Bar Charts Literacy Serious Game

Mariana Shimabukuro
University of Ontario
Institute of Technology
Oshawa, Canada
Email: marianaakemi.shimabukuro@uoit.net

***Abstract*—Literacy has a broad definition across different fields. However it is an important topic in any area, but when it comes to visualization literacy, we cannot say it receives the same attention as text literacy. More specific in the data visualization, narrowing it down to bar charts, people's literacy level is below the expected. Even though bar charts can be considered one of the simplest data visualization graphics and also one of the most common in our daily lives, people are usually not interested in improving their literacy level, what can cause misunderstanding and misinformation. The knowledge about building or reading a bar chart has been taken for granted when it should not. Regarding this issue, this project aims to develop a serious game that can teach people the meaning of each element in a bar chart (e.g., labels, axis, etc), also teach them how combine those elements in order to build a bar chart, at last the game will improve their capacity of interpret the bar chart visualization, in other words, improve their literacy level.**

***Keywords*—Visual, visualization, bar charts, literacy, serious game.**

I. Introduction

Bar charts (BC) are one of the graphical representations most commonly used in data visualization. Even though, the ability to build and interpret BC is considered as common sense, in the work developed by Boy et al. [1] as the authors assess the visualization literacy (VL) of participants, they realize the average of VL for bar charts is very low, so to compensate that they dumbed down the difficulty level of their assessment test in order to normalize its results. From a test in graphicacy [2] the authors concluded that the adult level of VL is achieved in fourth grade, and after that there is little to no room for improvement. However, they are not sure about what is an adult level in VL, another aspect to be considered is the fact that like many abilities we may have, when we do not practice them, they may fade out with time.

According to Bleed [3] even though, the way people are accessing and interacting with knowledge has changed, the way the institutions tend to teach and assess content hasn't changed as much, and the entertainment industry has a huge influence in people's lives, mostly for young adults that are growing up around movies, computers, the Internet, smartphones, video games, etc. Bleed [3] also claims that playing video games made people very familiar with problem-solving skills in order to accomplish a defined goal. A statement of the author about video games in education: "In a well-designed game, people learn new skills and see the consequences of their knowledge, or their ignorance, as their scores climb or fall" [3].

Having these ideas in mind, it is possible that people do not feel motivated enough to keep practicing/improving their VL skills using the existing means, but once it may lead them to misinterpretation or misinformation - defeating one of the main goals of a data visualization, we should provide better tools to support the process of teaching and assessing VL. Furthermore, these tools must approach people in an engaging and technological way, where they can learn with their mistake, and build up on their abilities.

To address this issue we would like to design and implement a serious game that aims to engage people while helping them to improve their VL level by both building and interpreting bar charts.

II. Related Work

A. Serious Games

Serious Games are defined as games designed to convey learning material in being played through [4]. Serious games are designed to foster learning of targeted skills that are particularly difficult and not rewarding for participants [5]. Important design goal elements mentioned by Whyte et al. [5] include: immersive storylines, goals directed around targeted skills, rewards and feedback about goal progress, increasing levels of difficulty, individualized training, and the provision of choice.

Breuer and Dante [6] points out serious games as an interesting area for inter- and multidisciplinary academic research. Although, serious games should aim for a blended learning experience which seamlessly integrates enjoyment and learning and presents the learning content as something which is neither external to the game nor a juxtaposition of entertaining sequences and educational material.

Gee [7] believes that use of games and game technologies for learning content in schools and skills in workplaces will become pervasive. To justify his belief he points out that all learning involves "playing a character", for instance, if the student plays the role as a scientist in the classroom, she/he will feel more motivated for new and deep learning in the classroom, or even in the workplace [7]. Games are often challenging, but do-able, they are often also pleasantly frustrating, which is a very motivating state for human beings, and games can be customizable to the players abilities level [7]. Adding to that, Gee [7] also mentions that games may be better sites for preparing workers for modern workplaces than traditional schools.

1) Data Games: Data visualization has already started to incorporate game elements, in order to become more attractive to users by creating data games. A data game is a game that allows the player(s) to explore data that is derived from outside

the game, by transforming the data into something that can be played with. In other words, games as a form of interactive data visualization [8]. For instance, the Bar Charts Ball created by [9]. Bar Charts Ball is a game where players indirectly control a ball by modifying a bar chart that the ball rests on. Its goal is to make data selection a core game mechanic in such a way that the player needs to learn about the data set in order to play the game better [9].

