Designing, Using and Evaluating Educational Games: Challenges, Some Solutions and Future Research

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Abstract. Educational games can use storytelling as the underlying model for designing their content and narrative to enhance learning outcomes. We need to evaluate their efficacy to maximise the user benefits. However, the field of user experience (UX) evaluation is full of challenges in itself; and evaluating the UX for digital educational games adds many other complexities. This paper presents various aspects involved in developing digital educational games and in evaluating the user experience derived from these. Felder Silverman learning style mode is presented to incorporate it into educational games and cater for a range of learners. A story design model called Movement Oriented Design (MOD) is presented to guide the process of creating effective educational narratives. A User Experience Research (UXeR) meta-model is presented as the pathway to advance research in this multidisciplinary field.

1 Introduction

Storytelling is a powerful model for developing educational content presented as linear narratives, or as non-linear narrative-based digital educational games (DEGs). The ultimate aim of these artefacts is to enhance user experience (UX) and learning outcomes. Being able to evaluate, and, if possible, empirically measure UX is necessary to be able to compare the efficacy of various processes involved in creating DEGs that use storytelling as the underlying model.

The interplay of these three domains –education, games and storytelling– makes the entire process of creating educational games, and then evaluating their efficacy a complex enterprise. To begin with we need to understand the relationship between these fields.

Fig. 1 shows a Venn diagram representing the relationship between education content design, story design and game design. The outer doughnut represents the creative design space, and the inner circle represents the UX space. Story plot and narrative lie at the intersection of story design and game design. Learning outcomes are closer to educational content design, having overlaps with story and game design; while emotions lie at the very centre of all user experiences.

All three design activities are creative endeavours; and evaluating the outcomes of

any creative endeavour is a challenging task. The difficulty in evaluating the outcomes of creative activities – such as designing stories, games and educational content – is exacerbated by the lack of well-defined theoretical models for the same.

Over the recent past, many research projects have developed new UX models [1] [2]. Such studies propose a number of models and definitions of UX, which, at times, contradict each other [3], leading to further difficulties.

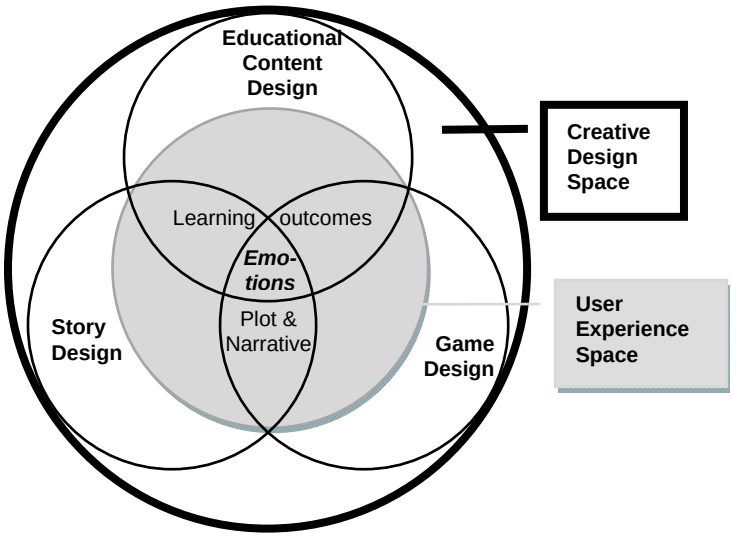

Fig 1. The relationship between Education Content Design, Story Design, and Game Design.

The main aim of this paper is to present models that link the three design domains, and a User Experience Research (UXeR) model to chalk-out a pathway for developing formal UX evaluation models.

2 Learning Style Models

For an educational system, the main objective is to enhance the learning outcomes. However, different learners have different learning styles, and the learning outcomes depend upon the match between their learning style and those offered by the Technology Enhanced Learning (TEL) system [4].

A learning style is the pattern for gathering information and assimilating knowledge. Many learning style models proposed over the years overlap with personality types proposed by Carl Jung, Myer Briggs, Kolb, and Howard Gardner [5].

