# Guiding Intuitive Learning in Serious Games

## An Achievement-Based Approach to Externalized Feedback and Assessment

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*Abstract*—**Despite the rapid emergence of game-based learning as a method for conveying educational content, constructing pedagogies which effectively combine elements of entertainment gaming with methods of instruction remains a demanding task. Through the notion of 'intuitive guided' learning, this paper presents an approach which seeks to facilitate a structured learning experience whilst allowing learners to explore a non-linear environment. To do so, a framework is presented which externalizes the assessment process in a serious game, whilst also providing a means for game content to be adapted dynamically to translate the outcomes of the assessment process to effective feedback. A developed prototype is implemented to examine the theory in-practice through the case of a game for civil defence training in schools. Using this prototype, a range of methods in which achievements might be related to learner actions are introduced, and their subsequent implications for intuitive learning discussed. Furthermore, the prototype illustrates how assessment rules can be defined as external to the game and subsequently used to generate feedback for a virtual companion who assumes the role of a more-able partner. The long-term potential of such methods as a source of data on player behaviour is discussed, suggesting further benefits the technique might offer to educators seeking to introduce game-based learning within the curriculum in a blended fashion.**

***Keywords: intuitive guided learning, serious games, learner assessment, learner achievement, game-based learning, exploratory learning***

### I. Introduction

A key motivator behind the use of an intuitive guided approach is the increasing tendency for learners to demonstrate an intuitive approach to learning [1]. Under such an approach, learners explore possibilities and potentials through correct and incorrect actions, and as such require environments and technologies which are non-linear and non-sequential in nature. A causal factor of this shift is the emergence of digital devices and technologies with high tolerances for user error, coupled to intuitive interfaces. In an environment where gaming is increasingly the norm [2, 3], it is natural to explore pedagogies based around non-linear and engaging experiences, addressing the increased disengagement of students with traditional and more didactic methods of instruction.

In this paper, the value an achievement-based system might hold for serious games is explored through its relationship to an 'intuitive guided' approach to learning. Under this paradigm, support for intuitive learners as defined in Section II is provided through an open, exploratory environment that allows for multiple outcomes to any given situation and scenario, allowing learners to explore the implications of both correct and incorrect actions. Under such an approach, ensuring learners adhere to a coherent pathway which allows learning requirements to be fulfilled is an important concern [4], as is providing relevant feedback to educators allowing for an effective blended learning experience to be created. To support these aims, in Section III a framework is defined for recording and reporting on player actions and accomplishments within a serious game in a semantic and pedagogically-salient fashion. Through an externalization of the assessment process, the framework supports interaction between educators and serious game designers, allowing pedagogic content to be identified at the development stage and then manipulated dynamically in response to learner actions and interactions within an overarching set of pedagogic goals defined by the educator or trainer. The method supports integration with automated assessment technologies, allowing such tools to recognize and respond immediately to learner actions by modifying the game environment or triggering feedback.

### II. Intuitive Learning and Serious Games

Though the learner typologies in Jungian theory [5] are disputed, similar theories such as those of Kolb [1] describe intuitive learners as emphasizing possibility in their learning, considering a range of ideas and possibilities when addressing problems, and exploring potential outcomes Abstraction, imagination, and prediction all feature heavily in intuitive learners' behaviour. Traits of these learners commonly cited [1, 5] include:

- Preference for abstraction and theoretical work
- Tendency to examine phenomena at a macroscopic level
- Appreciation of new challenges and situations

- Preference for short session work and segregation of tasks

Immediate parallels to the sandbox open environments games might provide can be observed, as can the appreciation intuitive learners might have of the abstract ways in which games can present pedagogic content [6]. Areas of education such as mathematics have particularly benefitted from the use of abstract and immersive virtual environments for intuitive learning [7], as have other numerical and scientific disciplines such as physics [8]. Hence, it is straightforward to map the preferences of intuitive learners as expressed by both Jung and Kolb to the characteristics of serious games. However, more essential is the consideration of the subsequent response of intuitive learners, and how games might be better designed to capitalise on these strengths whilst remaining inclusive.