Another data game example is Dataplay by Macklin et al. [10]. Dataplay is a data game that helps people to manipulate data visualization, and so far from their design, they concluded that these types of game mechanic platforms can help people to understand scatterplots, bar charts and sociograms better.

B. Visualization Literacy

1) Definition: Visual Literacy is defined as the ability to read, interpret and understand images and visual media [11]. For Visual Literacy being such a broad term, Taylor [12] prefers to define the ability to interpret specific types of visual medias (diagrams, maps, charts, graphs and so on) as *Visual Information Literacy*. On the other hand, Wainer [2] uses the term *Graphicacy* as opposed to Visual Information Literacy.

In contrast, Boy et al. [1] prefers to adopt a more general term, *Visualization Literacy*, considering that the authors belong to the Information Visualization (InfoVis) community. Therefore, Visualization Literacy is defined as "the ability to confidently use a given data visualization to translate questions specified in the data domain into visual queries in the visual domain, as well as interpreting visual patterns in the visual domain as properties in the data domain" [1].

2) Teaching Visualization Literacy: According to Rakes [13], the ability to interpret visual representations is overlooked by the educational system. Visual literacy does not necessarily come naturally, as many students have difficulty interpreting visuals [13]. The author [13] also suggests some strategies that could be included in the current education system, such as, create visualizations along with the regular text interpretation and the use of computer tools (image editors, presentation software, photographs, etc).

Abud Jr [14] acknowledges how difficult it is to teach visual literacy. Even though their work are 14 years apart (1999 and 2013), Rakes [13] and Abud Jr [14] agree on using technology to enhance visual literacy aptitude. Some digital tools are cited in his article [14]:

- **VisualDNA** makes an online quiz to test people's personality using a series of questions, of which the answers are given in pictures. In order to answer the question, the user needs to interpret the images, and in turn the users' visual literacy aptitude may improve [15].
- **lino** is a collaborative graphical environment, where users can post notes, videos and pictures. Users can comment in others people's content, which can make lino a good tool to interpret images [16].

Felten [17] in his work emphasises the importance of teaching visual literacy not only in basic education, but also in higher education. In the author's opinion academic disciplines are only starting to take visual representations seriously now, and it is the reflection of many academics failing to understand human learning, rather than a change sparked by technological advancement. This work also points out that, the tools for video, data visualization, and multimedia editors, will require a formal instruction in information, visual, and technological literacy [17].

Likewise, Bleed [3] exposes the lack of visual literacy in the higher education curriculum and explains that, in the 21st century, visual literacy is required of us as much as textual literacy. Most of the academic programs just focus on the ability of writing and reading words, consequently failing to acknowledge what being fully literate means today [3].

Another interesting point made by Bleed [3] is how the new generation of learners have changed by being so strongly influenced by the entertainment industry (television, video games and movies). In addition to that, Brumberger [18] defines that, the students that currently populate the classrooms are known as digital natives (millennial learners), whom have grown up with relatively new technologies, including cell/smart phones, and video games. Thus, they are intuitively visual learners [18]. However, the educational institutions have not adjusted to this change [3].

An illustration of academics becoming more aware of the importance of visual literacy is the new paradigm called constructive visualizations [19]. By creating flexible and dynamic visualizations introduced by Huron et al. [19], they believe their approach could be used to learn and teach visualization literacy. Their method can be applied to allow children, as well as adults, to learn about the relationships between visual variables and the data [19].

At last, Ruchikachorn and Mueller [20] created a platform that allows people to create a visualization, that has a simpler structure, in which their application morphs it into a more complicated or novel visualization (morphing from pie chart to a treemap). The learning principle they have used is the learning-by-analogy methodology, where the users can see their data representation from a visualization they are familiar with, to a novel one [20].

3) Assessment of Bar Charts Literacy: When Wainer [2] tests literacy levels in his work, he uses three different categories of queries that can be answered by charts:

1) Elementary: the extraction of exact information. For instance, "how much rain fell in February in San Francisco?".
2) Intermediate: the detection of trends. For instance, "in which season the amount of rain fall decrease each month?".
3) Comprehensive: the comparison of whole structures. For instance, "which season has the most rain?".

