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Small-Group Work and Relational Thinking in Geographical Mysteries: A Study in Dutch Secondary Education

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Abstract

Relational thinking is a necessary skill for building students' individual capabilities and a core concept in geography education. Geographical relational thinking refers to being able to give interrelated, causal explanations for geographical phenomena such as regional change. The aim of this study was to gain more insight into differences in relational thinking between small groups of students working together on an assignment to explain a regional event which was framed as a geographical mystery. This insight could help teachers to advance students' geographical relational thinking skills. Two geographical mysteries were examined with data from 69 small groups in Dutch upper secondary education. The two mysteries resulted in differences in the level of relational thinking, which were partly explained by small-groups' on-task behaviour. Many student groups showed a low level of geographical relational thinking. Findings point to the need to incorporate exercises into geography lessons which require the use of thinking and reasoning with interrelated causal relationships.

Keywords

Relational Thinking, Mystery, Small-Group Work, Geography Education, Secondary Education

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Teaching geography in secondary education introduces students to the beauty and fascinating variety of our planet. Geography lessons might also contribute to the development of students' individual capabilities outside the subject. For example, students learn how to live responsible lives with regard to issues such as sustainability, inequality and poverty. In their concluding remarks on the contribution of geography to the development of students' individual capabilities as human beings, Lambert, Solem and Tani (2015) propose that teaching geography should contribute to students': (1) deep descriptive world knowledge, to know how the world works; (2) conceptual knowledge providing a relational understanding of our existence on the planet; and (3) thinking through alternative futures in specific places and locational contexts (p. 732). In this study, we focus on the second of these contributions of geography lessons. We studied differences in relational thinking between small student groups in upper secondary education in the Netherlands working together on a geographical relational assignment framed as a mystery. More insight into students' geographical relational thinking could help teachers to find ways to support students in gaining a relational understanding of their existence on the planet.

Geographical Relational Thinking

Relational thinking belongs to the core of geographical thinking (Jackson, 2007) and offers students a powerful way of thinking. Using descriptions of powerful knowledge borrowed from Young, Maude interprets knowledge as powerful when, among other things, it "enables students to discover new ways of thinking; better explain and understand the natural and social worlds; think about alternative futures and what they can do to influence them" (2017, p.30). Our students live their lives in a globalised and interconnected world with many interrelated societal and ecological problems. To address these problems, students need to think in terms of interwoven causal relationships, as our contemporary problems cannot be explained by simple causalities (Arnold & Wade, 2015; Brown, 2018; Chee, 2010; DeVane, Durga & Squire, 2010; Fögele, 2017; Lezak & Thibodeaux, 2016). Being able to understand relationships between geographical phenomena and to give integrated, holistic explanations is an example of powerful thinking (Maude, 2017). Besides this, relational thinking in geography can also be powerful in Maude's interpretation when used as analogical reasoning. This means that objects or events in the world are seen as systems of relationships that can be compared with each other to find differences, similarities and deeper structures (Richland & Simms, 2015). For example, students can compare deforestation in Brazil for soy plantations with deforestation in Indonesia for palm oil plantations, or, as a next thinking level, between deforestation for palm oil plantations in Indonesia and gentrification in New York. Comparing these systems of relationships will reveal the similarities in the deeper economic forces between those processes and the power relationships in them that result in the forcing out of weaker parties like indigenous people or poor inhabitants. Differences will show the importance of the specific regional context.

One of the most important concepts in geography is interdependence (Lambert, 2004; Massey, 2014). "Interdependence is a potentially powerful way of recognising the scale, but also subtlety, of interactions among and between global and local processes of economic, social and environmental change" (Smith, 2015). With this focus on relationships and interaction, it is possible to understand, explain or predict changes in particular places or regions in the world. The study of the interaction between human society and its environment, in particular, has a long tradition in geography and is still the core of geography education (International Geographical Union, 2016). But places and regions are also the product of their connections with other places in the world; therefore, students need an understanding of how places or regions are connected to the rest of the world (Massey, 2014). Van der Schee's (2000) geographical analysis model for structuring geography lessons distinguishes between these two different kinds of relationships that cause regional change. Vertical relationships are relationships within a region. These are the interactions within and between natural and human geographical systems that cause regional change. Changes in one region that cause change in another region are horizontal relationships. For example, the large-scale irrigation agriculture in the south of Spain causes serious water shortages that trigger regional desertification (vertical relationships). Transportation of water from the river Ebro in the north of Spain to the south will probably solve these water shortages, but will also harm rice production in the Ebro delta (horizontal relationship).