A simple and widely referred learning style model classifies learners as Visual, Auditory, or Kinaesthetic learners [6]. Visual learners prefer to use visual aids such as diagrams, photos, and videos. Auditory learners prefer to learn by listening to lectures and discussions. Kinaesthetic learners prefer to learn by building physical systems or

models. A combination of these three learning styles is often used depending upon the individual's personality and the topic under study.

2.1 Felder Silverman Model

A more wholesome learning styles model was developed by Felder and Silverman based of five pedagogical dimensions [7]. This model was originally developed for engineering students; however, it can be applied in a wider context as well.

The Felder Silverman Learning Style Model divides the learning process into five dimensions: Perception, Input, Organisation, Processing, and Understanding –each dimension having two opposing learning styles, as described in the following.

1) Perception: How learners perceives information.
- **a) Sensing:** People who learn by understanding concrete facts and procedures.
- **b) Intuitive:** People who take a more conceptual view; they are innovative and oriented towards building theories to underpin facts and procedures.

2) Input: How learners absorb information.
- **a) Visual:** Prefer visual information: pictures, diagrams, and videos.
- **b) Verbal:** Prefer information as a sequence of written and spoken words.

3) Organization: How learners put together a series of information parcels.
- **a) Deductive:** Proceed from the general theory to specific examples.
- **b) Inductive:** Proceed from the specific examples to a general theory.

4) Processing: How learners process the gathered information.
- **a) Active:** Learn by trying things out, often working with others.
- **b) Reflective:** Learn by thinking things through, and generally work alone.

5) Understanding: How the learners develop an understanding of the subject.
- **a) Sequential:** Absorb information in linear and orderly steps.
- **b) Global:** Develop a big picture first, and then consider specific items.

For each dimension, learning style 'a' is more physical, and style 'b' is more intellectual [4]. Most people use a learning style somewhere between the two extremes, but with a bias for physical or intellectual learning.

In general, the aim of any learning system should be to offer alternative learning styles for the same subject matter, so that individuals can choose the one that matches their preferred learning style. Nonetheless, it is useful for individuals to try and break their habit and use the opposite learning style as well.

Games intrinsically provide a more active or physical learning experience. Therefore, it is important that a game based system should also provide more intellectual activities, to balance and reinforce the learning gained from the game. However, it should not be done in a way that it interrupts the game experience [8].

3 Digital Educational Games

Digital Educational Games (DEGs) are systems that use digital technology to create games for enhancing learning outcomes; and have been recognised as a pedagogical tools that are engaging and effective. Law and Kickmeier-Rust state that: "DEGs offer exciting and dynamic environments which engage gamers in meaningful and motivating learning activities, inspiring them to explore a variety of topics and tasks. Simulative characteristics of DEGs can contribute substantially to knowledge construction of individual gamers, and their social aspects can enhance gamers' collaborative learning skills [8]." However, there are three main challenges related to developing, using and evaluating DEGs, namely:

1) Personalising learning experience, i.e. developing DEGs that can provide content and experience to match various learning styles.
2) Reusing the learning objects created for the same or other DEGs.
3) Evaluating DEGs vis-à-vis user experience and learning outcomes.

The solution to the first two challenges can come from the use of storytelling as the underlying model for developing DEGs. The third challenge is more complex, and needs further research to develop formal models for evaluating UX. To advance such research, this paper presents the User Experience Research (UXeR) meta-model.

4 Storytelling as a Pedagogical Model

Storytelling is a universal cultural activity; however, it can also be used for enhancing learning, and therefore, can be used as a model for developing DEGs. Storytelling has been used for passing knowledge from one generation to the next since prehistoric times, as it is closely connected with how the human brain works.

Anthropologist Levi-Strauss predicates that brain uses a story oriented structure to store and recall life experiences [9]. Furthermore, Heo has asserted that even facts, ideas, and theories are learnt more effectively if these are linked as a narrative [10]. Storytelling provides a powerful model of effective communication because it links with a basic human need: to create emotional engagement and movement [11].

However, to be able use storytelling as a model for developing effective educational content, we need a process that allows one to develop educational stories systematically. Movement Oriented Design (MOD) provides a systematic process for developing the plot and the narrative of a story [11].