An observation here is that the "sensing" type of learner relates directly to Kolb's experiential model [1], which is frequently applied as a basis for simulation-driven education [9]. They learn through experience, reflecting and developing knowledge to increase their skills. Contrast this to the intuitive learner, who emphasizes more adaptivity and improvisation to address new challenges rather than relying on learnt processes and causal chains. Both learners might be supported by a serious game implementing a virtual world which allows exploration coupled with problems that can be solved by the application of learnt knowledge, though does a benefit exist in favouring one approach? It is important to note that critiques of the learning style theories presented by Kolb, as well as the typologies of Jung, are numerous [10], with particular evidence considering whether these manifest themselves through teaching style as opposed to intrinsic traits of learners [11]. If, as this meta-analysis suggests, evidence fails to support the typology being inherent to learners, and hence no measurable benefit emerges from the tutor adapting delivery to suit the type of each student, then difference instead must emerge from intrinsic contextual or representational benefits a given approach presents.

Capitalizing on an intuitive approach, therefore, is less a case of focusing on the group of students who will respond well due to a measurable typology, and instead utilizing the capacity all students may have to learn through intuitive methods. Through such an approach it becomes possible to consider the approaches advocated by type-theory approaches to learner classification, without extensive exposure to the associated criticisms of rigid type theory and its implications. Emphasis within the approach for intuitive guided learning advocated by this paper must, therefore, be placed on creating solutions which capitalize on the suitability of games to deliver intuitive learning whilst acknowledging the capacity of learners to respond to an intuitive model to a greater or lesser degree. In such a context, inclusivity becomes less a matter of supporting a sensing approach to learning, and more one of realizing the intuitive approach as effectively as possible so as to reach all learners in a meaningful fashion whilst relying on blending to provide content suitable for a range of learning styles. To this end, heed should be paid to the general principles of technology acceptance [12]: games must be perceived as both useful and easy to use. Ease of use relates to the design of the game and its user interface, and can be suitably assessed through user response and performance. In particular linking learnt knowledge to game performance pre- and post- hoc provides an ideal vehicle for assessing whether knowledge of learners is accurately reflected in their performance in-game, and if not, considering the relationship this might have to ease of use and the ability of learners to demonstrate this learnt knowledge. However, usefulness can be a harder issue to address, particularly as the nature of games can lead to them being perceived as a trivial or entertainment device rather than a meaningful learning aid [13].

The role of the tutor can again become essential here, as can the fashion in which the game is introduced [14]. Returning to the nature of intuitive guided learning described at the start of this section, it could prove more effective to deliver games as smaller, independent elements of a blended course, and studies have suggested greater efficacy when feedback is segregated into multiple smaller components [15]. Achieving such blending requires that games be integrated into curricula whilst allowing the educator to retain control over the feedback and assessment cycle, allowing them to adapt and adjust game-based content as readily as other resources. Increased involvement in design and development can boost acceptance of new technologies [12]; similarly it could be argued that resistance from educators towards emerging mediums such as game based learning may in certain cases stem from the lack of control educators have over how these games assess and provide feedback to the learner, as well as their limited capacity for adaptation to meet educational needs.

Towards resolving these issues, in Section III a framework is introduced for scaffolding feedback and assessment in a serious game through a method which externalizes the assessment process, with the game providing output on player achievements, and providing an interface for input from an assessment engine. The assessment engine is thus empowered with the ability to disable or selectively enable and adjust elements of game content, such as objects and dialogues with virtual characters, and respond immediately to player actions. Furthermore, by advocating a method which records player actions in a pedagogically-salient fashion and subsequent export in a structured data format, the framework demonstrates a route by which serious games might serve as a provider of large-scale data on their efficacy suitable for a range of assessment engines, which can then adapt the game and respond through a diverse range of methods.

## III. SCAFFOLDING AND EXTERNALISING FEEDBACK AND ASSESSMENT THROUGH ACHIEVEMENT

This section introduces a framework for scaffolding intuitive learning in a serious game through the implementation of an achievement-based system for providing assessment and feedback to both learners and tutors, externalizing the assessment process. It details the rationale behind this technique, which builds upon the considerations presented in Section II to outline the nature of intuitive learning. It is suggested that by orienting assessment and feedback in-game to provide learners with a dynamic experience, a guided approach can be introduced which allows detailed and instant learner feedback without obstructing the non-linearity and exploration at the core of the intuitive approach. Such achievements might be used to add meaning to player actions allowing data from the game engine to be analyzed at a meta-level and fed back to educators, allowing them to identify and tackle skills deficits as part of a wider, blended approach to game-based learning within the curriculum.