Meanwhile, Danos and Norman [21] in order to assess charts literacy, they investigate the following abilities:

1) Identify and represent information in graphical form.
2) Elaborate diagrammatic forms to represent planned sequences.
3) Use methods of representing three-dimensional objects in two dimensions.

Finally, in the assessment test designed by Boy et al. [1] considers the following skills:

1) The user has a pre-specified goal to extract a specific piece of information.
2) The user looks at the graph and the graph schema and gestalt processes are activated.
3) The salient features of the graph are encoded, based on these gestalt principles.
4) The user now knows which cognitive/interpretative strategies to use, because the graph is familiar.
5) The user extracts the necessary goal-directed visual chunks.
6) The user may compare 2 or more visual chunks.
7) The user extracts the relevant information to satisfy the goal.

In addition to that, Taylor [12] mentions the importance of understanding scales and baseline (sometimes the baseline does not start from zero) of a bar chart, this knowledge is essential to interpret the differences between values.

4) Visualization Literacy Serious Games: The Topmarks Online Ltda [22] gives to children the opportunity to learn online, through safe, fun and engaging games and activities, while providing safe access to high quality, free teaching and learning resources. Topmarks [22] has several games for teaching visualization literacy. The most relevant examples to teach bar charts in particular are:

1) Bar Charts (5-11 years old): in this game the player is asked to interpret bar chats in different levels of difficulty.
2) Grapher (5-11 years old): in this game the player is asked to create a block graph, and he/she is given the resources to change the scale, column titles and graph title.
3) Collecting Data (5-7 years old): in this game you collect the data from the avatars, and with these information the children create a bar chart and a pictogram for several examples. So, it teaches concepts of collecting the data, organizing the roll and then creating the visualizations.
4) Fishing(5-7 years old): in this game the player is fishing from a boat and when he/she catches the fish, it will show in a pictogram. It is good for understanding quantitative data and visual representation.
5) Data Analysis Explorer (5-11 years old): in this game the player is supposed to help an avatar to decide which flavours are the most popular in a sweet factory. The player will be asked to collect and order data, in order to create a bar chart.

Clearly, visualization literacy is an important topic to be learned [3], [18], [17], [19], [13], and serious games seem to be a good approach on how to teach visualization literacy, once games mechanics has already been used to help people to explore data visualizations (data games) in a more attractive and interactive way [10], [9]. The current tools' audience are mainly children from 5-11 years old, and the data games are meant for specific datasets exploration, consequently the literature is lacking tools to teach a more general audience, like people who needs to refresh and enhance their visualization literacy skills. this work provides enough evidence to prove that well designed serious games are attractive for the current generation of learners. Therefore, serious games should be designed aiming to balance between fun and learning elements in order to be effective, in this case, effective teaching visualization literacy [18], [5].

In summary, serious games is the missing link to teach visualization literacy to the new generation of learners [14], [3]. In order to design the learning objectives, we should follow the abilities that the assessment of bar charts literacy aims to evaluate [1], [21], [12], [2].

III. Methodology

A. Target Audience

The targeted audience is people in fourth grade or higher. Our goal is not to introduce concepts about bar charts (BC), but to help to consolidate and improve concepts about building and interpreting BC. Regarding that, we assume people who play our game have already been introduced to the topic. Once people tend to achieve their VL skills already in fourth grade [2], any person from that point would be a potential user of this game.

B. Educational goals

The educational requirements were listed and we categorized them in groups of tasks as follow:

1) Basic tasks: this group of tasks should teach the player to identify and understand the role of each element in a BC. It should include activities to simply find elements, and to place elements in their positions.
2) Analytical task: it will include analytical activities such as the comparison of two bars, sorting bars and being able to make a statement about what they can interpret from the chart.
3) Advanced tasks: this category will introduce different styles of BC including inverted axis, baseline and three-dimensional (3D) BCs.
4) Advanced analytical tasks: after getting to know more advanced styles of BC, in this group of tasks we intend to test the players analytical skills in them.

The main goal of the basic tasks is to consolidate the structure of a BC, because a BC as other kinds of graphics are generally used for analytical tasks (e.g., comparing two bar values). However, if the person does not understand how a BC is built, then performing those analyses would be complicated. That is the reason the basic block of tasks is presented, and only after they have been completed we introduce the analytical tasks. After concluding the first two groups of tasks, the player is encouraged to learn how to read and interpret advanced BC models by finishing the last two group of tasks.

