Ori-Gami – An App fostering spatial competency development and spatial learning of children

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Abstract

Fostering spatial competencies of children has been positively discussed across disciplines and institutes. As most exiting tools for spatial learning are based on existing software such as geographic information systems, these tools may not be suitable for children at the age of 8 to 12. With this goal in mind, we designed the Orientation Gaming App (Ori-Gami) fostering the development of spatial competencies and spatial learning of children in a gaming scenario. Children only need to follow intuitive instructions combined with visual and auditive hints given by the app to complete the game in an outdoor environment. Throughout the process, children engage in activities involving essential spatial competencies such as map learning, orientation, and wayfinding. This paper presents the concept, design and usability tests of Ori-Gami used by both children and adult students. Results confirm our principles of designing a tool specifically for children to foster their development of essential spatial competencies such as orientation, wayfinding and map understanding.

Keywords: spatial competencies, orientation, education, spatial learning

1 Introduction

What children learn in school forms the basis for their approach to society and to science. To foster the role of spatial information in society and to support the development of spatial skills and competences it is important to point learners early on to the transdisciplinary power of spatial information and spatial thinking. When Goodchild coined a spatial literacy to appear in the curricula and in education on the same level as a mathematical and linguistic literacy [1] he was speaking about a transdisciplinary competence to think spatially in all subjects: from STEM[1], to social sciences and arts. The NRC report "Learning to think spatially" was leading into this direction and presented solutions for Geographic Information Systems (GIS) as a support system to think spatially [2]. Minimal GIS approaches for all grade levels at school, when particular spatial concepts were incidentally used, followed this direction in several studies [3-5].

In our Geospatial Learning project, we develop software to support spatial thinking by following the known principles to foster orientation, wayfinding and map understanding skills. We combine them with user-centered design, game-based learning, and situated computing and evaluate our software with different usability and spatial competence tests. Our applications concentrate on the targeted group at the age of 8 to 12, following the developmental stage [6, 7] and its representation in most curricula [8, 9]. The applications developed within this project are following the curricular requirements ("spatial orientation") and practical requirements, since schools do not concentrate on outdoor activities for classes of geography [10, p. 74] where spatial competencies can be fostered.

[1] short for science, technology, engineering, and mathematics

In this paper we present our app "Ori-Gami" (Orientation Gaming), which is a game to support children to enhance their map understanding, orientation and wayfinding skills, and explain the educational background of this game. Usability and user satisfaction is a key factor for the success of educational games. Thus, this paper describes the concept, design and usability-test of Ori-Gami. Section 2 gives an overview of related initiatives working on spatial thinking and spatial learning. In section 3, we describe our app and explain the educational motivation behind the game. Section 4 presents the design and discusses the results of the usability study. Section 5 concludes the paper by outlining implications from the usability study for the development of focused spatial learning apps and directions for future work.

2 Related Work

Numerous researchers worked on supporting spatial thinking and competency development. These topics have been the focus of several recent and distinctive academic initiatives and programs around the globe (e.g. SILC[2], spatial@uscb[3], LENS[4], CSISS[5], SPLINT[6]) and have been picked as a central theme at an NRC specialist meeting in the United States documented in the NRC-Report Learning to think Spatially [11]. In the following, we review recent activities from a GI Science perspective.

[2] http://spatiallearning.org/
[3] http://spatial.ucsb.edu/
[4] http://www.spatial.redlands.edu/lens/
[5] http://www.csiss.org/classics/
[6] http://www.le.ac.uk/gg/splint/spatialthinking.html

The main goal of the "Spatial Intelligence and Learning Center" (SILC) is the understanding of spatial learning and using this knowledge to produce course specific software to support spatial skills. SILC participants include researchers from cognitive science, psychology, computer science, education, and neuroscience, as well as practicing geoscientists and engineers who are particularly interested in spatial thinking in their fields.

Spatial@ucsb is a research center at the University of California, Santa Barbara. Its mission is to facilitate the integration of spatial thinking into processes for learning and discovery in the natural, social, and behavioral sciences, to promote excellence in engineering and applied sciences, and to enhance creativity in the arts and humanities. Spatial@ucsb also is promoting the development of spatial analytic tools.

LEarNing Spatially (LENS) is an initiative promoting spatial literacy at the University of Redlands working on spatial thinking in school curricula and research. They define spatial thinking as "the ability to visualize and interpret location, distance, direction, relationships, movement and change through space" [12]. They use geospatial technologies to teach a critical way of spatial thinking and support geography students in solving spatial problems, visualizing results and interpreting relationships better through spatial technologies.

