Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-52, 2016
Manuscript under review for journal Hydrol. Earth Syst. Sci.
Published: 10 February 2016

Hydrology and Earth System Sciences
Discussions

Learning about water resource sharing through game play

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Abstract. Games are an optimal way to teach about water resource sharing, as they allow real-world scenarios to be enacted. Both students and professionals learning about water resource management can benefit from playing games, through the process of understanding both the complexity of sharing of resources between different groups and decision outcomes. Here we address how games can be used to teach about water resource sharing, through both playing and developing water games. An evaluation of using the web-based game *Irrigania* in the classroom setting is first presented, supported by feedback from several educators who have used *Irrigania* to teach about the sustainable use of water resources, and decision making, at university and high school levels. We then present the development of two water games in a course for master students in geography, as a way to teach and communicate about water resource sharing, together with a discussion of the learning outcomes based on our experience and student feedback.

1 Introduction

One of the best ways to engage students and instill enthusiasm for hydrology is to expose them to hands-on learning. Using (serious) games in the classroom can engage students, and inspire enthusiasm, while also helping to solidify formal concepts learned in standard curriculum. Learning through games has been shown to increase soft skills, such as critical thinking, creative problem solving, and teamwork (Johnson, 2012), skills that are important for future water resource managers. When teaching hydrological concepts, and especially in the context of water resource sharing, where compromises between different interest groups need to be made and conflicts sometimes arise, games can be a good tool to enact different real-world scenarios. Learning through game play can thus be instructive in showing the complexity involved in the management of water resources, for both students and professionals alike (Douven et al., 2012; Rajabu, 2007). The active participation in mock decision making, through to the outcomes of those decisions using games, also allows different learning goals, including critical thinking and problem solving, to be better realized (Wu et al., 2012).

There are several games that focus on water resources, many of which have been used and tested at various levels in educational settings. Some examples include: *Aqua Republica* (aquarepublica.com), an on-line game aimed at promoting

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Hydrology and Earth System Sciences
Open Access
Discussions

sustainable water resource management under growing water demand and scarcity; the *World Water Game* (Deltares, 2015), where the player decides on measures to avoid water shortages in different regions of the world; and *Water: more than just a game*, from the Swiss Federal Office for the Environment (FOEN, 2015), where the player can take different water management actions for a city and rural areas along a stream reach. Seibert and Vis (2012) recently developed a web-based, multi-player game called *Irrigania*, to teach about water resource sharing between several actors (or farmers), based on game theory. In *Irrigania* players act as farmers living in a village and decide how to irrigate their fields over several years, and are thus presented with water sharing situations with other farmers that are typical in real-world water-related conflicts. Other games with a focus on water resource sharing include board games like the *River Basin Game* and *Globalization of Water Management* (Hoekstra, 2012), that demonstrate issues related to sharing a common resource in an up- and downstream setting, incorporating the concepts of a water footprint and virtual water trade.

In the following, we address how effective games are in teaching about water resource sharing to different educational levels, through both game play and game development. An evaluation of *Irrigania* in the classroom setting is first presented, supported by feedback from several educators who have used *Irrigania* for teaching about water resource conflicts at both university and high school levels. We then discuss our experiences, together with student feedback, from a course on water games that we facilitated for masters students in geography, where students developed a board and computer game, to be used in secondary school classrooms.

2 *Irrigania* as a teaching tool

Since its inception, *Irrigania* (Seibert and Vis, 2012) has been used in different classroom settings and as an outreach tool, to teach about water resource sharing and to explore the role of cooperation and competition of water as a limited common-pool resource (Seibert and Vis, 2012; Pierce and Madani, 2013; Cuadrado et al., 2014). The game is played between villages made up of several farmers (usually 4-6 famers per village). Each farmer has 10 fields and they can choose to irrigate the fields with a combination of rain water, river water or groundwater. Each irrigation source has a certain cost and revenue associated with it. Rain water and river water both have a fixed cost, while the revenue for river water depends on the number of farmers using it. For groundwater, the revenue is fixed, but the cost of groundwater increases with increasing depth to groundwater. The goal of the game is for each farmer to maximize his/her individual income, which to some degree requires considering the total village income. The game is usually played several times with different levels of communication and cooperation during play.

