Cellulo City Learning Activity Design Details

***Abstract*— This document is supplementary material giving details on the open-ended learning activity named *Cellulo City*, where a tangible *Cellulo* robot is moved to explore different paths on a paper-based map with the goal of finding the best path.**[1]

I. PILOT STUDY

A. Activity Pipeline

1) Introduction to Cellulo: In order to familiarize the children with the Cellulo platform, we used a simple map that is printed on an A3-sized sheet. Each team of learners was asked to i) put the Cellulo on a location in the map, where the locations are displayed via clip arts, ii) hold and move the Cellulo on the road that connects this location to another location, and iii) feel the haptic feedback associated with the type of the road while moving the Cellulo. We confirmed by asking each learner that they could feel the difference in the haptic feedback for the different types of roads. During this activity, the buttons on the Cellulo robot were not illuminated.

2) Phase 1—Immediate Feedback Phase: After the introduction, the first six teams were given Map 1 and the remaining six teams were given Map 2, and the teams were asked to find the best path from *home* to the destination. In this phase, the remaining battery level is shown throughout the map and haptic feedback is given on all of the edges. Each team was given a blank sheet as a note-taking sheet, with heading "Hey friends, you may use the paper to keep track of your battery for each solution on this sheet". The maps were printed on A1-sized sheets, which allowed teams sufficient space to engage with the task space easily, e.g. move the robot with ease. The purpose of employing two different maps is to see whether the order of the maps affects the task performance. This phase was about 10 minutes. The authors would like to mention that the timings were not adhered to very strictly. In the end of this duration, the teams were asked to move the Cellulo on their choice of best path, and then also draw it on a piece of paper that has the map on it for backup. The note-taking sheets were collected at the end of this phase.

Each button, representing one battery, changes color according to the mapping scheme as follows: One full battery (100%) amounts to a value of 4 and is shown in green. Then, a value of 3 (75%) is displayed with color yellow, value 2 (50%) is in orange, value 1 (25%) is in red, and 0 (0%) is shown with the light turned off. The current battery value is the sum value displayed by the six buttons.

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3) Phase 2—Delayed Feedback Phase: In Phase 2, the maps were swapped so that the first six teams that previously worked on Map 1 were given Map 2, and the last six teams were given Map 1. In this phase, the battery level is only shown at the goal node and not on the intermediate nodes or edges, and haptic feedback is given on all of the edges. The purpose of this phase was to analyze empirically if the kids exploit their knowledge from previous phase to successfully find the optimal path in this phase despite delayed feedback. Each team was given a new blank sheet as a note-taking sheet, and these sheets were collected at the end of this phase.

4) Individual Quiz: After the two phases in which the kids worked in teams, each learner individually was asked to draw the best path on a set of maps, separate from the other learner(s) in the team. The idea behind this is to gauge the individual understanding and how it compares to team-level performance. The set consisted of three maps printed separately on A4-sized sheets. The maps are similar to the ones seen in the two phases, and designed as follows: The first map is Map 1 with a different source node, and shuffled clip arts; The second map is Map 1 rotated about the x-axis and shuffled clip arts; and the third map is identical to Map 1—See Fig. 2 for the maps used in individual quiz.

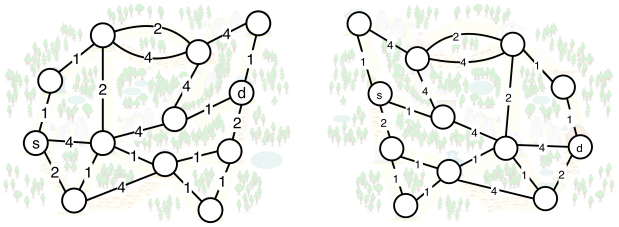
5) Collaborative Quiz: After the individual quiz, each team was asked to answer a list of questions that were designed to gather the learners' understanding about the underlying notion of cost, that connects to the learning outcome of the activity. The goal of having them work in teams after an individual quiz is to promote discussions, and collaboratively learn from each other e.g. by correcting each other—See Section I-D for the questions asked in collaborative quiz.