We introduce three phases within the framework shown in Figure 1. In the **development** phase the game world is created. During this phase the game's developers identify and flag content objects deemed pedagogically-salient; the essential criteria in defining these objects being their pedagogic composability (i.e. can they be removed without compromising the validity of the entire simulation as a learning object?). Subsequently, the game's developer identifies *achievements*, broadly defined as interactions with content which demonstrate a potential relationship to learning objectives. The discussion presented in Section II regarding intuitive learning hence becomes relevant: allowing a learner to explore requires a non-linear environment and hence achievements should similarly be non-linear in their definition. Similarly, detachment of assessment at this stage avoids the issue of negatively reinforcing a linear approach wherein the learner avoids exploring incorrect actions, as such exploration can be beneficial in developing understanding.

Achievements may then be combined into data streams exported by the game in response to automated requests for content lists and recorded player actions. Whilst no explicit format for this data is required by the framework, a medium such as XML has the benefit of being both machine-readable and directly editable by the educator; however, a comprehensive solution should consider carefully the development of tools to make the platform accessible to educators with as broad a range of technical skills as possible. In the **definition** phase, the role of the educator is supported in adjusting the data and assessment rules prior to the learner interacting with the game. In effect, these assessment rules take achievements as input, apply a set of rules defined by the educator, then export new content for the game to provide feedback to the player [18]. The format of this feedback can range from simple enablement or disablement of objects within the virtual space through to direct messaging to the player or response from a virtual companion, as illustrated in Section IV. Furthermore, deeper asynchronous feedback might be achieved by passing this information to the educator or directing the learner to supplemental resources to address an identified knowledge deficit.

In the final **gameplay** phase, the dynamic properties of the system are exploited to export player actions as they interact with the game, then apply the assessment rules created by the educator, with subsequent generated feedback passed to the player through a communication mechanism. Again, an aim here is not to be overly prescriptive within the framework; the method used to pass information to the player should be dependent on the overall pedagogic design as well as the context of the learner and the fidelity of the game. The framework as a whole is illustrated in Figure 1.

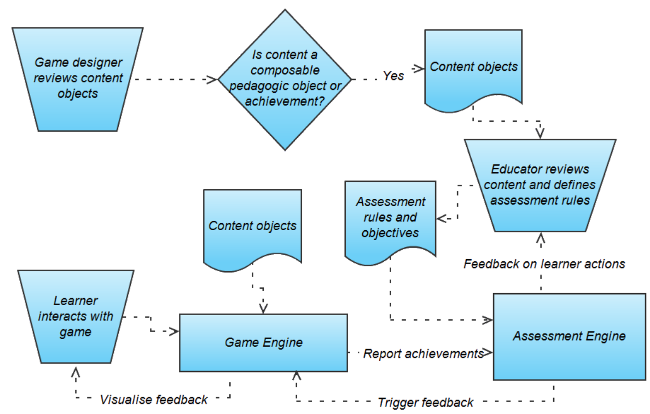


**Figure 1: Framework for feedback and assessment through reporting of in-game achievements**

The particular relevance of the approach to intuitive guided learning lies in the flexibility and non-linearity with which content and actions can be specified. Rather than taking a linear approach at which regular checks on performance lead to repetition of scenarios, a more flexible approach can be adopted which allows learners to explore worst-cases and incorrect actions, as well as giving educators a high degree of control over how the game responds to the learner. In such a design, implemented achievements can play a role both in directly feeding back to the learner, whilst also providing educators with information on progress at both an individual and group level. As such, they can support the crucial task of guiding the learner and ensuring deviation from productive learning activity does not ensue. As studies have shown the patterns and levels of achievement goals to influence both performance and enjoyment [16], these must be implemented with regards to both progression and frequency of achievement, obeying the balance of perceived task difficulty and learners self-perceptions of ability essential for a flow experience [17]. In the next section, an implementation of a system utilizing this framework is described, identifying how externalization of assessment and feedback can support educators in gaining increased control over the learning experience in a serious game, whilst providing an experience which meets these fundamental requirements of an intuitive learning experience.

## IV. IMPLEMENTATION

The case study used for a preliminary study of the framework proposed by Section III applies the principles discussed in the previous sections to create a serious game for civil defence training in school, built around an earthquake-based scenario. The emphasis of this activity is to provide students with an ability to apply and rehearse their knowledge of safe evacuation processes and procedures within an immersive game environment. Figure 2 illustrates a range of content in game with which the learner can interact. The Unity game engine is used for development. Within the engine, a script is created which can be attached to individual objects to mark them as content using the definition proposed in Section III.