Before play the moderator (teacher) sets the length of the game, rainfall conditions and whether or not communication between farmers and/or villages occurs (making the game either cooperative or non-cooperative), and whether users can see each other's input (information is shared). It is recommended that several rounds be played, and the settings adjusted so that different levels of information and cooperation can be explored. The game can also be played over several days, to give

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Hydrology and Earth System Sciences
Discussions

students more time to strategize and discuss results after a certain number of years have occurred, before continuing. After playing the game several times, patterns related to the amount of communication and information shared usually emerge (Seibert and Vis, 2012; Pierce and Madani, 2013). In a non-cooperative setting, where no information is shared (farmers are not allowed to discuss and don't see each others input), villages typically perform worse, whereas when full cooperation occurs, and each farmer knows who the other is, there is less selfishness, more cooperation between farmers, and this high amount of cooperation usually results in a high income for the village. Pierce and Madani (2013) who played *Irrigania* as part of a larger study to better understand decision making related to common pool resources, showed that the most important factors to promote sustainable resource use were communication and cooperation, followed by trust, information disclosure and social learning.

When uncertainty is introduced in the weather in the *Irrigania* setting (i.e., random amount of rainfall), decisions become more difficult and differences between farmers in their risk taking also tends to emerge. Between the different water resources, there is also learning as players improve the more they play simply by better understanding the longer term effects of overuse in groundwater, compared to river water which, in the game, has no year-to-year memory. In a recent study on sharing common resources amoung farmers in Tanzania, Lecoutere et al., 2015, showed that gender and social status were also found to play a role; during times of water scarcity, high-status women shared fairly, whereas rich and powerful men were less worried about being greedy. Low social status (both men and women) tended to distribute water equally when it was abundant but were more selfish when water was scarce. These different outcomes and aspects that emerge when *Irrigania* is played with different scenarios and groups of players, make *Irrigania* a useful tool to both explore and understand the complexities of water resource sharing.

2.1. A survey of using *Irrigania*

To evaluate the effectiveness of *Irrigania* in teaching about water resource sharing, we carried out a survey, with an online questionnaire sent out to users (teachers) who had registered to use *Irrigania* (since 2012; 18 in total). We asked these users 15 questions in total, and received feedback from 9 users. We asked users questions ranging from basic information on how they have used the game in their classrooms, or as an outreach tool, and how they have incorporated playing the game into their curriculum. We then asked for details on the educational level of their class, the type of course it was used in and how many students played. As responses, teachers have used *Irrigania* mainly at university level, for both bachelor and graduate courses, with one exception of using it for a high school geography course with 30 students. It has mainly been used in courses with a water resources focus (including departments of hydrology, environmental engineering, and natural resources management). One group however, in the department of psychology, played it with students to better understand environmental decision making. Group sizes ranged from 20 students to 110.

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Hydrology and Earth System Sciences
Open Access
Discussions

This was followed by more detailed questions on the specifics of play (how many times they played with the same group, and with different groups, and duration of play). Although some groups played it only one time, most played it frequently, and some have incorporated it into their regular class curriculum. Most groups played it once during the semester in a block of 2-4 hours, but several also played it over several weeks, with up to one full semester for play.

Following the first set of questions, we asked more targeted questions to gauge the effectiveness of *Irrigania* in engaging students (whether the game held students' interest for the duration of play and how enthusiastic students were when playing the game). Teachers' responses depended strongly on the level of study. For bachelor classes that used it, most said that the game held the enthusiasm of the students for the full period, and that the students were quite enthusiastic about playing it. For the graduate level courses however, many said that a 3-hour period was sufficient, since after this amount of time, the students understood the mechanics of the game and some lost interest somewhat. For the high school students however, they wanted more graphics and visualizations to make it more interesting, and teachers commented that this would have likely held their attention for longer periods.