The Center for Spatially Integrated Social Science (CSISS) at the University of Santa Barbara emphasizes the growing significance of spatial information in social science research. CSISS supports unrestricted access to tools and perspectives that will advance the spatial analytic capabilities of researchers throughout the social sciences.

The Spatial Literacy in Teaching (SPLINT) Centre of Excellence in Teaching and Learning (CETL) is a consortium of three British Universities (Leicester, Nottingham, UCL) aiming to enhance the teaching and learning of spatial literacy focusing on geospatial technologies.

Education systems all over the world start integrating the use of spatial technologies in their curricula to foster competences like spatial orientation – mostly in the geography context, but also interdisciplinary in and beyond K-12 and undergraduate studies (i.e. [13]). However, still fundamental definitions on spatial thinking and interconnection of concepts in the related disciplines and communities are not established. Especially in the domain of spatial learning in connection or in relation to spatial information, there is a lack of organization, concrete vocabularies and conceptualizations. Test methods for the measurement these competences are still missing. While spatial competence is a central aspect of human adaption [6] we have to face new developments in technology and education by strengthening these competencies.

Our research also aims at supporting spatial competency development through spatial technologies. While most existing research initiatives make use of using existing GISs to teach and support spatial thinking processes, we develop our own apps designed for fostering particular competencies of children at a particular age range.

3 Ori-Gami and its Educational Concept

3.1 The App

Ori-Gami is an app for browsers or tablets. Depending on the platform it can be used stationary or mobile with the use of GPS. It consists of a simple base map and displays route instructions of varying complexity (use of directions, cardinal directions, landmarks and distances) provided by a teacher, or game leader in an online editor. The user can either click on the decision points described in the verbal instructions (browser version, Figure 1) or walk along the instructed path with the device (tablet version, Figure 2).

Feedback, help and game elements allow the user to orientate and find reference points in the map and the real world. The blue dot in the map indicates the current position located by the device or selected by the user. The smiley provides feedback on the current position: It changes color and friendliness to give easy-to understand hints whether the player is moving into the direction of the next waypoint. Each time the player reaches a waypoint, the app signals this by playing a sound and visually via a happy smiley. The next wayfinding instructions are automatically displayed. A trumpet sound and a text at the end of a route gives the user feedback, that she has reached the goal.

Figure 1: Screenshot of the Ori-Gami App (browser version).

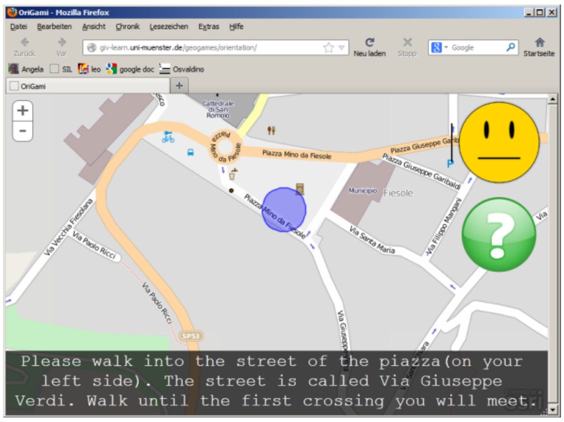


Figure 2: Screenshot of the Ori-Gami App. (tablet version).

3.2 The Educational Concept

The app fosters spatial competencies such as map understanding, orientation, and wayfinding in a game-based learning style.

Map understanding. The visualisation of the user's position via GPS in the mobile version (Figure 2) is a major support in map understanding. Children in the target group are usually not able to locate themselves on a map, since it is difficult to connect the real world environment to its spatial representation on a base map (where buildings are represented as polygons and streets as lines). The movement of the user's representation on the map continuously updated by the moving blue dot helps the user to create a representation and understand map concepts and symbols.

Orientation. The available spatial representations in the map help the user to gain survey knowledge of her environment. Together with the reference of her own position she is able to orientate herself and point to or walk into distinct directions.

Wayfinding. The use of verbal directions during an exploration task leads to accurate environmental learning [14] as the user needs to construct an appropriate spatial representation from the verbal directions [15] which is essential for wayfinding.

Game-Based Learning. By using several elements of digital game-based-learning (DGBL) in the app design (cf. section 3.1.) we try to motivate the users, while training their spatial competences at the same time. DGBL can be understood as "any marriage of educational content and computer games" [15].