C. Game Engine

The genre of this game is adventure and puzzle in a low fidelity environment, where the player will be introduced to a storyline and will have to solve a series of activities in order to be allowed to continue evolving his/her character. The player

evolution throughout the game will be given in a level system, which will be presented in the storyline section of this paper.

We like to define this game as a goal oriented game, where the participants have to achieve a minimal amount of points (reward system) in an activity in order to be able to do the next level activity. However, the learner will be granted as many trials as needed to pass a level, in this way he/she can learn by trial and error.

Considering the fact our target audience is people with previous knowledge, that are willing to improve and/or practice their skills, the players will have the option to skip sets of activities only if they are able to pass the more advanced activities in their first trial. For instance, the players wants to skip the basic level activities, where they are supposed to learn more about the bar charts elements, they have to get enough points in the first activity from the next set of tasks in their first trial, demonstrating their already master the previous category and there is no need to go through it. On the other hand, if they fail, the learners will not be able to try to skip it again, and they have to pass through the whole basic category in order to proceed to the more advanced one. With this skipping system, we can avoid the situation where the player gets bored and/or frustrated for having o go through category of tasks they don't need to practice.

1) Storyline: This game storyline is, the learner is newly graduated and is looking for a good position in a marketing company, in order to make decisions in this position, there will be bar charts that need to be interpreted. The player will start the game as an intern, when mastered the first set of activities, he/she will be promoted as an assistant, then a manager junior, then a manager senior and at last the marketing president for the company.

In order to show their ability to be promoted, they will pass through a more complex task presented as a challenge. The challenge tasks, are the milestones where the players will have the chance to skip a whole group of activities, if when achieved a manager junior position the player wants to do the challenge for manager senior and successfully completes it, they will be allowed to skip the training tasks.

We chose this storyline, because it represents a real life situation, and emphasizes the importance of knowing how to interpret bar charts.

D. Game Evaluation

Ir order to evaluate this game, we will design a crowd-sourcing experiment via a crowd-sourcing platform, where web workers get paid a small amount per task, but it offers researchers almost immediate access to hundreds of users [23].

For the full experiment, we would pay the participants an amount of $20.00, and the desired amount of participants that finish the full experiment is ten people. The following steps represent the design of the evaluation:

1) Participants will do an assessment test provided by Boy et al. [1] to measure their bar chart literacy level, then they will be invited to play my game. (Participants will be paid $1.00 for this task)
2) Participants will play the game, and then they will be redirected to a second assessment. (They will be paid $5.00 for this task)
3) Participants literacy level will be tested again using the same test, followed by a questionnaire about their experience. (They will be paid $14.00 for this task)

When participants finish the full experiment they will be granted $20.00 each in total, otherwise they will be paid proportionally to their work. These conditions will be explained to participants prior their agreement to join the study.

All the data from participants who finished the whole experiment will be analyze to answer the research question: is the second assessment measurement significantly higher than the first assessment? Only If the answer is yes, then we can consider the game effective in helping people to improve their bar charts literacy.

The pos experience questionnaires will also be analyzed in order to determine which kind of improvements can be done to the game (gaming or/and teaching aspects).

IV. Implementation

All the development is done in web using HTML5, CSS, JavaScript and JQuery technology.

A. Work in Progress

At this point, we have only implemented some activities prototypes described bellow. However, most of the game elements haven't been implemented yet, such as the points reward system, and the levels within the storyline integration. The prototypes simulate some of the individual tasks included in the game.

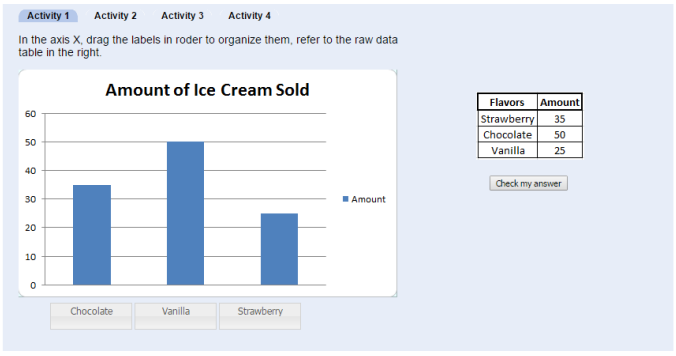

Fig. 1. Screen capture of activity 1 prototype.