Questions to evaluate the effectiveness as a teaching tool were then asked, including how well *Irrigania* taught about collaboration and conflicts with regard to shared water resources and whether there was improved understanding of shared resources like surface/river and groundwater. All teachers (regardless of level) said that *Irrigania* was moderately (4 replies) to very successful (5 replies) (when asked 'how successful' (not; moderately; very) in teaching about collaboration and conflicts with regard to shared water resources. When asked about whether they thought there was an improved understanding of shared resources like surface/river and groundwater, all answered that there was increased learning about shared water resources, but that a discussion session afterwards was key to solidifying the concepts learnt, especially for the high school and early level bachelor students.

Since *Irrigania* is based on game theory, but is also simple in its rules, it can be a good way to teach about game theoretical considerations related to water resource sharing (Seibert and Vis, 2012). As a follow-up after game play, we asked whether any interesting patterns had evolved and how much discussion the teachers incorporated into the process of playing the game (e.g., whether they had discussions on the topics before and/or after play). We then asked a few questions related to game theory including whether game theoretical considerations related to water resource sharing were discussed (before and/or after playing) and whether *Irrigania* was successful in teaching students (or other players) about the tragedy of the commons. Almost all teachers discussed game theoretical considerations related to water resource sharing briefly before play, but also in a final discussion after play, and this also helped to solidify learning concepts related to game theory. Almost all teachers also found that students understood, by the end of the session play, that cooperative behavior and communication were both key to succeeding. All teachers said that *Irrigania* was successful in teaching students about the tragedy of the commons and supporting discussion of these concepts (all answered 'yes' to this).

Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-52, 2016
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Additional questions were asked on whether the teacher had used other educational games, and differences they found in teaching aspects in these games compared to *Irrigania*. Four teachers used other games in the classrooms, and all said that in comparison, *Irrigania* was very easy to use and required little preparation before using it in the class, which made it appealing. In a final question, we asked for general feedback that teachers thought would be useful for evaluating *Irrigania* as an innovative tool for learning about water resource sharing and suggestions for improving the game. Several suggestions were given, e.g., for younger students (high school) it was suggested that it should be more game-like and visually engaging. University level students however seemed to find it engaging enough, but also suggested that a spatial interface be developed where villages could be represented visually. It was also suggested that more game settings would make it more interesting, allowing students to explore more scenarios and play longer, for e.g., by setting different amounts of water from different sources and having rewards or punishments for level of sharing. Two teachers recommended that a more flexible groundwater level evaluation be implemented by allowing the game to be played with different amounts of available water to start. Another commented that allowing the results to easily be exported would be an advantage for follow-up discussion and analysis of game play.

Overall, the feedback from the survey was positive, and all teachers felt that *Irrigania* was a good tool for teaching about both shared water resources, and game theory. The results highlight that the use of *Irrigania* for different levels of teaching is quite different, and that it seems to be best suited to higher bachelor level to master level courses where students were the most engaged, it held their interest for longer, and teachers had less comments for improvements for these groups.

An additional analysis of user data since July 2013 (since user histories have been saved; excluding our own use) was carried out to further analyse how often users played *Irrigania* (number of games played), how long their rounds were (average game length), and over what period of time they played. The number of games played varied from only one game (users 8,9) to 26 games played (user 10), with most users playing games with 10 years (the default setting), although user 10 played consistently shorter games, with an average of five years. For the game length, many users played over one day, but users 1 and 12 played over a 2 month period, and user 10 (with 26 games played), playing over the full period (July 2013 - present). This agrees with some of the user feedback from the online questionnaire, where many teachers had used it once during the semester in a block of 2-4 hours, and several also played it over several weeks, with up to one full semester for play.

3 Developing water games in the classroom

An ‘Integrative Project’ course within the master's program at the Department of Geography at the University of Zurich, is a six credit point course, corresponding to 180 working hours for the students, running over two semesters. This course has the aim of putting theory learned in the classroom into practice, and is led by different teachers or research groups within the geography department each year. In the “Integrative Project” course on “Water Games” (fall term 2014 and spring term

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Manuscript under review for journal Hydrol. Earth Syst. Sci.
Published: 10 February 2016

2015) five students, four female and one male, from the MSc program in geography participated. All students had German as a mother language and the class was taught partly in German and partly in English. In the following, we first present the course as well as the design and development of two games by students that participated in the course, followed by an evaluation of learning outcomes from the course.

