In 2006, the famous gesture-based games system, the Nintendo Wii (2006), was released worldwide. The Nintendo Wii consists of a console and two controllers, a Wii remote and a Nunchuk unit, and incorporates haptic technology. The remote is the primary controller and contains built-in sensors that consist of accelerometers and infrared detection. These allow the identification of the user's hand gestures that are used to play the game. The Nunchuk unit also contains accelerometers that provide the basis for gesture recognition in the game.

The Nintendo Wii is proving to be an effective means of learning through play and there are a variety of games that focus on learning in an interactive, gesture-based, and enjoyable manner. The term Wii Learning has been developed over the past few years and is based on the concept of using the Nintendo Wii as a learning tool for multiple skills. This is especially evident in learning sports such as tennis and baseball, as the user gains an understanding of the physical movements required (Weir, 2008). Specifically in relation to gestural learning, as mentioned earlier in the previous chapter, the use of the Nintendo Wii in
medical training has proved to be a very effective tool (National Public Radio, 2008). Consequently, it has become increasingly popular for use within learning environments.

Microsoft’s Kinect for the Xbox 360 (Microsoft, 2010) is a gesture-based interface and is one of the latest commercial products in gesture-based technology. The Kinect incorporates two cameras, one used for face tracking and taking pictures, while the other distributes infrared light to accurately model objects and people within range. The Kinect uses the information it detects from the user to perform a variety of functions in the game; waving a hand in the air may cause the character in a game to cast a spell for example. However, despite Microsoft’s Kinect being aimed primarily for use in games, one could argue that the use of such motion-tracking and gesture recognition software could actually be used within learning too. For example, such systems are currently in use today to train surgeons in virtual surgeries, providing them with real-time feedback and giving them the chance to practice innumerable times before performing the actual surgery (Wachs et al., 2011). Some systems even incorporate robotic devices, which surgeons can operate to aid with surgery (Venere, 2011). Furthermore, a team of cardiothoracic surgeons from the School of Medicine in New York University have developed a virtual reality system that integrates tactile feedback (Solomon et al., 2011). This system provides surgery training using haptic devices and medical visualisations. The study revealed that trainees responded well to the system and that some of the problems associated with typical hands-on surgical instruction (i.e. tissue destruction and patient risk) were successfully resolved (Solomon et al., 2011).

Gestural interfaces also play a significant role in gesture-based technologies, especially in relation to learning. Gestural interfaces include technologies such as touch screens and multi-touch screens. Large multi-touch screen displays allow multiple users to interact with content simultaneously, therefore supporting collaborative work among students and potentially providing an effective tool for learning (Oka et al., 2002; Lee et al., 2005; Han, 2006; Microsoft, 2007; Oblong Industries, 2011). Multi-touch screens have also been used in medical training. For example, BrainLAB’s Digital Lightbox (BrainLAB, 2008) was developed to provide doctors and surgeons with the ability to view and manipulate data from MRI and other scan images.
In summary, evidence suggests that existing gesture-based systems offer significant benefits to a wide range of learning environments. Furthermore, these benefits might be expected to increase with future technological developments.

**Gesture Recognition**

The term *gesture recognition* is commonly associated with gesture-based technologies. Researchers and proponents of such technology argue that gesture recognition has significant potential for a variety of uses, ranging from educative medical tools to military applications (Geer, 2004, p. 20). Gesture recognition systems detect human gestures and convert them to *input data*, which are sent to the device, application or computer system. Existing devices that incorporate such technology include computers, games, mobile phones and even MP3 players such as the iPod, with its scrolling functionality to scroll between songs and playlists (Geer, 2004, p. 20). Gesture recognition systems can be traced back to the early 1960s, when one of the first gesture-based systems was developed. This system introduced the use of a light-emitting pen that allowed users to control a Sketchpad computer-aided design system (Sutherland, 1963, p. 329-346).

It is worth noting an important characteristic of many gesture recognition systems called the *Hidden Markov Model (HMM)*. The HMM is particularly noteworthy for its temporal pattern recognition. This model detects hand and finger motions as symbolic events based on a probabilistic framework, which in turn distinguishes symbolic gestures given by the user for application in gesture-based systems (Oka et al., 2002, p. 64). The HMM is often used within gesture recognition systems. It is a key feature that allows such systems to correctly identify and compute gestures, therefore providing the framework that allows these systems to function correctly.