Using Van der Schee's model, geographical relational thinking can be described as analysing, explaining and/or predicting the relationships that cause regional change on different scales and the interactions between them. The concept of "interaction" in this description underlines the interconnectedness of the relationships. The concept of "geographical" refers to relational thinking as a part of geographical thinking, for the focus is on meaning-making with respect to regional change with the help of geographical concepts and questions (Van der Schee, Trimp, Béneker & Favier, 2015; Uhlenwinkel, 2013, 2017). Our description of geographical relational thinking connects to systems thinking. Systems thinking, relational thinking and holistic thinking are strongly related constructs and are often used interchangeably for thinking in dynamic, interconnected wholes as opposed to reductionist thinking. Actually, holistic thinking and relational thinking refer to different elements of systems thinking. Whereas holistic thinking refers to the functioning of the system as a whole and considers the consequences of events or decisions for the system, relational thinking refers to the causal relationships within the system (Lezak & Thibodeaux, 2016).

Relational Thinking in Secondary Geography Education

Only a limited number of studies have included empirical work on the ability of secondary school students to establish causal relationships to explain geographical phenomena or events. Two studies on systems thinking from the earth sciences, a related discipline to geography, provide evidence of students' difficulties with cyclic causal relationships. Kali, Orion & Eylon (2003) conducted a study on students' systems understanding of the rock cycle. Understanding the rock cycle implies that students are able to think and reason in cyclic chains of cause and effect. After a learning program, students still had great difficulties understanding and representing these cyclic chains of causality. Assaraf and Orion (2005) analysed the progress of junior high school students in various components of systems thinking concerning the hydro cycle. At the start of the learning program, students had an incomplete picture of the hydro cycle and also showed many misconceptions, but they showed a significant increase in understanding after learning about the hydro cycle. Two main factors explained differences in this progress in students' system thinking: students' individual cognitive abilities and their involvement in the learning activities. In a quasi-experimental study on the effects of the use of geospatial technologies on geospatial relational thinking of students in Dutch secondary geography education, Favier & Van der Schee (2014) developed a geospatial relations test which was used as a pre-test and as a post-test. In their experiment a three-lesson series with geospatial technologies on water management in Dutch polders was compared with a conventional geography lesson series which had the same content. The students were 14 and 15 years old and in their 3rd year of HAVO (higher general secondary education) and 3rd year of VWO (pre-university education). The authors concluded that students identified only a proportion of the possible relationships, well below the maximum possible. Students in pre-university classes did better on both the pre-test and the post-test compared to students in higher general secondary education. Students in the experimental groups showed more progress in relational thinking than students in the control group. In the experimental groups, the effect size of their experiment was higher for lower complexity assignments than for assignments involving more complex geospatial relational thinking. Cox, Elen & Steegen (2017) investigated the current state of the art in systems thinking in geography of students aged 16-18 in their final and penultimate years in secondary education in Belgium. They developed a systems-thinking test in which students had to identify relevant variables and establish and describe relationships between them in order to construct a causal diagram. They found large differences between students in geographical systems thinking. Students with the highest chance of achieving an academic-oriented bachelor degree performed better than the other students and students in their final year did better than students in their penultimate year. The overall level of systems thinking in geography was, however, "problematic, keeping in mind the future global challenges this student generation will be facing" (p. 8). This low level of relational thinking corresponds with an analysis of Dutch geography exams in higher general secondary education in 2009 and 2010, which revealed that students had particular difficulties with relational questions (Karkdijk, Van der Schee & Admiraal, 2013). Furthermore, research on established relationships to explain mysteries (Karkdijk, Van der Schee & Admiraal, 2019) revealed that many small student groups neglected both the more difficult causal relationships and the interrelationships (the cross-links) necessary to give a coherent explanation for the mysteries. The evidence of the low level of relational thinking in secondary geography education corresponds with findings of studies on relational thinking with ecosystems, which show that students have more difficulties with complex causality than with simple causality and linear flow (Hmelo-Silver, Jordan, Eberbach & Sinha, 2017; Perkins & Grotzer, 2001).