A first goal of the course was for the students to carry out a survey of existing water-related games, including both computer and board games. These games were then played and both positive and negative aspects of each game were discussed, followed by an analysis of what makes a good game. Students also had a couple of lectures, with one on project management followed by two lectures on game theory, given by invited game theory experts, introducing students to game theory (which *Irrigania* is based on). The second part of the course focused on the development of their own games, first through brainstorming ideas for new games, and then forming groups. The students then developed two different games: a board game, *Wiapuna* (Figure 1, left), and a computer based game, *Habitat Ganges* (Figure 1, right) over a period of 6 months. Game development began with initial 'idea boards' (Figure 2) where students brainstormed possible game ideas, discussing aspects of each in class, and further in working group sessions, to narrow down their ideas. Most ideas built upon already existing games that the students had reviewed and played in the first part of the course. The games were then developed over three months of group work with students organizing their own group time together (including summer). During game development, students also tested (played) the games with a couple of smaller groups of their intended target audiences, to get feedback and make improvements. In a final three hour class, the games were played by the students in the class and other geographers in the department. Overall, the players enjoyed the games and comments for improvements or changes were discussed amongst the players.

Wiapuna: Wiapuna was developed as a multiplayer board game (Figure 2, left) for both family play or play in schools or as an outreach tool, for ages 10 and older. It is based on the topic of water resource scarcity, and could be incorporated into regular geography curriculum to supplement and enhance regular lectures. In Wiapuna, players build and develop settlements around four central wells (Figure 3 left), where water is supplied by buying water pipes, and shared between neighbors using the same well. Natural resources (copper, gravel, wood and food, Figure 3 right) are used to buy infrastructure. Water supply through wells is slowly depleted as more and larger houses are built around each well. New efficiency measures need to be implemented to reduce the amount of water use (e.g., through buying drip irrigation, harvesting rainwater for agriculture, and increasing efficiency in household appliances). An element of uncertainty is introduced into the game with natural events that include global and regional heavy rainfall, water poisoning, floods, droughts, tornados or storms. The board design is based on the well known *Settlers of Catan* board game, where players are also awarded points as their settlements grow, and like *Settlers*, is won by the first player to reach a certain number of points. Game play is approximately 70-100 min long, and thus could be incorporated into the regular curriculum, where several sessions could be devoted to game play.

Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-52, 2016
Manuscript under review for journal Hydrol. Earth Syst. Sci.
Published: 10 February 2016

Habitat Ganges: Habitat Ganges is an online game (Figure 2, right) about the sustainable use and sharing of water resources along the Ganges. This game is aimed at German speaking geography students in secondary schools, ideally for groups of 16-24 students. Time needed is approximately 90 mins, which could be played in a classroom where 2 x 45 min sessions could be planned for play (approx. 15 rounds). The focus of the game is on the development of sustainable water use for communities (the cities of Kanpur, Varanasi, Calcutta and the district of Chamoli), and the consequences for the river, the communities relying on it, and the environment, caused by poor river management. Students developed the game based on the sustainability triangle, described by Heins (1994), as way to show that sustainability needs to be approached by considering ecological, economical, and social aspects equally and all together, in an integrative way. They applied this to the idea of river management and the interaction between upstream and downstream use. The overall objective of the game is to create a sustainable river environment between the different communities (played in teams), with each community's action affecting the others, as in the case of a real river with upstream-downstream consequences for each community. The game is played by buying and trading resources (with the different resources shown in the field; Figure 1, left; Table 1), in an attempt to optimize the economy, life quality, and water quality of the Ganges (Table 1 "Auswirkungen", German for 'Effects'), starting with a certain budget. The game is won by achieving the highest overall score from these three indicators, while also taking into account the total population and remaining budget.