1) Activity 1: In the activity 1 (Figure 1), the learner has to show the ability to understand the correspondence of data displayed in a raw table versus a bar chart. Their task is to drag the labels from axis X in the graph matching the right bar. This task would be categorised in the "basic tasks" group.

2) Activity 2: In the activity 2 (Figure 2), the learner has to show the ability to understand the meaning of the graphical representation, as the height of the bars, being able to point out which of the bar has the biggest distribution among all. Their task is to select the label(s) that represent the greatest amount in the given bar chart. This task would be categorised in the "analytical tasks" group.

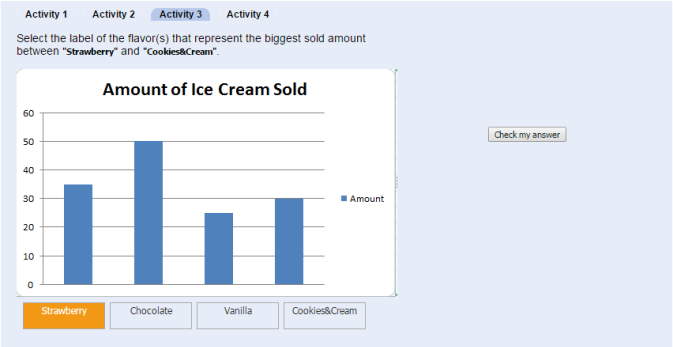

Fig. 2. Screen capture of activity 2 prototype.

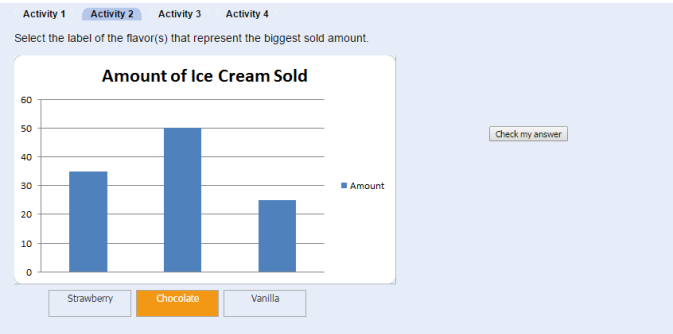

Fig. 3. Screen capture of activity 3 prototype.

3) Activity 3: In the activity 3 (Figure 3) similar to activity 2, the learner has to show the ability to understand the meaning of the graphical representation, as the height of the bars, being able to point out which of the bar has the biggest distribution considering only two of the four displayed bars. Their task is to select the label(s) that represent the greatest amount between two options in the given bar chart. This task would be categorised in the "analytical tasks" group as well.

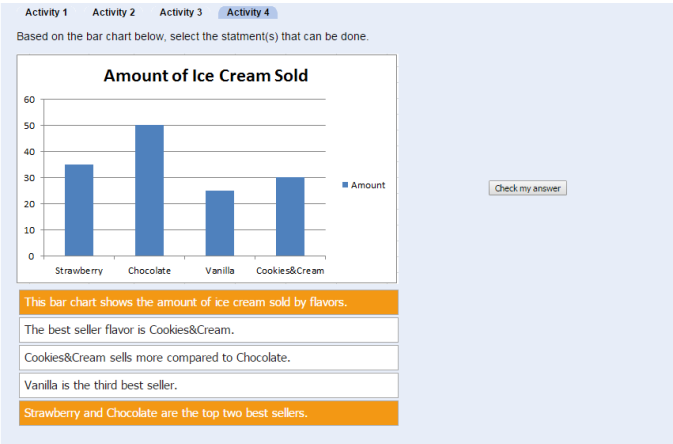

Fig. 4. Screen capture of activity 4 prototype.

4) Activity 4: In the activity 4 (Figure 4), the learner has to show the ability to understand the bar chart and make statements from its interpretation, demonstrating he/she are able to abstract the information displayed in a high level. Their task is to select all the statements that can be done based on the information showed in the presented bar chart. This task would be categorised in the "analytical tasks" group as well, however, it would be more advanced within this group of tasks.

V. Conclusion and Future Work

Bar charts literacy is an important set of skills, that just like any other knowledge needs practice. This paper presents a solution for this problem, knowing that serious games is usually a good approach for teaching, mostly for being challenging, but do-able, and for being customizable to the learners abilities levels, we described our bar charts serious game design.