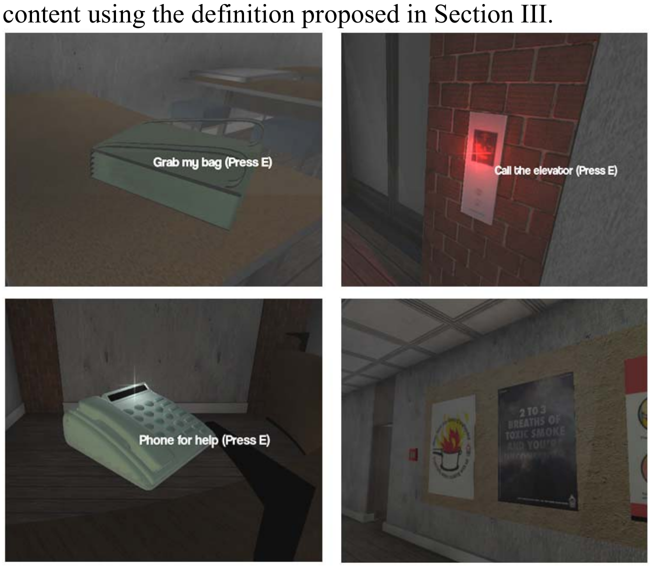


**Figure 2: Pedagogic content in game can take a range of interactive forms, from collectable objects through to educational posters and control objects.**

Achievements, again under the definition proposed in Section III, are identified in-game via a number of methods related to the scenario:

- Indirect movements of the player between specified game areas. These are implemented using bounding volumes which execute code as the player enters and exits, for the simplest cast of spherical volume of radius r and tuple (xyz) position p an example could be expressed as:

```
IF |player_position – p| < r THEN
award_achievement)
```

- Direct player to object interactions, for example:

```
IF |player_position – p| <
minimum_interaction_distance AND
player_is_pressing_interact_key THEN
award_achievement)
```

- Composite interactions requiring multiple criteria to be fulfilled, for example for the player to crawl in a smoke filled area requires both presence in the correct area and crawling for a significant proportion of this time, for example if the area at p as specified previously were smoke filled:

```
FOR EACH frame {
        IF |player_position – p| < r AND
        player_is_crawling THEN
        timeSpentCrawling+=delta_time
        IF timeSpentCrawling>10 seconds
        THEN award_achievement
        }
```

Through the composite process, it becomes possible to represent any given action of the player in binary terms, using thresholds to define binary performance against scalar metrics. This is a necessary process given the nature of the achievement process itself, which emphasizes the formatting of achievements as binary goals with clear success criteria. In the award_achievement method, two processes are undertaken. The first is to visually inform the player the achievement has been obtained through an on-screen image. The second is to record this achievement in an XML format suitable for subsequent analysis and assessment. The visual information step can be bypassed, allowing achievements to be inserted which are triggered by the player without explicitly informing them. Fundamental here is the ability to specify these achievements in terms of pedagogic meaning, allowing specific learner actions and activities to be recognized. However, in-line with the intuitive guided learning paradigm, rather than attempt to reward correct and penalize incorrect behaviour, a non-linear, exploratory approach in encouraged in which achievements can also be gained for exploring incorrect actions and their consequences: in the civil defence scenario, achievements are attached to events such as collecting possessions before evacuating, giving poor advice to another evacuee, attempting to use a lift, or triggering a backdraft. The XML file records multiple attributes of events as shown below [18]:

```
   <event time="00:00:52.0149751" player-
id="noname">
   <action name="EnterSection">
   <add property-
name="section_attributes">SmokeOnCeilingArea
</add>
   </action>
   </event>
```

In the above example, the player approaches a smoke-filled area within the building, identified as a unique game area. This creates an EnterSection event. Similarly, as the player is exposed to smoke, their level of exposure, reflected in reduced visibility and audible coughing within the game, increases. In response they begin crawling through the section to reduce this exposure. After leaving the section, the level of exposure reduces, and the player subsequently ceases crawling, again captured in a similar XML form. From the captured data, it is possible to examine the learner's understanding of the need to remain low in a smoke-filled area both in terms of their interaction with an explicitly marked area for demonstrating the knowledge, and also their behaviour throughout the simulation.