A story comprises a collection of events, i.e. individual incidents. However, a story is created when events are combined into a plot to create some meaning. The sequence in which the events are revealed to the audience is called the narrative. A given story plot can be told with many different narratives, and each narrative can have a different emotional impact on the audience.

Communicating knowledge as a series of facts and theories can be boring, and thus, does not lead to deep learning. The MOD methodology predicates that learning systems –lectures, presentations, seminars, or games– can be perceived as storytelling artefacts. MOD uses a concept originally given by Aristotle: i.e. every story must

have a beginning, middle and an end [11]. It adds another idea articulated by the Dramatica theory of story design: i.e. stories are exercises in problem solving.

The core element of a MOD-based story is a Movement: defined as a micro story with its own Begin (short for beginning), Middle and End [11] – see Fig 2. A complete story is then a collection of Story Units, where each Story Unit is a sequence of Movements [11].

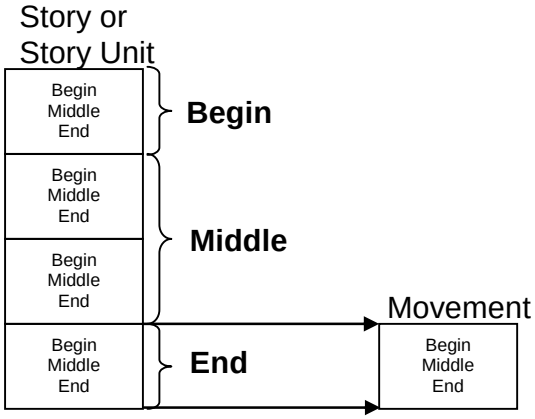

Fig 2. A Complete Story is a collection of Story Units, which in turn is a collections of Movements

By dividing a story into Begin, Middle and End components, it becomes possible to create more effective narratives. Each Begin should be designed to grab attention; the Middle can then be used to deliver the message, and the End to conclude it.

If an educational story starts by relating facts and figures, the learners' interest wanes. By getting the learners' emotions engaged with a good Begin the educational message can be delivered more effectively in the Middle part of the Story Unit.

Furthermore, one must link the Story Units into an effective plot and present the plot as an engaging narrative. McKee has given the principles for creating emotionally moving plots [12]. These principles are given for fictional stories, nonetheless, these apply to educational stories as well [13].

An engaging story experience requires that the story connects with and moves viewer's emotions. McKee defines Emotional Charge based on accumulated emotions. In an educational story we can associate Positive Emotional Charge with feeling happy or satisfied with the learning experience [13]. Negative Emotional Charge with anxiety or confusion as one encounters new knowledge areas.

As per McKee, to keep listeners interested in a story, the emotional charge must move up and down [12]; and this should happen even in an educational story [13]. This emotional movement is represented in Fig. 3 using the arrows pointing up and down. These arrows create a Narrative Envelope around knowledge being transmitted; consequently, by engaging the learner's emotions, knowledge transmission proceeds with greater efficacy [13].

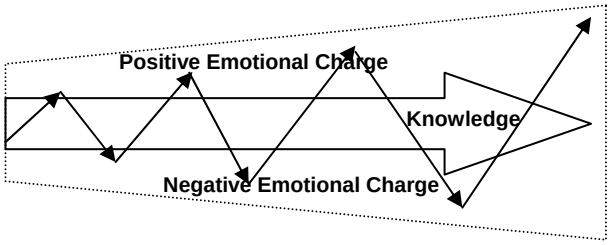

Fig 3. Moving Emotional Charge for effective knowledge transmission [4].

To create an emotionally charged story, McKee suggests five story stages: Inciting Incident, Progressive Complications, Crisis, Climax, and Resolution [12].

An Inciting Incident should start the story, e.g. a problem to be solved. To keep the listeners emotionally engaged, Progressive Complications should be introduced throughout the story; i.e. as one problem is solved, a new one arises. A Crisis implies insurmountable problems, and Climax an explosion of emotions. Including Crisis and Climax in an educational story is desirable but not necessary. Resolution must come for every problem. However, the resolution in one Story Units should raise a new problem to be solved in the next.

By combining the Movement Oriented Design process with the McKee principles we can create more effective educational stories. As MOD views stories as a collation of Movements, the educational content developed as Movements can be reused and re-combined to fulfil the needs of learners with different learning styles.