There are many different types of gesture recognition systems, but most commonly they consist of either computer vision software or glove-based technologies. Computer vision software incorporates a camera that detects the user's gestures and relays this information to the gesture-based system to perform a specific function. Glove-based gesture recognition systems take a more physical approach to detecting the user's gestures by identifying and processing their hand and finger movements. The hand and finger movement data is then relayed back to the system to perform a specific function. Data gloves are a common tool used in gesture-based systems and provide the user with an
immersive experience with minimal difficulty. Paul Dourish (2001) provided an interesting definition of *data gloves* in the context of *virtual reality*:

*A data glove is a glove augmented with sensors that report the position and orientation of the hand and fingers to a computer; the hand of the user wearing the glove is projected as a virtual hand into the same computer-generated three-dimensional space that the virtual reality system generates, so that the user can pick up virtual objects, examine them, move them around, and act in the space.* (Dourish, 2001, p. 38)

Another type of gesture-based equipment is the head-mounted display. In the 1960s, Ivan Sutherland developed one of the most pioneering virtual reality systems of its time, which incorporated the use of a *head-mounted display (HMD)* (cited in Packer and Jordan, 2001, p. 233). A HMD is a helmet-shaped apparatus designed to fully immerse the user in a virtual, three-dimensional environment and is often used in interactive, immersive systems (Packer and Jordan, 2001, p. 233). HMDs have been used in multiple interactive training systems, such as the flight training simulators discussed earlier, and have proven to be an effective training and learning tool.

In relation to computer interfaces there are two types of gestures; offline gestures, which consist of gestures that are used to interact with menus for example; and online gestures, which consist of gestures that are used to interact with virtual objects by rotating, scaling and positioning them. Gesture recognition has been used with computer interfaces for fulfilling many varied roles in gesture-based systems such as sign language recognition, facial gesture recognition, eye tracking, gestural-based interfaces, immersive and gestural-based games and virtual controllers such as the Nintendo Wii (Nintendo, 2006).

According to David Geer (2004) the use of gesture recognition would benefit disabled people due to the fact that they frequently have trouble interacting with standard input devices. Consequently, Geer (2004, p. 20) argues that they would benefit greatly from gesture-based technologies that detect eye movements, head motions and other gestures. This can also be applied to interactive learning systems as the use of eye and head motion detection in gesture-based technologies could potentially assist disabled people significantly in the learning process. For example, an individual that is disabled and can’t move their hands without great difficulty could benefit from a gesture-based system that incorporates eye tracking to perform specific tasks; eye movements could initiate mouse movements on a computer for example. Indeed, a gesture-based product that is aimed at
helping disabled people is *Navigaze* (Cybernet, 2001). *Navigaze* enables users to interact with applications by moving their head to move cursors and by blinking their eyes to perform mouse clicks. This system was created to aid disabled people who can only use their heads and eyes to interact (Geer, 2004, p. 22). One could argue that the use of such systems within learning is consistent with active learning methods, consequently providing the learner with a more effective and efficient learning experience.

Many gesture-based systems have been developed to aid the disabled with carrying out certain tasks such as interacting with applications, performing specific tasks on computers and more importantly, learning. For example, Lee et al., (2005) explored the effectiveness of using gesture-based games, developed at the Georgia Institute of Technology in Atlanta, for helping deaf children to learn sign language. The game incorporates the use of a camera to detect and record the user's gestures and uses this to relay information to the system, which in turn sends feedback to the user. By giving the learner real-time feedback it helps to create an effective, efficient and enjoyable way of learning sign language. However, despite this being an effective interactive learning tool for deaf children, it suffers from several limitations, namely the effects of varying lighting conditions as the cameras encounter difficulty when identifying gestures in dark environments.

There are a variety of gesture recognition products that are used to educate, train and inform individuals on various aspects of life. One such product developed by iMatte called *iSkia* (iMatte, 2005) is a technology that captures the user's gestures, which in turn allows them to interact with projectors and screens by simply moving their hands (Geer, 2004, p. 21). This technology could prove useful in education as it allows teachers to easily interact with the learning material and present in a far more effective and efficient manner. Thus, emphasising active approaches and providing a far more interactive learning process.

**Haptic Technology**

*Haptic technology* also has strong links to gesture-based technologies. The term *haptic technology* derives from a combination of the Greek word ‘*haptikos*’, meaning one's perception of the sense of touch, and technology (The American Heritage Dictionary, 2002). It is based upon the concept of using tactile feedback technology to provide the user with various forces, vibrations, and motions, which in turn stimulates their sense of touch. This technology therefore provides the user with mechanical stimulation. It can be used to
assist in controlling virtual objects, enhanced controlling of remote control machines and devices, and can even be used for training purposes such as medical training in virtual surgeries. However, this technology should not be confused with touch and tactile sensor technology such as touch-screens and data gloves, due to the latter purely measuring the force exerted by the user in relation to an interface, rather than providing force feedback per se.

Haptic technology is used in medical simulators for training surgeons (Solomon et al., 2011; Wachs et al., 2011) and flight simulators for pilot training. For example, it has been used in multiple medical simulators, such as those used to teach remote surgery (Simulated Surgical Systems, 2011). A great advantage of using such training systems is that it provides the trainee surgeon with almost unlimited practice time, offering ample opportunities to improve their skills. It also allows them to carry out certain procedures using haptic technology-based systems, which in turn reduces fatigue and improves efficiency (Wachs et al., 2011). Furthermore, the use of this technology within learning builds upon active learning methods and promotes active engagement of the user.