3.1 Evaluation of learning outcomes

Based on feedback we received after the course from the students, one of the main comments that most of the students had about this course, was that the time (two full semesters), was not enough to get introduced to different games, get into groups, and finally develop, test and produce their own games. In the end, the rush to complete a final project, and actually produce a game (especially the board game which required a lot of technical expertise to produce) that could be played during the final session (and used later on as a teaching or outreach tool), meant that the game testing phase was very limited. Since the course was really aimed at getting students to apply theory to practice, there is a goal to produce a product at the end that can be used for either teaching or as a communication tool. This problem in time management likely resulted out of a combination of this (not having much experience in turning theory into a practical product in their studies), and having difficulty getting started with the project (deciding on a group and idea and getting going). The latter could have been improved by giving students more time at the beginning of the course to discuss ideas. The introductory sessions/lectures could have been shorter, and possibly more direction while developing ideas and forming the groups given.

Students commented that the lecture on game theory was maybe the least useful part of the course, although they found it interesting, several said that what they learned in the lectures was too theoretical and not useful for them to immediately apply in their game development. Following the lectures, the next part of the course, where students reviewed existing games, worked rather well, and the students all gave positive input about this part and said it was critical for them in developing their own game ideas. This was also clear in the development of the final games, since both of the games were

Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-52, 2016
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Published: 10 February 2016

based on existing games that they had reviewed during this part of the course. After this, when students were given time to get into groups, discuss ideas and get down to work, proved to be challenging – some students had quite strong ideas about how they wanted to proceed, and what type of game they wanted to develop (based on their skills, interests and review of what makes a good game), without wanting to discuss too much with other students. This was however to be a group activity, and reaching a consensus was rather important for the game development to get started. In the end it was decided that the two games would be developed, and that one of the students would contribute to both groups. Once this decision was made, game development went reasonably smoothly, and students spent many hours discussing and testing the intricacies and complexities of water resources sharing. In each step of game development, all the possibilities resulting from of each player's next move had to be evaluated, and through this process, many scenarios were thought through to the final outcome. This process meant that students learned about water resources sharing in great detail and that soft skills learning, including critical thinking, problem solving and team work, was reinforced. Several students who didn't have a background in either physical geography or hydrology also participated in the course and although their learning curve for the material was very steep, had an excellent grasp of the topic after having developed their games.

The overall impression of the course from students was that they had put a lot of work into the course (for the given number of credit points received) – the group project was intense, requiring them to meet and work together frequently. The deadline for the final games to be submitted was also extended into summer and the next fall semester, but they nevertheless scrambled to get the games finished over the summer holiday. As mentioned, this course was meant to emphasize practical aspects of what students learn during their master's curriculum, and students found the transition from theory to practice to be a more challenging step. Although they also had a course on project management, most of them felt that they couldn't apply the information learnt to their actual project. Indeed, working through the theory of project management, is not likely useful without a concrete project to apply those theories to. This lecture could have maybe come later in the course, after they had formed groups, and finalized their project ideas, and then finally apply some of the project management principles to their planning. Given these minor glitches, the students were quite satisfied with having taken the course, and produced their games, and it was definitely a very new (learning) experience for everyone. A next step is to now to get others to play the games, either incorporating the games into teaching curriculum for the age appropriate levels, or possibly during hydrology/water focused outreach events as a communication and teaching tool.

4 Discussion and Conclusions

In this paper, we have presented a short evaluation of how both playing games and developing games can be effective ways to learn and communicate about water resource sharing. Using *Irrigania*, a recently developed web-based game, we presented results from a survey carried out to evaluate the effectiveness of its use in the classroom to teach about water resource sharing. Our survey showed that *Irrigania* is an effective tool for learning about: i) water resource sharing, and that both cooperation and communication are key factors for sustainable water use; ii) different shared resources including

surface/river and groundwater and differences between them; and iii) tragedy of the commons and support discussion of these somewhat theoretical and sometimes difficult concepts for students to grasp. Overall, teachers found *Irrigania* to be an effective and also easy tool to incorporate into curriculum, ideally for upper level bachelor to master level students, studying either water resources or decision making.