Mysteries and Relational Thinking

In the current study, we used two mystery assignments to elicit students' relational thinking in geography. A mystery is an educational strategy originally designed within the Thinking Through Geography programme to advance students' relational thinking and reasoning skills by investigating complex situations (Leat, 2001; Leat & Nichols 2003). A mystery is centred around a problem formulated as an open question with more than one answer or solution. After a short introduction to the whole class, students have to explain or solve the mystery in small groups. They use 20-30 information strips that contain some information about a person's life, facts, background information and some red herrings. These strips contain no relationships: students are challenged to think about and discuss relationships between them. A student has to explain to the other group members the reasons why certain strips should be seen as categories or as related to each other. In this way, a mystery triggers shared reasoning amongst the group members (Leat & Nicols, 2003). Leat & Nichols (2000, 2003) observed the explanation of a mystery in small groups and found five stages that characterise this. After the reading (1) and categorisation of the data (2), most groups created one or several separated or more integrated cause and effect chains (3). In the next stage, the higher ability groups reworked their explanation by formulating new sets of relationships, which were increasingly abstract, and incorporated more data in order to give a more coherent explanation (4). The highest ability groups moved on to the last stage: they hypothesised and generalised beyond the given data (5). The authors suggest that these stages coincide with the progression in the thinking processes of the levels of the SOLO taxonomy (cf. Biggs & Collis, 1982).

The SOLO Taxonomy and Relational Thinking

Biggs and Collis (1982) constructed the SOLO taxonomy in an attempt to measure the quality of learning as represented by the outcome of a learning process. They identified five levels that indicate a progression in the structural complexity of an outcome: each higher level compared to the former is more abstract, uses more organising dimensions and shows more internal consistency and coherence due to established interrelationships. The highest level of the taxonomy is characterised by using self-generated principles. In a *prestructural* response no relevant datum is used to answer a question; in a *unistructural* response a student uses correctly one relevant datum to answer the question; in a *multistructural* response several correct but unrelated data are used to answer the question; in a *relational* response a student is able to use several interrelated data to give a coherent explanation; while in an *extended abstract* answer, abstract principles beyond the given data are formulated. Stimpson (1992) conducted a study on the relationship between the levels of the SOLO taxonomy and geographical thinking of secondary students in Hong Kong and found evidence that the progression of these levels reflects an increase in the level of geographical thinking as in the what-where-why-sequence in geographical questions. He also found that 12-13 year-old students in the first year of secondary education operated mostly on a unistructural or multistructural level, while many fourth-year students had started to operate on a relational level, demonstrating relational thinking.

Research Questions

The current study aimed to gain more insights into secondary school students' geographical relational thinking. To this end, we applied small-group work to a geographical mystery. We designed two mysteries to elicit collaborative relational thinking and reasoning. One was about floods in Jakarta and another about landslides and slum dwellers in Rio de Janeiro. The two mysteries are presented in the method section. Our first and second research questions were: (1) *How did geographical relational thinking in terms of the SOLO taxonomy differ between groups?* and (2) *How did geographical relational thinking in groups differ between the two mysteries?*

Leat and Nichols (2003) suggested the influence of students' age, group ability (mixed or more homogeneous) and gender (male or female groups) on the outcomes of mysteries as an area of educational research. Explaining complex problems such as a mystery in small groups also requires effort and focused attention. We therefore expected that the time students spent on-task would also be a factor explaining differences between student groups. Our third research question was therefore: (3) *How can differences between groups in geographical relational thinking be explained by characteristics and collaborative behaviour of the groups?*

Methodology

Research Design

A quantitative research project was carried out on a relational task framed as a mystery. We used the concept maps constructed by small student groups and the transcriptions of their group discussions. The project was carried out between January and June 2015 in six secondary schools in the Netherlands.

Sample

Twelve qualified and experienced geography teachers from six schools and 205 students in higher general secondary education (HAVO, 4th and 5th years) and pre-university education (VWO, 4th, 5th and 6th years) were part of the project. These teachers and their schools were selected, because they responded positively on a call to participate in our research project. The schools are located in different parts of the Netherlands: two schools are located in small cities in a rural, less densely populated region in the southwestern part of the Netherlands (Goes and Middelharnis), three schools are located in cities in the most urbanised and densely populated region in the western part of the Netherlands (Rotterdam, Gouda and Hilversum) and another school is located in a small city in the less densely populated northwestern part of the Netherlands (Hoorn). Students were between 15 and 18 years old. Teachers were instructed to arrange three groups of three students based on the students' geography grades: (1) one group of students belonging to the highest thirty per cent of the class; (2) one group of students belonging to the lowest thirty per cent of the class; and (3) one mixed group (one student from the highest thirty percent and two from the lowest). In some cases, because of the absence of selected student(s), an intermediate ability group was created (with two or more students between the highest thirty per cent and lowest thirty per cent of the class). Each class worked on one of the two mysteries. Table 1 gives the composition of the 35 groups who worked on the Rio mystery and the 34 groups who worked on the Jakarta mystery.