The effectiveness of these educational stories can be measured in terms of their learning outcomes as well as user experience. Learning outcomes can be evaluated by using various knowledge testing models. Many well established models for evaluating knowledge have been developed over the years, such as the one developed by Bloom in the 1950s & 60s, and more recently updated by Anderson and Krathwohl [14]. However, evaluating UX is a bigger challenge; since well established formal models for defining and evaluating UX are not available.

4 User Experience

Many usability models and evaluation methods have been proposed over the past few decades. However, more recently, the importance of taking a holistic view of user experience (UX) has been mooted; and the importance of emotions in analysing UX has been appreciated [15].

Early human computer interaction (HCI) research focused primarily on the tasks performed in a system, and usability testing measured the efficacy of achieving functional outcomes [16]. With time, the importance of product aesthetics was realized [17]. This led to a transition from pragmatics focused ‘usability’ research to aesthetics focused ‘user experience’ research. To facilitate the transition to user experience research, Hassenzahl separated system attributes into Pragmatic Attributes and Hedonic Attributes [18]; implicitly including user emotions as an important element.

According to Hassenzahl and Tractinsky, "User experience (UX) is a strange phenomenon: readily adopted by the human–computer interaction (HCI) community – practitioners and researchers alike – and at the same time critiqued repeatedly for being vague, elusive, ephemeral" [16]. However, they attempt to expand upon user experience by considering the following three aspects [16].

- The experiential: dynamic, complex, unique, situated, temporally-bounded.
- Beyond the instrumental: holistic, aesthetic, and hedonic.
- Emotion and affect: subjective, positive, antecedents & consequences.

While many models assert the important role of emotions in user experience, they fail to provide a clear relationship between emotions and the various other aspects of the system. This nebulous link between experience and emotions is confirmed by Mutlu, by stating: "Current theories of emotions fail to explain the relationship between experience and emotions" [2].

To overcome some of the criticism levelled on UX research (e.g. being ephemeral and nebulous), a new user experience model is proposed; called the User Experience Research (UXeR) model, shown in Fig. 4. UXeR is a meta-model, i.e. a guide for further research to derive formal UX model(s). The UXeR model places experience at the apex of a triangle, and connects experience with the system under study and its components –which lie at the base of the triangle– via three intermediate levels.

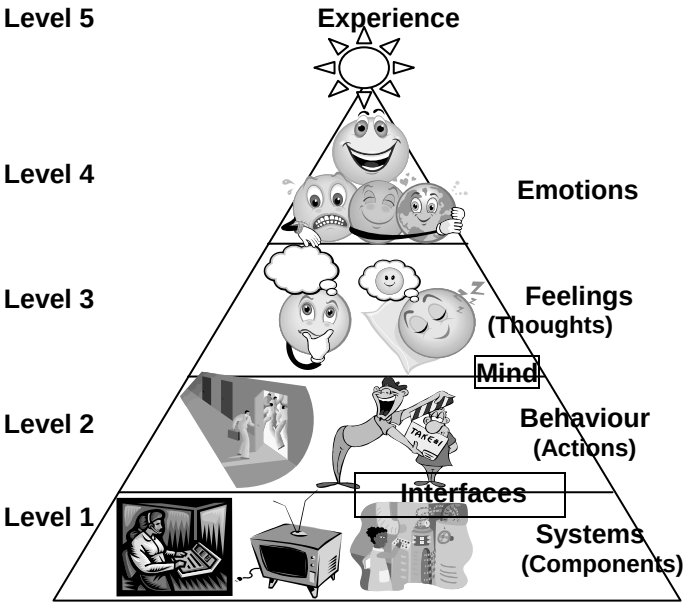

Fig 4. The User Experience Research (UXeR) model

Experience is the most ephemeral concept, and components of the systems under study (e.g. hardware and software) are the most tangible components. As we go down

from the apex to the base of the UXeR triangle, the linking elements go from being ephemeral concepts to more tangible concepts.