4 Usability Test

The usability test investigates the usage performance and the subjective user satisfaction. As this is a usability test, we do not examine the learning success with respect to spatial competencies.

4.1 Design

The tablet version of the Ori-Gami App is used for the usability test. The test involves two phases: In phase one, participants play the game on-site. The experimenter leads the participants to the starting point. The app shows the first wayfinding instruction. The participants have to follow each instruction until the smiley and the audio signal indicate that they reached the waypoint. We tested two alternative routes. The system automatically switches to the next instruction to follow. The tablet is equipped with GPS signal and tracks the route as well as the touch interactions on the display.

In the second phase of the usability tests, participants have to complete a questionnaire, designed for this distinct project, with a focus on the map-based application. Questions one to four refer to their previous experience with paper and digital maps, with tablets and the familiarity with the environment. They required a yes/no response and offered a text field for further details if the question was answered with yes. Questions five to seven refer to the subjective user satisfaction where participants indicate their agreement. In questions eight to thirteen, participants are asked to for feedback to outline problems, report on their experience with the app and give suggestions for improvement. These were open question. Figure 3 lists the questions asked in the usability test.

Figure 3: Questions in the Usability Questionnaire.

Questionnaire:
1. Did you use a paper map to search for a location before?
2. Did you try to orient yourself with a map at an unfamiliar place before?
3. Did you work with a map (such as GoogleMaps/Earth) on a computer or a notebook before?
4. Did you work with a map on a tablet or iPad before?

5. Did you like working with our app?
6. Would you like to use such an app in in the lectures?
7. Would you like to play such a game in your leisure time?

8. What did you like about this app?
9. What did you not like about this app?
10. What was particularly easy for you?
11. What was particularly difficult for you?
12. Was there anything you did not understand?
13. Do you have any ideas to improve the app?

The usability of the software was tested with two user groups: a group of 9 geoinformatics students (age *M* 24.5, *SD* 4.4) and a target group of 12 ten-year old children of a local school. The first group includes experts in geoinformatics with high-developed spatial competencies and experience as indicated by the first four statements in the questionnaire. The second group is assumed to have lower spatial competencies (as they are still to be trained according to educational guidelines), but they have very good knowledge of the environment, since the game took place in the surroundings of their school.

4.2 Results and Discussion

The location of the participant during the experiment was recorded while navigating via the integrated GPS-receiver. The participants from both age groups walked similar distances on both routes. A significant difference could be found in the average walking speed, as the children user group was walking with an average speed of approx. 4 km/h, the older user group with an average speed of approx. 6 km/h. This may be a general manner of different walking speed, another reason could be, that the younger group did not feel comfortable to walk with a tablet device and constantly look at the device and their surroundings. On both routes two children made an error in following the instructions, which concluded in a longer walking distance of 20-40m. The error was taking a wrong direction on a decision point (crossing) or just missing a decision point by walking to far (Figure 4). The errors were found in different locations. The older participants did not make any errors and followed the route instructions very quickly. A reason for that may be their well-developed spatial competences as map understanding and orientation. They could follow the instructions properly without knowledge about the environment.

Table 1: Route 1 – children (long)

	Distance (m)	Time (s)	Speed (km/h)	Errors
child 1	647	585	3,98	0
child 2	689	607	4,09	1
child 3	645	632	3,67	0
child 4	668	570	4,22	0
child 5	688	619	4,00	0
child 6	662	646	3,69	1

Table 2: Route 2 – children (short)

	Distance	Time	Speed	Errors
child 7	352	359	3,53	0
child 8	429	401	3,85	0
child 9	418	405	3,72	0
child 10	514	398	4,65	1
child 11	427	348	4,42	0
child 12	551	588	3,37	1

Table 3: Route 1 – students (long)

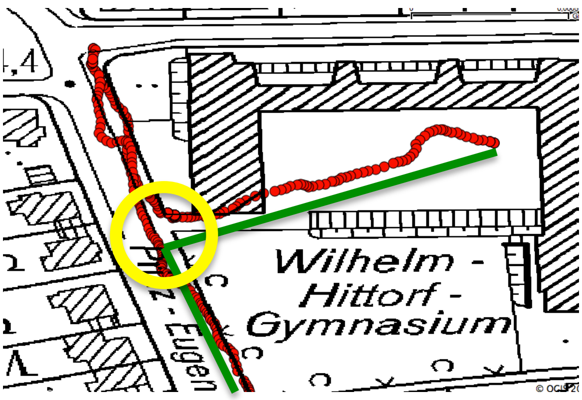
	Distance	Time	Speed	Errors
Stud1	614	376	5,88	0
Stud2	727	382	6,85	0