Table 1
Description of student groups

	Rio	Jakarta
Total number of groups	35	34
Geography grades		
Groups in highest 30%	11	11
Intermediate groups	7	4
Groups in lowest 30%	9	12
Mixed groups	8	7
Gender		
3 girls	5	11
Mixed groups	23	18
3 boys	7	5
Educational level and year		
HAVO-4	17	3
HAVO-5	0	19
VWO-4	9	3
VWO-5	6	6
VWO-6	3	3

Data Collection

The two mysteries that were part of the assignment were designed for students in upper secondary education as a regional event that challenged them to use complex causal relational thinking and reasoning, although each mystery had its own regional context and problem. The regional context of both mysteries is a mega city in two developing countries (Rio in Brazil and Jakarta in Indonesia), but the Rio mystery was designed with a human geographical focus and the Jakarta mystery with more emphasis on physical geography, to capture the breadth of geography as a school subject. The geographical content of both mysteries is part of the curriculum of the previous years in higher general secondary education and pre-university education in the Netherlands. They were designed in line with the design principles of Leat and Nichols (2003), reviewed by a professional educational geographer familiar with mysteries and tested in upper secondary geography classes. Groups had to represent their explanation of the mystery as a concept map consisting of causal relationships. Each group worked in a separate room, supervised by the researcher (the first author). Their discussions were recorded by a video camera. The rest of their class discussed the same mystery in small groups in the classroom, guided by the teacher. The group discussion was used together with their draft concept map to construct a final concept map that included all correct and relevant relationships the group had formulated.

Description of the two mysteries. Both mysteries were based on real data, gathered from a wide variety of sources. One was about Fabio Pereira, a favela dweller in Rio who refused to move to a new dwelling on the outskirts of Rio. The government offered him this new place because his favela was threatened by landslides. Students had to think about the geography and society of Rio, in order to understand and explain why Fabio wanted to stay in his old threatened house. Factors that explained Fabio's decision were: his present house was built by his father; the community bonds in his present favela; the current proximity to his work in the centre of Rio; the high real estate prices in central Rio; and former government actions to remove favelas which had fuelled distrust in government intentions with regard to the rehousing of slum dwellers; and the football World Cup in 2014 and the Olympics in 2016 in Rio, which is also a famous tourist city. A core element of the mystery was Fabio's distrust in the intentions of the government, because his favela, relatively close to the central business district of Rio, could become gentrified and transformed into a more profitable district. Students had to make this inference by themselves based on the information provided.

The second mystery was about slum dwellers on the riverbeds in Jakarta, like Nani, who were accused by a high government official of being the main cause of regular floods in Jakarta. Students had to understand and explain the hydrological system of Jakarta in order to evaluate this accusation. Factors that explained Jakarta's vulnerability to floods were: heavy monsoon rains; deforestation of the surrounding region; the construction of slums in the beds of the main rivers in Jakarta by migrants and the resulting narrower riverbeds; blockage of rivers by waste and badly managed water channels; Jakarta's location in a delta near the sea; and the rising sea level. For a complete and coherent explanation of the mysteries, students had to establish interrelationships between the different factors. Both mysteries were geographical mysteries, for the focus was on regional change, human-environment interaction and on the significance of a particular location within a specific regional context.

Measures.

***Relational thinking*.** Groups had to create a concept map that represented their explanation. A concept map consists of relationships between concepts (propositions) and provides a representation of the knowledge structure of the student group: it provides insight into how students understand relationships between concepts (c.f. Novak & Gowin, 1984; Ruiz-Primo, Shavelson, Li & Schultz, 2001; Srinivasan, McElvany, Shay, Shavelson & West, 2008). Creating a concept map as a collaborative activity also elicits and stimulates reasoning within a group (Van Boxtel, Van der Linden, Roelofs & Erkens, 2002; Cox, Steegen & Elen, 2018).