An evaluation of a course on water games, based on our experience and student feedback, found that designing and developing their own water games was a positive learning experience for students, although they found it somewhat difficult putting theory into practice to produce their final games. During game development, students had to think through the intricacies and complexity of water resource sharing, as they thought through players' moves and water resource outcomes, and then had to reevaluate game variables. Through this process, fundamental learning about water resources took place, emphasizing soft skills, including critical thinking, problem solving and team work and time management. Further using these water games as either a teaching or communication tool, will encourage students to think about water resource sharing in a more critical and insightful way.

Acknowledgements

We would like to thank the students in GEO401: Water games; Marc Vic for helping to create and continue managing *Irrigania*; Sandra Pool for helping with pedagogical aspects of the "Water Games" course; and H2K for playing games with us. Our water games can be found at: http://www.geo.uzh.ch/en/units/h2k/services/water-games/

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Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-52, 2016
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Published: 10 February 2016

Hydrology and Earth System Sciences
Discussions
Open Access
EGU

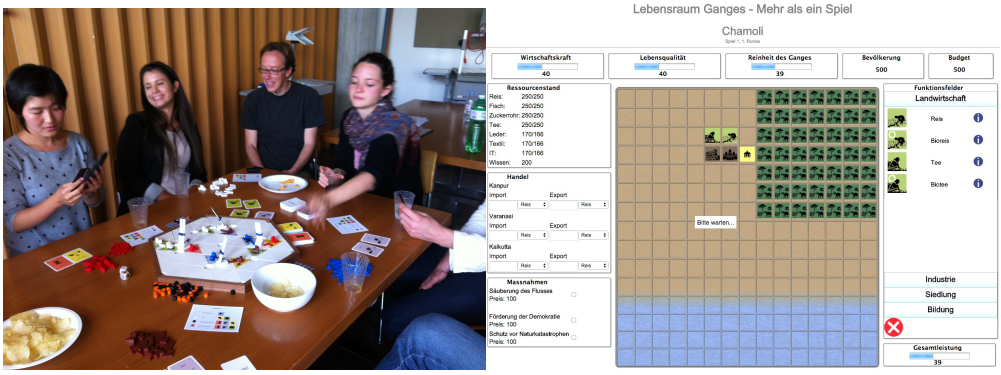

Figure 1: Playing *Wiapuna* (left) in the final class, and a screen-shot of *Habitat Ganges* (right).

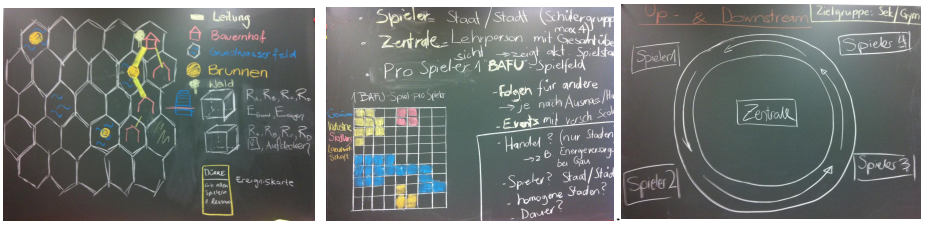

Figure 2: Initial stages of game development with idea boards.

Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-52, 2016
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Published: 10 February 2016

Figure 3: Board set-up for Wiapuna centered around four wells (left). Settlements are developed on different land use tiles (right), corresponding to the natural resource cards (copper, gravel, wood and food) that are used to buy infrastructure and energy efficiency measures.

Resource	Price/year	Yield/year		Effects		
		Resource	Budget	Economy	Quality of life	Ganges water quality
Agriculture/Fisheries						
Tee plantation	60	30	20	+	0	-
Rice field	60	30	20	+++	0	--
Sugar cane plantation	60	30	20	+++	0	--
Fishery	60	30	20	+++	0	--
Industry						
Textile factory	80	50	60	+++++	+	---
Leather factory	80	50	60	+++++	0	-----
IT firm	90	60	70	++++++	+	---

Table 1: Each community in Habitat Ganges is given a sheet of paper indicating the list of prices for each resource together with the qualitative outcome (+/-) for each of the indicators (economy, life quality, and water quality) needed to win the game (here only "Agriculture/Fisheries and Industry" are shown for Calcutta resource prices, as an example).