DIGITAL QUANTITATIVE ASSESSMENT OF QUESTION-ASKING-BASED EXPLORATION

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ABSTRACT

Curiosity is one of the 21st century skills and is especially paramount in the digital age. However, curiosity is multifaceted and can be expressed in many ways. Furthermore, assessment of curiosity is often based on self-report or subjective observations. We present work in progress for the development of a digital quantitative assessment game for question-asking based exploration. The student selects her question-based exploration in a simulated alien world, wherein the game extracts several important quantitative measures which are derived from graph theory and compute different values of questions, e.g. novel information, exposed uncertainty and uniqueness. To evaluate the tool, we aim to conduct a large study with Youth University students who will play with the game and administer a curiosity-based questionnaire to their class guides, as an external validation.

KEYWORDS

Curiosity, Assessment, Question-Asking, Tablet Game, Children's Exploration, Graph Theory

1. INTRODUCTION

In the Information Age, where knowledge is just a click-away, curiosity becomes one of the most significant aspects of human learning. Research on curiosity has shown its great effect on learning processes. Curiosity drives the curious person to actively explore and seek new information - ask questions, test hypotheses etc. (Engel, 2011; Jirout and Klahr, 2012a). As a result of this active learning, the person's learning process and information acquirement will usually be much greater and more effective (Chi and Wylie, 2014; Fisher et al., 2013). This effect was also demonstrated in brain study researches, which showed that the more curious people are while learning new information, the better they will remember it (Gruber et al., 2014).

Curiosity, however, is multifaceted and can be expressed in many ways (Engel, 2015). It can lead to physical exploration of objects, to uncertainty seeking (Jirout and Klahr, 2012a) and to question asking (Jirout, 2011). The latter is usually associated with more developed curiosity expression, as it is one of the main venues for seeking epistemic knowledge, mainly in the educational system.

In order to better understand curiosity and how to promote it in the educational system, one must have a proper assessment tool. The most used tool for assessing one's curiosity is a self-reporting questionnaire (Kashdan et al., 2018, 2009). While there has been great advancement in these questionnaires and their validation, they still suffer from all the disadvantages of a self-report. Another common assessment method is subjective observation, e.g. observing students in the classroom and assessing their behavior (Engel, 2015).

In this work, we strive to create a more objective and quantitative assessment tool for curiosity, by leveraging digital technology and gamification. We have created a novel tablet game, in which students can explore a simulated alien world by selecting which question to ask about which object. They thus navigate a pre-defined "concept network". This novel game promotes exploration via visual question-asking, i.e. selecting icons of either "what"/"how"/"why" for each selected object, thus enabling us to administer to a wide age-range of students. Furthermore, by constructing a unique "concept network" to explore, we define novel measures of questions, namely, breadth which measures how many answers a question has; depth which measures how many new questions stem from a question's answers and; specificity which measures how many other questions have the same answer. We hypothesize that these quantitative measures can bring to light individual differences and that these are linked to expressions of curiosity.

The contribution of this paper is the presentation of a novel digital quantitative assessment tool for question-asking based curiosity exploration, that enables the extraction of several behavioral parameters related to exploration and learning.

2. RELATED WORKS

The strong relation between curiosity and effective learning has an important meaning for the educational system. Curiosity is usually expressed in behaviors (such as active information seeking, concentration, visible interest etc.) which are deeply related to improved academic performance (Schiefele et al., 1992). It has been shown that even though intelligence and effort play a great part in predicting scholarly success, curiosity is a no less important, strong, and distinct predictor for it (von Stumm et al., 2011). Furthermore, these mentioned visible behaviors that derive from curiosity, also lead to higher teacher ratings of attention, motivation, competence and persistence (Jirout and Klahr, 2012b), for the curious child is much more engaged in class. These results suggest that being curious in school can greatly and positively affect academic performance.

In recent years, several digital curiosity assessment tools have been developed for children. These tools, usually tablet applications, are intended to be more objective and behavioral-based than the current questionnaire type assessments. One application is the Fish Task app (Jirout and Klahr, 2012b), which aims to determine uncertainty seeking. This app is portrayed as a game in which children are in a submarine with two windows. They can open one window and see a fish through it. The two windows differ in the uncertainty of which fish will be outside. Thus, one window is presented with one fish next to it, indicating that with certainty that fish is outside the window. Another window can be presented with five fish next to it, indicating that one of those five fish is outside the window, but the child cannot know until he opens it. Thus, the child needs to select which window to open, i.e. which amount of uncertainty he seeks. The app is designed to explore many differences in uncertainty in a repetitive yet step-wise manner (Jirout and Klahr, 2012b).

A second application created for the task of curiosity assessment is the Free Exploration app (Gordon et al., 2015) in which children can move different characters on the tablet and receive information about them. Measures such as exploration time were used as a proxy of curiosity. These games represent a beginning of a solution for the current subjective measurement methods. However, one important expression of curiosity does not appear in these games, namely, question-asking (Engel, 2011; Harris, 2012).

In the world of game design, uncertainty and hidden information have a great role, for they are directly linked to the player's game experience (Costikyan, 2013). Uncertainty can trigger curiosity, challenge and engage the player to the game, but that is only if it comes in the right balance (To et al., 2018). Too little uncertainty might create a lack of interest. Too much uncertainty can invoke fear of failure and can be very irritative. We used this link between uncertainty and games to design a game in which we will be able to test players' tolerance for uncertainty and look for patterns in the methods they choose to gather information, via question asking, about the game's hidden model.