Each group was given a piece of paper, pen or marker and short instructions on how to construct the concept map. No concepts were provided and all propositions had to be formulated by the student groups in their own words. They could use the information provided and were also allowed (and encouraged) to add extra concepts necessary for their explanation. We intended the task to be as student-led as possible. Compared to fill-in-the-map techniques, this construct-a-map technique better reveals differences between the knowledge structures of students, for the low-directedness of the task offers students more opportunities to show what they know about a specific topic and to express misconceptions and partial understandings (Ruiz-Primo et al, 2001). The arrows students were required to draw between concepts had to express causal relationships and had to be provided with linking phrases that expressed the relationship. This meant that their concept maps could be characterised as causal schemes and did not necessarily have a hierarchical structure. We wanted to use all the correct and relevant relationships a group formulated in our analysis. However, most students were unfamiliar with the construction of concept maps, so there was a risk that not all of the correct and relevant relationships a group identified would be represented in the concept map. Assaraf and Orion (2005) observed that some students who presented relationships in other tools preceding the construction of a concept map were not able to represent these relationships in the concept map itself. For this reason, we also gathered the data from the group discussions to be analysed in combination with the concept maps. First, the group's concept map was analysed and scored for relevance and accuracy. Then the same was done for the data from the group discussion, which was video-taped and transcribed verbatim. Relevant and correct relationships that were rejected later in the group discussion were deleted from the data set. The data from the discussion and the concept map were merged into a total data set that was used to construct the final concept map of a group.

We used a criterion map as a benchmark in the coding process. The criterion map for each mystery was dynamically constructed, because of the task requiring the students to formulate relationships in their own words and to use extra concepts besides those provided. To construct the mystery, the designer (first author) used different factors or dimensions of the problem, which were also used as a frame for the criterion map. Both criterion maps were discussed with two other raters (experienced geography teachers who were familiar with the content of the mysteries) and reworked. Analysis of the outcomes of the group work revealed that groups often established correct and relevant extra concepts to explain the problem. We added the new propositions to the final criterion maps. These criterion maps are included as appendices (Figure A1 and A2).

Four aspects of the total data set for each group were used as indicators to analyse relational thinking in a group. Three were based on research on analysing concept maps (McClure, Sonak & Suen, 1999; Rye & Rubba, 2002; Turns, Adam & Atman, 2000): (1) the accuracy of the propositions; (2) the number of cross-links; and (3) the number of factors used (in this study factors are the different dimensions to explain the mystery). The number of accurate propositions reflects the depth of understanding, while cross-links indicate the connectedness of understanding, necessary for a coherent explanation. The number of factors used to explain the mystery refers to the breadth of understanding.

Table 2
Scoring system of the group concept maps

Indicators	score
Total proposition score	(a + b + c)
a. each correct and relevant proposition	2
b. each correct and relevant proposition, but intermediate concept(s) missing	1
c. each correct and relevant proposition, but unclear formulation	1
Number of cross-links	total number
Number of factors used	total number

In addition to the data on the three indicators shown in Table 2, the SOLO level of the outcome of each group was determined as a fourth indicator of students' relational thinking. The SOLO taxonomy has five levels as described above and between these levels there are transitional levels. To determine the SOLO level of the outcome of each group, the number of factors which were correctly connected with the outcome of the mystery, the use of branches within factors, the number of cross-links and the use of abstract reasoning or transfer to other regional contexts in the group discussion were used as criteria. Our operationalisation accurately followed the way Biggs and Collis (1982) characterise responses at different SOLO levels for geography assignments, and this has been described elsewhere in detail (authors 2019).

The first author coded all the data. Two other raters coded the concept map and discussions of four groups each. One other rater analysed the data of the four groups working on the Rio mystery and another rater coded the four groups working on the Jakarta mystery. The inter-rater reliability between the scores of the first author and the two raters was satisfactory (Cohen's k = 0.823). After instruction and several try-outs and discussions on the determination of the SOLO level of the outcome of each group, an experienced and qualified geography teacher analysed the work of 12 groups as a second rater and found the same SOLO levels as determined by the researcher.

Group characteristics and group effort. The educational level of the groups was higher general secondary education (HAVO) or pre-university education (VWO) and students were in their 4^{th}, 5^{th} or 6^{th} year. Teachers provided students' mean geography grades based on their grades starting from the 4^{th} year. We standardised these grades to Z-scores for each class, from which we calculated mean Z-scores for the groups. The gender composition of the groups included girls-only groups, boys-only groups and mixed groups (see Table 1).