Table 4: Route 2 – students (short)

	Distance	Time	Speed	Errors
Stud3	376	247	5,48	0
Stud4	370	222	6,00	0
Stud5	342	218	5,65	0
Stud6	336	250	4,84	0

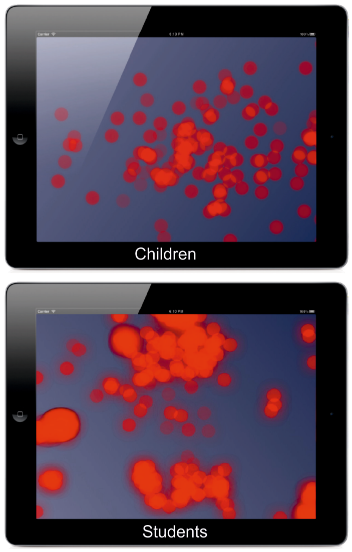
note: missing data due to the iPad of one student loosing connection

Figure 4: Location data (red), correct route (green lines) and error (yellow circle) of one participant.



The interactions between participants and the app such as zooming and panning were recorded during the experiment. There were no additional instructions needed for the map interaction as feedbacks and instructions were provided automatically according to the participant's location. First of all, the interaction between participants and the app was effective as all participants completed this experiment in reasonable time. Secondly, the heat maps of interaction (Figure 5) shows that children and students performed very distinctive interactions with the app on the tablet. Children in this experiment mostly touched the map area in the app during the experiment. But students touched also the area where the instructions were given. In follow-up interviews with the student participants they explained that they touched the instruction areas with the intention to learn follow-up instruction in order to grasp an overview of this task. The interaction with the map was more intense (more touches) for the children who made the errors, as they tried to zoom-out and –in to recognize streets. It seems that children stick with the game better making interactions with the areas where interactions were designed. Students seem to take a more controlling role to acquire additional information. Data collected from the usability questionnaire reveal more information regarding the user experiences in our app below.

Figure 5: Heat maps of user interactions with app.



In general, all participants from two age groups like this app. Students liked this app mostly because they felt it was intuitive and easy to follow the instructions. Besides similar reasons stated by children, they also explicitly stated that they liked this app because they had to orient themselves using the information provided in the app. Furthermore, all participants indicated that they would use this app for courses and leisure. Without further elaboration of students, some children stated that they particularly like using it for leisure to explore unknown areas. However, the usability data also show differences between children and students. As sound effects were designed in this app to provide participants feedbacks, children particularly like the sound effect. But the students indicated that they felt the sound effect was annoying or not adjustable. While the game design seems to pleasure children, many students suggested removing the sound effect. Another major difference is that students indicated the access to all instructions before the experiments. But children didn't request any change to the accessibility of instructions but used the app as the way it was designed. Another small difference is participant's experience working with tablet maps. While all students have used tablet maps before, only a small portion of children had this experience. These differences show that the features designed in this app attract children to fully engage in this game. Three of the four children who made errors indicated suggestions for the improvement of the app, mainly a help or feedback mechanism warning if one is walking in the wrong direction.

5 Conclusions and Future Work

Following the principle of fostering children's spatial competencies including map reading, orientation, wayfinding, we designed this Ori-Gami app and tested its usability with both children and adult students. The comparison between children and students help us confirm our design specially aiming at children. Children in our usability test did not show difficulty using this app even though they had limited experiences using tablet maps. The longer time taken by them indicated the children engaged in our designed components such as instruction following, map learning, orientation, and navigation. Game based learning serves as a promising method in our test for children to learn essential spatial competencies. While students, who have developed much more spatial competencies than children over time, intend to acquire more information for their own judgment or validation, children in this test followed our designed procedure very well. This usability test confirms the promising effect of design intuitive and engaging game for fostering the development of children's spatial competencies. Future work will concentrate on the role of the map (a map solution designed for children's needs concerning scale, resolution and symbols is planned) and on understanding the learning impact, the role of map/mental rotation and the differences between indoor and outdoor use are of main interest.

Acknowledgements

This work was supported by Esri Inc. and the German Research Foundation (DFG) through the project ''SketchMapia: A Framework for Collaborative Mapping" (Grant SCHW 1372/7-1). Thanks also go to the study participants and to the developers of the Ori-Gami app: Benjamin Böcker, Matthias Pfeil and Carolin Hesse.

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