3. METHODS

Question World game. We created a tablet game we called *Questions World*. In *Questions World*, the player encounters different alien worlds which they can explore. Their interaction with the worlds is by selecting different objects within them, e.g. aliens, technology or indigenous plants, and selecting which question to ask: *How* does it work? *What* is it made of? *Why* is it here? Each object-question pair results in a verbal utterance of an answer, which is part of a different arch-story for each alien world, and the appearance of more objects which the child can interact with.

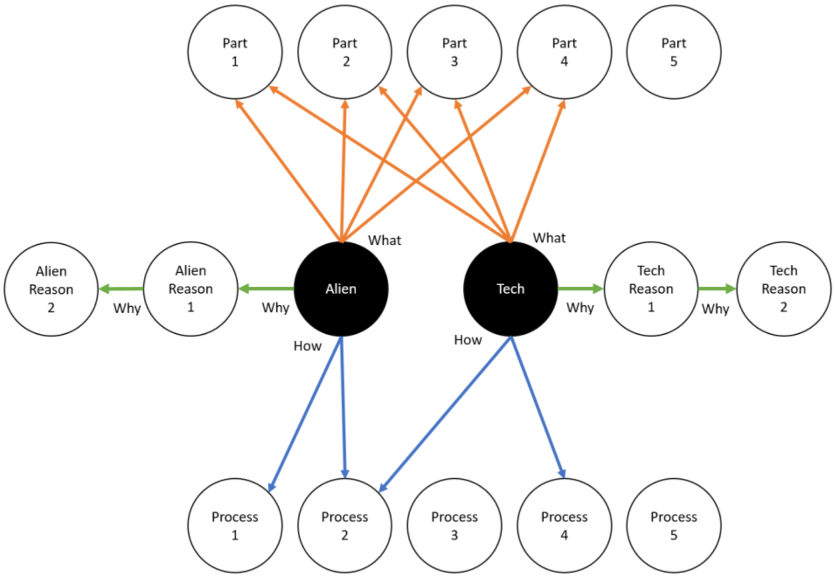

Figure 1. The "Concept Network". The nodes represent the game objects (the starting objects are signed as white over black), and the arrows represent the questions that can be asked about the object, that leads to the discovery of new items. For instance, asking "What is it made of?" about the Alien, will make Parts 1,2,3 and 4 appear on the screen (but the player cannot ask any questions about the parts). This graph is partial - it does not include all the items and questions that can be asked about each item

We have created a Directed Graph-based model that represents the questions-answers connections between the different objects in the world, which we called "the concept-network" (Figure 1). A graph *G* is an ordered pair *(V(G), E(G))* consisting of a nonempty set *V(G)* of nodes (or vertices), and a set *E(G)*, disjoint from *V(G)*, of edges (Bondy, 1976). A directed graph is a graph in which the vertices have a direction – a start node *A*, and an end node *B*. In our game, the nodes are represented by the world's objects, and the vertices are represented by the questions that can be asked about the object (that lead to new objects). Thus, the concept network is a directed graph (a question about an object "points" to the object that represents the answer, but this does not mean that it also points the other direction). This type of modeling lets us create different mathematical parameters for the subjects' questions-asking patterns.

The concept-network (i.e. the graph of objects and questions), is identical for all worlds, but the story differs. The network was constructed such that graph-parameters of each question type is different, with the assumption that these parameters reflect a basic curiosity-based behavior goal. The concept-network was built in a way that each question asked about a different object has its own values of parameters. For each object *o* and question *q* we have calculated the following parameters values: Breadth, $B_{o,q}$, the number of answers for the question; Specificity, $S_{o,q}$, the sum of the inverse of the number of questions that lead to the answer, for each answer; and Depth, $D_{o,q}$, the number of new questions that are potentially available from the given answer.

Let $A_{o,q}$ be the set of objects that are the answers to question *q* about object *o* and K_i be the set of object-question pairs that lead to object *i*. Then:

$$\mathrm{B}_{o,q} = |A_{o,q}|,\ D_{o,q} = \sum_{i \in A_{o,q}} \sum_{j \in \{why, what, how\}} D_{i,j},\ S_{o,q} = \sum_{i \in A_{o,q}} \frac{1}{|K_i|}$$

These measures represent different possible *value* of a question, namely, breadth represents the amount of information that question can provide; depth represents possible new uncertainty an answer can provide and; specificity represents the uniqueness of a question with respect to other questions.

In total, the player visits 5 alien worlds: worlds 1, 2 and 5 are time-limited; world 3 is limited to only five questions; and world 4 is limited to one question type (what/how/why). This is designed so as to assess initial exploration (world 1); change in exploration patterns (comparison between worlds 1, 2 and 5); structured inte-subject comparison (world 3) and categorical force-choice comparison (world 4). We hypothesize that each game thus provides a rich set of exploration parameters that can then be correlated with external measures of curiosity.

4. CONCLUSION

In this contribution, we have presented a work in progress for the development of a novel digital curiosity assessment tool that emphasizes question-asking based exploration. In future work we aim to validate the tool via an extensive study using a wide range of students and external validations, such as teachers' and parents' questionnaires.

ACKNOWLEDGEMENT

The authors would like to thank Tel-Aviv Youth University for their support and Dvir Kleper for this insightful comments. The work is supported by the National Institute for Testing and Evaluation, Israel. G.G. is a Jacobs foundation fellow.

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