6) Time for Telling: Our activity corresponds to a constructivist model of learning, where the learners actively constructed the knowledge regarding the underlying notion of cost in the maps. In this sense, the learners are prepared to be told the importance of the differences that they have discovered, which creates a "readiness" or "time for telling" [1]. Hence, in this part, we explain the notion of cost and what makes a path an optimal path as a general case, as well as by linking it to the activity at hand. What we assumed they learned implicitly through the activity was told them explicitly in this short session on *notion of cost* in path planning. We explained the notion of cost and what makes a path an optimal path both in general terms and by linking it to the activity at hand.

APPENDIX

B. Underlying Graphs of the Maps

Map 1 and Map 2 have the same underlying connected, edge-weighted undirected graph with 12 nodes and 23 edges—see Fig. 1 for drawings of the underlying graphs as overlaid on the matching maps. Map 2 is obtained by rotating Map 1 around y-axis, swapping source and destination nodes, and then shuffling the node clip arts except for the source node. The maps are printed on A1-sized sheets.



(a) Graph 1 on Map 1 (b) Graph 2 on Map 2

Fig. 1: Drawings for the underlying graphs of Map 1 and Map 2 as overlaid on the corresponding maps. s and d denotes the source and the destination nodes, respectively. The goal on a map is to find the optimal path from s to d by moving a Cellulo robot on the edges of the graph. The number on an edge stands for the cost of that edge, that is incurred to the robot if it traverses it.

C. Maps of the Individual Quiz

(a) First Map (b) Second Map (c) Third Map Map

Fig. 2: The maps used in the individual quiz. Each is printed on an A4-sized sheet, and stapled in the given order.

D. Collaborative Quiz Questions

For the collaborative quiz, each team of learners is asked to answer the following multiple-choice, multiple answer questions on paper. The questions and answers are presented both in English and French. Here, only the lines in English are given. The correct answers are boxed. At the top of the first page there is the following statement: *Please discuss and respond to these questions. (You can choose multiple options)..*

Q1. What do the number of lights on robot show to you?
1. As robot moves further, number of lights change
2. As robot moves further, number of lights stay the same
3. As robot moves further, number of lights decrease
4. I do not know

Q2. Which robot has more battery level?

(A) (B)

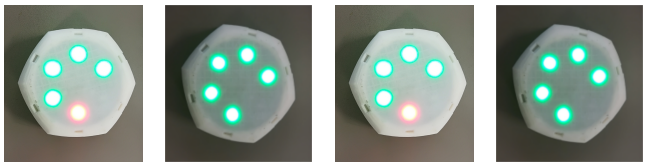
1. A
2. B
3. Both have same
4. I do not know

Q3. In which road your robot loses most battery?
1. Mountain road
2. Plain road
3. Stony road
4. All are the same
5. I don't know

Q4. Was moving the robot on the plain road different than moving the robot on a mountain road?
1. No, it wasnt
2. It is more difficult to move the robot on a mountain road
3. The battery level after a mountain road is same as after a plain road
4. The battery level after a mountain road is different than after a plain road
5. I do not know

Q5. Imagine you want to go from home to cinema or from home to gym..which option/options is/are important when you choose the path for your robot?
1. The length of a road
2. The type of road: simple, through mountains or rocks
3. Both of them
4. None of them

Q6. Choose one of the following four options for the three questions below. Take note of the type of road.



(A) (B) (C) (D)

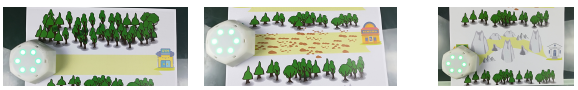


Figure 1 Figure 2 Figure 3

(a) Suppose that you want to go from home to gym (Figure 1), how much battery do you think Cellulo will lose?
1. (A)
2. (B)
3. (C)
4. (D)

(b) Now suppose that you want to go from home to cinema (Figure 2), how much battery do you think Cellulo will lose?
1. (A)
2. (B)

3. (C)
4. (D)

(c) Lastly, suppose that you want to go from home to library (Figure 3), how much battery do you think Cellulo will lose?

1. (A)
2. (B)
3. (C)
4. (D)

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REFERENCES

[1] D. L. Schwartz and J. D. Bransford, "A Time For Telling," *Cognition and Instruction*, vol. 16, no. 4, pp. 475–5223, 1998.