A behavioural framework for designing educational computer games

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Research has indicated that computer games can be innovative and powerful tools for education [1-6]. Indeed, combining psychological research and games design principles offers a framework for developing educational games that promote learning while maintaining high motivation of the players [7]. If designed correctly, it appears that games can utilize the inherent motivation demonstrated by game players to teach skills that are of immediate practical benefit [1, 2, 8, 9, 10]. The current paper explores "the edges of gaming" in terms of proposing a novel theoretical and methodological framework for the design of educational games.

While various methodological, theoretical and pedagogical approaches have been adopted to the design of educational games, there has yet to be consensus on the most effective method of combining psychological research with games design principles. The current paper proposes that behavioural teaching methodologies already resemble game structures in some respects, and thus may be ideally suited to inform the design of educational computer games. Indeed, designing games based on behavioural teaching principles would have the reciprocal benefit of providing a medium through which these highly successful teaching programmes can be rolled out on a much larger scale than is currently possible.

Behavioural teaching methods are based on the science of behaviour analysis and have evolved side-by-side with this basic science over the course of the last century. Behaviour analysis is an environmentally based approach to psychology that assumes that all psychological events are to be understood as interactions of organisms in and with historical and situational contexts [11]. Mental constructs such as states of mind, feelings, personalities, and so on are rejected as explanatory tools for behaviour as they cannot be directly manipulated in an experimental setting. Only the environment in which behaviour occurs can be manipulated with any degree of rigour and accuracy, and thus only the environment is provided as an explanation for resulting behaviour. Consequently, behavioural teaching methodologies focus on identifying and manipulating elements of the students' environment that lead to increases and decreases in the targeted behaviours. This process is known as functional analysis and is guided by the concept of operant conditioning.

The concept of the operant is considered central to all behavioural accounts. Operant behaviour identifies a situation where, "consequences of behaviour may 'feed back' into the organism," and, "when they do so, they may change the probability that the behaviour which produced them will occur again" [12] (p.59). For example, a rat may engage in many different behaviours while trapped in a cage. If one of these behaviours, such as pressing a lever, is followed by a consequence, such as the delivery of food, then the probability of this behaviour occurring in future will have been altered. If that probability, as would be expected in this example, is increased, then the delivery of food in this context may be described as a reinforcer.

The principle of reinforcement is particularly relevant for behavioural teaching programs. A reinforcer is defined as any stimulus, the presentation of which as a consequence of an instance of behaviour, leads to an increase in that behaviour, in that

particular context, in future [13]. In the context of computer gaming, for example, the earning of experience points for killing a monster may be described as a reinforcer if the player is more likely to kill the next, similar, monster as a result. Indeed, any stimulus in a game that maintains or increases player behaviour, such as earning points, money, unique items, or access to new areas and levels may be described as a reinforcer (Interestingly, a number of games researchers have tried to model player behaviour using precisely these sorts of behavioural methods. See [14-16])) Crucially, behaviour analysis has concerned itself with the analysis of how best to maximize the level, or frequency, of behaviour produced by the learning organism. This involves dynamically manipulating the number of responses required before reinforcement is delivered (i.e., the schedule of reinforcement; [17]). Research has indicated that schedules of reinforcement may constitute the process underlying the 'addiction' observed with players of one-arm-bandit gambling machines [18, 19] and have also been suggested as the process that maintains engagement with computer games [20, 7].

The basic concepts of operant conditioning have driven the design of behavioural teaching methodologies such as Precision Teaching (PT). Specifically, PT is a unique method of teaching that involves almost no lecturing. It is based on the assumption that custom-tailored programs and high performance targets maximize learning. In this way, it is very similar to the method in which athletics is coached. PT uses 'frequency,' rather than simply percentage correct, as its base measure of success and all tasks are carried out repetitively and under time constraints (see [21-24] for a full review of the theoretical basis of precision teaching). The precision teacher essentially performs as a coach, advisor, and instructional designer. The teacher arranges materials and methods for the students to teach themselves. Specifically, for each program designed for each student, the teacher defines the target behaviour, the target frequency of this behaviour, and clearly states the rewards for reaching this target. The student then practices the behaviour under time constraints until the target is met. For example, the goal may be to answer forty 12-times-tables problems in a 30 second period. Once performance targets have been met, the student obtains the pre-defined reward and the teacher sets a new task. Students record their own performance under supervision of teachers on specially designed charts. From viewing these charts, students have constant access to feedback on their performance relative to previous sessions. This is in stark contrast to regular teaching paradigms, in which performance feedback may only be available weekly, monthly, or at the end of a semester. These charts are analysed by teachers and parents in order to guide the composition of future programs and reward schedules.