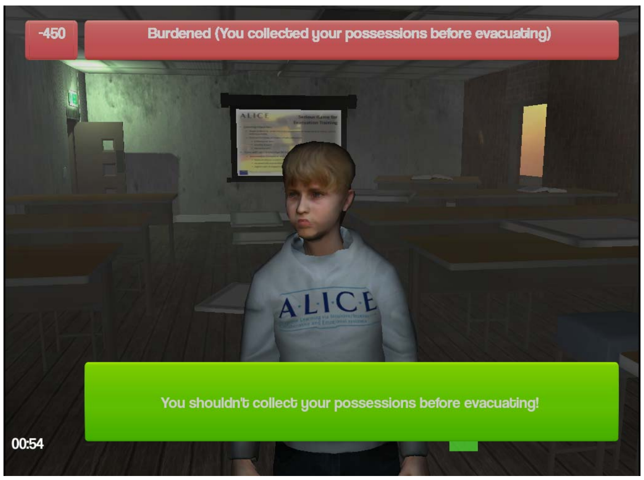


**Figure 3: Illustration of the feedback cycle: exported XML from the game is used to identify the player has collected their possessions before exiting, and the assessment engine invokes a response from a virtual character, who changes mood and responds.**

In the simple example in Figure 3, a basic assessment rule is applied such that if the player performs the single action of collecting an object, the virtual character responds. Whilst a similar effect could be achieved through in-game scripting, the technique shown here applies the assessment rule externally (in this case through a JavaScript function embedded in the web page). Significantly, this enables the rule to be modified without recompiling or editing the game itself, and allows player actions to be recorded externally to the game, suitable for review by an educator. Furthermore, straightforward parsing or visual inspection of XML for multiple learners can be used to identify common areas of action or inaction, empowering the educator with the ability to reflect on both individual and group behaviour.

Given the volume of XML data generated, substantial benefit can be gained from machine-driven analysis techniques, enabling both analysis of individual learner behaviour and common traits amongst groups. This feedback can then be compiled and fed-back to the educator, identifying common failings and errors as well as positive behaviours amongst groups. By using the LCMS platform underpinning the game to facilitate data transfer to an assessment engine, it becomes possible to visualize this output as simple evaluative feedback. This feedback from pedagogically-defined achievements, whether directly visible to the player or not, can be used to guide the intuitive learning process through subsequent adaptivity and blending into the wider educational context. Supportive feedback from the educator reflecting on in-game achievement can be augmented using machine-driven feedback which monitors and tracks achievement within the game using the LCMS system within which it is deployed. In the case of the Intelligent Web Tutor system used for the case study, passing information between game and LCMS through web-scripting.

## V. SUMMARY AND CONCLUSIONS

This paper has introduced a framework for externalizing the process of assessment in a serious game through the use of in-game achievements and feedback from an assessment engine. A key benefit of the proposed technique is the provision of a means for assessment engines to interface with the serious game, providing dynamic feedback without requiring the game itself be directly adapted [18]. Data generated through play using the XML schema described in Section IV can also provide an important basis for learner analysis towards a quantitative assessment of efficacy.

The prototype presented in Section IV uses a simple assessment rule embedded within the web service that provides the game to the user. However, using an identical paradigm it becomes possible to interface with other web services and tools to provide more detailed and effective assessment. Future work must consider how middleware may be provided to effectively translate the outputs of these services and tools to formats suitable for incorporation in a game-environment, for example translating them to plausible dialogues and character interactions. The pivotal role an LCMS or LMS might play in handling this data and providing suitable interfaces must also be considered. Moreover, this decoupling of the game engine - as a complex learning resource - and the assessment engine – utilized via web services - fosters the accommodation of various learning contexts and pedagogical approaches [20].

In the longer-term, as linked and big data techniques evolve to provide methods for gaining detailed insight into learner behaviour from large-scale data sets, information such as that provided by this a framework will gain increasing relevance as a means for providing data allowing for game-based and other learning approaches to be refined with greater understanding of their impact and outcomes. Similarly, as means for creating increasingly adaptive and diverse content for games from sources such as the semantic web emerge, methods for importing this content into games and utilizing it as a means for providing supportive and interpretive feedback [19] will become increasingly viable.

With such technologies available, assessment engines will gain increased potential to understand and respond effectively to the needs of both learners and educators.


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