The presented serious games has an engaging storyline that can be easy to relate to, our levels system allows people that have higher ability level to skip the basic level, avoiding boredom and frustration. Adding to that, our points reward system provides feedback about the learners ability, while the progression in the game is an analogy to getting promotions at work, which will encourage the learners to keep practicing.

As a future work, we intend to finish the implementation of the game, inserting the points reward system, the activities integration in a main platform along with the storyline elements. After the implementation is done, we want to do the game evaluation, which will allow us to test the effectiveness of the game and to implement feedback from the users.

In summary, the presented serious game can help people to practice and improve their bar charts literacy skills in a fun and engaging way.

Acknowledgment

The author would like to thank Dr. Bill Kapralos, and the Vialab members, mostly Dr. Christopher Collins.

References

[1] J. Boy, R. Rensink, E. Bertini, J.-D. Fekete *et al.*, "A principled way of assessing visualization literacy," *Visualization and Computer Graphics, IEEE Transactions on*, vol. 20, no. 12, pp. 1963–1972, 2014.

[2] H. Wainer, "A test of graphicacy in children," *Applied Psychological Measurement*, vol. 4, no. 3, pp. 331–340, 1980.

[3] R. Bleed, "Visual literacy in higher education," *Educause Learning Initiative*, 2005.

[4] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness: defining gamification," in *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*. ACM, 2011, pp. 9–15.

[5] E. M. Whyte, J. M. Smyth, and K. S. Scherf, "Designing serious game interventions for individuals with autism," *Journal of Autism and Developmental Disorders*, pp. 1–12, 2014.

[6] J. S. Breuer and G. Bente, "Why so serious? on the relation of serious games and learning," *Eludamos. Journal for Computer Game Culture*, vol. 4, no. 1, pp. 7–24, 2010.

[7] J. P. Gee, "What video games have to teach us about learning and literacy," *Computers in Entertainment (CIE)*, vol. 1, no. 1, pp. 20–20, 2003.

[8] M. Friberger and J. Togelius, "Data games — building games on data," 2014. [Online]. Available: http://data-games.org/

[9] J. Togelius and M. Gustafsson Friberger, "Bar chart ball, a data game," 2013.

[10] C. Macklin, J. Wargaski, M. Edwards, and K. Y. Li, "Dataplay: Mapping game mechanics to traditional data visualization," in *Proceedings of DiGRA*, vol. 2009, 2009.

[11] T. Stafford, *Teaching visual literacy in the primary classroom: comic books, film, television and picture narratives*, 2010.

[12] C. Taylor, "New kinds of literacy, and the world of visual information," *Literacy*, 2003.

[13] G. C. Rakes, "Teaching visual literacy in a multimedia age," *TechTrends*, vol. 43, no. 4, pp. 14–18, 1999.

[14] G. G. Abud Jr, "Digital activities for visual literacy," 2013. [Online]. Available: http://abud.me/digital-activities-for-visual-literacy/

[15] VisualDNA.com, "Free insightful personality test - VisualDNA," 2015. [Online]. Available: http://you.visualdna.com/quiz/personality?c=us/quiz

[16] Infoteria, "Sticky and photo sharing for you - lino," 2015. [Online]. Available: http://en.linoit.com/

[17] P. Felten, "Visual literacy," *Change: The Magazine of Higher Learning*, vol. 40, no. 6, pp. 60–64, 2008.

[18] E. Brumberger, "Visual literacy and the digital native: An examination of the millennial learner," *Journal of Visual Literacy*, vol. 30, no. 1, p. 19, 2011.

[19] S. Huron, S. Carpendale, A. Thudt, A. Tang, and M. Mauerer, "Constructive visualization," in *Proceedings of the 2014 Conference on Designing Interactive Systems*. ACM, 2014, pp. 433–442.

[20] P. Ruchikachorn and K. Mueller, "Learning visualizations by analogy: Promoting visual literacy through visualization morphing," *IEEE Trans. Visual. Comput. Graphics*, vol. 21, no. 9, pp. 1028–1044, 2015.

[21] X. Danos and E. Norman, "The development of a new taxonomy for graphicacy," 2009.

[22] Topmarks.co.uk, "Fun data handling games for children," 2015. [Online]. Available: http://www.topmarks.co.uk/maths-games/5-7-years/data-handling

[23] J. Heer and M. Bostock, "Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design," *Proceedings of the 28th Annual CHI*, 2010.