Importantly, behavioural teaching methods have been extremely successful wherever implemented. Indeed, wherever precision teaching has been used it has almost always doubled student learning [25]. Lindsley [24] describes two examples from a school that employs behavioural teaching methodologies. In this school, students gain an average of two to three grade levels per year. Illiterate adult education students in the same school gained an average of two grade levels per month; over 10 times the gain required by the government standard. Behavioural teaching methodologies have also been hugely successful as early interventions for children diagnosed with autistic spectrum disorders [cf. 26, 27]. McEachin et al. [28] report a long-term follow-up of autistic students who received early intervention behavioural treatment. Approximately half of the students who received this behavioural training were indistinguishable from non-clinical children of the same age

at this follow-up. Thus, it appears that behavioural teaching methodologies are extremely effective and may be of huge benefit in mainstream education.

Despite the empirical evidence for the effectiveness of behavioural teaching methods, they have not yet been widely adopted within mainstream education in any country to date. Lindsley [29] lists a number of reasons for why this has happened in the USA. One of the core barriers to acceptance, according to Lindsley, is the focus on repetition and discipline within behaviour methodologies and how these don't fit well with current views commonly held by educators that learning should be fun. Lindsley insists that learning itself is not fun, but that fluent performance of the task (the result of learning) is fun. Crucially, the technology of computer games appears ideally suited to by-pass this philosophical impasse. Specifically, students appear to be having fun when playing computer games, while in reality they are performing disciplined repetitive tasks in order to reach defined goals. Thus, it appears that computer games may provide a 'back-door' way of inserting effective behavioural learning programs into mainstream education.

Interestingly, many of the processes involved in designing effective behavioural education programs appear to mirror the processes involved in the designing of popular modern entertainment computer games. For example, highly engaging games typically have clearly specified and measurable goals (such as to level-up), require a great deal of repitition of skills in order to reach that goal (fighting numerous similar enemies), are often conducted under time constraints, have clearly specified rewards for reaching the specified goal (stronger player/more weapons/access to new levels) and provide constant feedback from the game state on how successfully the player is performing. In addition, successful games pay a great deal of attention to the rate in which complexity is increased over the course of game levels [30, 31] and to the balance and pacing of player advancement through these levels. These issues of rates, balance and pacing appear to precisely parallel the process that the precision teacher undertakes in defining programs for students. Thus, it appears that successful entertainment games designers already act as precision teachers in some respects. Indeed, it appears likely that the particular game design elements that maintain player engagement in entertainment games may be precisely those that have parallels in behavioural teaching.

Unfortunately, a great deal of currently available educational games focus too heavily on the delivery of content and disregard the elements of game-play that engender player motivation and engagement. Indeed, great deals of educational games appear to struggle to incorporate their learning outcomes into the game-play and instead merely present both, one after the other [32, 5]. Habgood [5], in two studies, demonstrated experimentally that games in which the play and learning were not merely placed side by side, but were intrinsically linked, were motivationally and educationally more effective than an almost identical game in which learning was not intrinsic to game play. Thus, it appears essential for educational games designers to follow the lead of their entertainment game design colleagues in carefully considering the 'gaming' elements as essential to content delivery. Due to the similarities between PT and game design described above, we suggest that designing educational games within a behavioural teaching framework would ensure that the focus was never taken away from the engaging, rewarding and successful learning.

Behavioural teaching methods would appear to form an ideal theoretical and methodological framework for designing educational computer games. This approach should ensure that educational games benefit from similar motivation and engagement as is observed with entertainment games, while also providing a vehicle through

which highly effective teaching methodologies can be rolled out in mainstream eduation.

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