Experience is the most difficult concept to define; however, we can connect it to emotions which are somewhat more tangible. Emotions are linked to feelings and thoughts which are even more realisable. Feelings and thoughts provide a link to behaviour and actions, which are still more tangible. Behaviours and actions connect well with a system and its components under study. In general, we can tackle a higher level concept by building on our knowledge of the relatively easier to observe elements at the lower levels.

Emotions play a central role in any user experience. Thus, we place emotion at level-4, just below experience. Feelings and thoughts are closely linked and are responsible for producing emotional responses; these are therefore placed at level-3. Thoughts are somewhat more tangible than feelings, and therefore placed lower than feelings within level-3; also because, thoughts provide a link to behaviour and actions through the mind.

Here feelings refer to emotional feelings (happy, sad), and not physical feeling (hot, cold). Thoughts are stream-of-consciousness brain functions, often accompanied by verbal and visual activities in the brain, usually linked to physical actions.

The concept of a mind defies a clear placement in the body; it certainly is not just the physical brain. In the UXeR model we conceive mind as a gestalt of the information flow in the body. Hromek clarifies this concept by stating: "…mind becomes body through a multidirectional flow of information throughout the whole organism… [making it a] manifestation of the mind" [19].

Furthermore, the mind has two parts, called the conscious and the subconscious mind [20]; consequently, our emotions, and thus experiences, are influenced not only by the conscious mind, but also –and often very powerfully– by the subconscious mind. Therefore, this aspect needs to be included in any UX research agenda.

The mind provides a link between thoughts and behaviours. Behaviours are collections of actions, and thus a higher level concept than actions themselves, and are placed at the higher end of level-2 in the UXeR model. It can also be viewed as a collection of certain action patterns repeated with or without variations. Behaviours can be attributed to even inanimate objects; for example, toys and computer games.

Level-1 comprises the components of the system, including user interface entities (physical or screen based) that are needed by the user to perform actions and tasks.

$$Be = f_1(Sy), \text{ where } Sy \subset (C_1, C_2, ...) \quad (1)$$

$$Fe = f_2(Be), \text{ where } Be \subset (A_1, A_2, ...) \quad (2)$$

$$Em = f_3(Fe), \text{ where } Fe \subset (T_1, T_2, ...) \quad (3)$$

$$UX = f_4(Em) \quad (4)$$

$$UX = f_4(f_3(f_2(f_1(Sy)))) \quad (5)$$

As a pathway to formalise the UXeR graphical model (Fig. 4), the generic UX equations 1-5 are proposed. Equation 1 states that behaviour (Be) is a function of the system (Sy) that consists of various components (C1, C2,…); equation 2 states that

feeling (Fe) is a function of behaviour (Be) that consist of many actions (A1, A2,…); equation 3 states that emotion (Em) is a function of feelings (Fe) that comprise many thoughts (T1, T2,…); equation 4 states that UX is a function of emotions (Em). These predicates are combined in equation 5, where UX becomes a composite function of the system, user behaviours, feelings and emotions.

These equations offer a starting point for developing formal EX models; however, to put UX research on a formal ground we need to take the following steps:

1. **Fully define the UX equations** using appropriate mathematical techniques.
2. **Validate the UX equations** using empirical data.
3. **Verify the results** obtained from UX equations.
4. **Develop measurement techniques** based on usability research.
5. **Adapt the UXeR model** for specific application domains.

The above process is proposed to advance UX research, because currently there is no well defined model for evaluating UX for digital games, let alone for digital educational games; and without further research "a standard … is not likely to emerge any time soon" [21].

In conclusion, the area of digital educational games is an exiting but fledgling field. It needs to import existing design models from storytelling and education fields. However, its biggest challenge is to develop formal models for evaluating the user experience.

5 Conclusions

This paper discussed the challenges in developing digital educational games (DEGs), and offered some solutions for designing educational games using storytelling as the underlying model. It introduced Movement Oriented Design (MOD) and McKee principles for designing the narrative of story-based DEGs. Being cognisant of different learning styles is important so that the DEGs cater for different learners' needs. Presently, evaluating User Experience (UX) is also full of challenges; and the process for evaluating UX for story-based educational games is not well defined. A User Experience Research (UXeR) meta-model was presented; however, this area needs further research to develop formal models for evaluating UX in general, and UX for educational games in particular.

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