**Challenges Gesture-Based Systems Face**

While gesture-based systems have proved beneficial (Oka et al., 2002; Han, 2006; BrainLAB, 2008; Wachs et al., 2011) they also have their limitations. For example, there are a number of potential problems to overcome when aiming to sustain natural user interaction in gesture-based systems. One such problem involves the requirement of specialised devices such as *surgical simulators*, which have excessive running costs and power consumption. However, whilst such devices may prove costly at present, future technological advancements might be expected to resolve these issues in terms of reducing power consumption and running costs.

Another challenge is that teachers must be provided with the time and technical support to explore and become confident with such technology on their own, before using it within a classroom environment. Additionally, another limitation revolves around the physical use of such systems within learning due to the fact that most interactive and gesture-based systems are designed for use by a single, individual learner, not multiple learners at the same time. To solve this, multiple systems would be required within each learning environment, essentially giving each student their own interactive learning system, or
implement multi-user features within such systems to accommodate a larger number of students. Another limiting factor involves the matter of fatigue. For instance, after a short time of using a gestural interface the user could develop arm fatigue, which in turn could lead to a loss of performance and could potentially lead to less effective learning. Future technological advancements should aim to develop a solution for this potential limitation. Finally, perhaps the most limiting factor at present concerns the requirement for a common gesture language, which the user must learn in order to interact with the system effectively. Thus, such systems require a period of time in which the user must learn to use the system itself before they can begin to learn the material or physical movements. However, as the current and future focus is upon natural user interaction, in time this should prove more intuitive in terms of the gesture language required. This should therefore help to improve the usability of such systems.

Despite these drawbacks, many of which are likely to be resolved in response to technological improvements, there are a large number of advantages to using such technologies within learning. For example, gesture-based learning systems provide users with intuitive and adaptive interfaces that promote a high level of user engagement and collaborative working. Furthermore, the information provided is more easily accessible allowing the user to absorb and process information at a much deeper level. Finally, arguably the most important advantage is that the learner is always actively engaged. As discussed previously, active engagement is critical for effective and efficient learning.

**Chapter Summary**

This chapter has examined a variety of interactive and gesture-based technologies. The effectiveness of these technologies within learning has been discussed by analysing existing systems against the theoretical foundations established in the previous chapter, which emphasise active learning. Both interactive and gesture-based systems appear to have potential as effective, efficient, enjoyable and transferable tools within learning environments. However, at present they both face certain challenges and have their own limitations, which must be resolved. Nevertheless, when combined with active learning methods, of which evidence suggests is the most effective form of learning (Dewey, 1938; Bruner, 1961; Chickering and Gamson, 1987; Bonwell and Eison, 1991; Mayer, 2004; Merriam et al., 2007), one could argue that gesture-based technologies could indeed be highly beneficial to the learning experience.
Chapter 4 - Conclusion

It is evident that gesture-based systems are vastly improving with technological advancements that are truly astounding (Oka et al., 2002; Lee et al., 2005; Han, 2006; Microsoft, 2007, 2010; BrainLAB, 2008; Oblong Industries, 2011). This dissertation has discussed the potential of using these technologies to provide an effective, efficient, enjoyable, transferable and active method of learning. Importantly, gestural learning is an example of active learning, given that it incorporates technology which ensures that the user remains actively engaged. Numerous theories emphasise the importance of active engagement in producing the best learning results. Furthermore, a wealth of evidence suggests that a gestural learning experience may prove superior to an unaided one in terms of real-time feedback, practice time and reduced risk to both the learner and others (i.e. patients and teachers) (Oka et al., 2002; Lee et al., 2005; National Public Radio, 2008; BrainLAB, 2008; Solomon et al., 2011; Wachs et al., 2011).

However, despite the many proposed benefits to incorporating gesture-based systems into learning environments, it is important to note that at present they also propose certain limitations and challenges. For example, introducing gesture-based systems may initially prove costly, time-consuming and require the full support and confidence of instructors. Given that gesture-based systems could potentially replace the role of instructors this may prove problematic for some. Furthermore, current technology may not be sufficiently advanced to support all of the proposed uses and benefits. For example, the majority of systems are currently aimed at individual use. However, despite these limitations, the potential long-term benefits suggest that gesture-based learning systems remain an important area for research and development.

In conclusion, this paper has discussed the potential of using gesture-based technologies within learning. Thus, this dissertation contributes to the ongoing debate by discussing both the advantages and disadvantages to incorporating gesture-based technologies within learning. While a definitive conclusion is difficult to establish given the current challenges and limitations presented by such technologies, a wealth of research evidence suggests that interactive and gesture-based systems may be effective within learning. Therefore, despite their current limitations, given the rapid progression of technological advancements, it is
potentially only a matter of time before these technologies become pervasive tools within the learning environment.

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