To analyse group effort to explain the mystery, we coded the group discussions on on-task, procedural and off-task words. The on-task category contained that part of the discussion aimed at understanding the content of the mystery or designing a strategy to solve it. The procedural category comprised those parts of the discussion aimed at organising the task without discussing the content of the strategy ("We need paper"; "Who is going to write?"; "How much time do we have?" or "What are we supposed to do?"). Off-task words were all the utterances irrelevant for the task. As indicators of group effort, we used: (1) the proportion of off-task words of all words uttered from the start of the group discussion prior to the construction of the concept map; and (2) the number of on-task words uttered from the start of the group discussion prior to the construction of the concept map.

Data Analysis

We used the SOLO taxonomy of Biggs and Collis (1982) to analyse differences in relational thinking between groups (first research question). A series of independent t-tests on the indicators of relational thinking (total proposition score, number of cross-links and number of factors used) were carried out to test differences in relational thinking between both mysteries (second research question). To answer the third research question, four hierarchical multiple regression analyses (MRAs) were performed with the total proposition score, the number of cross-links, the number of factors and the SOLO levels of the groups used as dependent variables. The four MRAs were performed for both mysteries together. We standardised the variables total proposition score and factors used to Z-scores for each mystery. Standardisation of the number of cross-links was not necessary, because means for both mysteries did not differ significantly. The MRAs were performed with five independent variables as predictors in the following sequence: educational level, school year, standardised mean geography grades of the groups ("mean geography grades"), proportion of off-task words of all words uttered prior to the construction of the concept map ("proportion off-task words") and finally the number of on-task words uttered prior to the construction of the concept map ("number on-task words"). The categorical variables educational level and school year were transformed into dummies. Because a majority of the groups were mixed boys' and girls' groups, gender was not included in the analyses. As the group data were nested within teacher and school, multilevel variance components analyses were carried out but they did not indicate significant variance in three of the four dependent variables at either school or teacher level. For this reason, all subsequent regression analyses were performed at the group level only.

Findings

Differences in Relational Thinking between Groups

We used the SOLO taxonomy to analyse differences in relational thinking between the groups. Table 3 shows the distribution of the groups on SOLO levels. We found no groups with an outcome on the prestructural level: all groups were able to find at least one relevant and correct relationship to explain the mystery. One group connected only one factor to the problem of the mystery accurately (unistructural level). Twenty-two groups with an outcome on the multistructural level used two or more factors to explain the mystery, but without establishing any cross-link between these factors. Twenty-four groups showed an outcome on the relational level: these groups accurately connected four or more factors to the problem of the mystery and established at least one cross-link between these factors. This means that these groups provided a more or less integrated, coherent explanation of the problem of the mystery. Only one group was able to give a coherent explanation for the mystery as well as to use abstract reasoning in their discussion: this group showed an outcome on the extended abstract level. Twenty-one groups had a transitional level.

Table 3
Distribution of groups on SOLO levels

SOLO level	Total	Jakarta	Rio
Prestructural P	0	0	0
Unistructural U	1	0	1
Transitional U/M	4	1	3
Multistructural M	22	11	11
Transitional M/R	13	7	6
Relational R	24	11	13
Transitional R/EA	4	3	1
Extended Abstract EA	1	1	0
Total number of groups	69	34	35

To illustrate these differences in relational thinking between groups, three examples will be described: (1) a group with an outcome on the multistructural level; (2) one with an outcome on the transitional level (between multistructural and relational); and (3) one with an outcome on the relational level. All three groups worked on the Rio-mystery. To facilitate comparison of the student groups, we revised all their propositions (from both their concept maps and group discussion) into the format of our criterion map. The additional propositions from the group discussions are represented with dotted lines.

The concept map of group 22 is shown in Figure 1. This group consisted of two girls and one boy aged 15-16 from a fourth year HAVO class. It was an intermediate ability group: two students had an intermediate position in their class and one student belonged to the highest thirty per cent as regards their mean geography grades. This group had an on-task discussion, albeit relatively short: they started to work out their solution in the concept map after 14 minutes of discussion. As can be seen in Figure 1, the outcome was on the multistructural level: the students in this group used only three, not interrelated, factors (1, 2 and 3) to explain the mystery. Their explanation of the mystery was very limited. Their total proposition score is 8 (three correct propositions, one incomplete proposition and one unclearly formulated proposition). The group used three factors to explain the mystery (the score for factors is therefore 3) and made no cross-links between these factors (the score for cross-links is therefore 0).

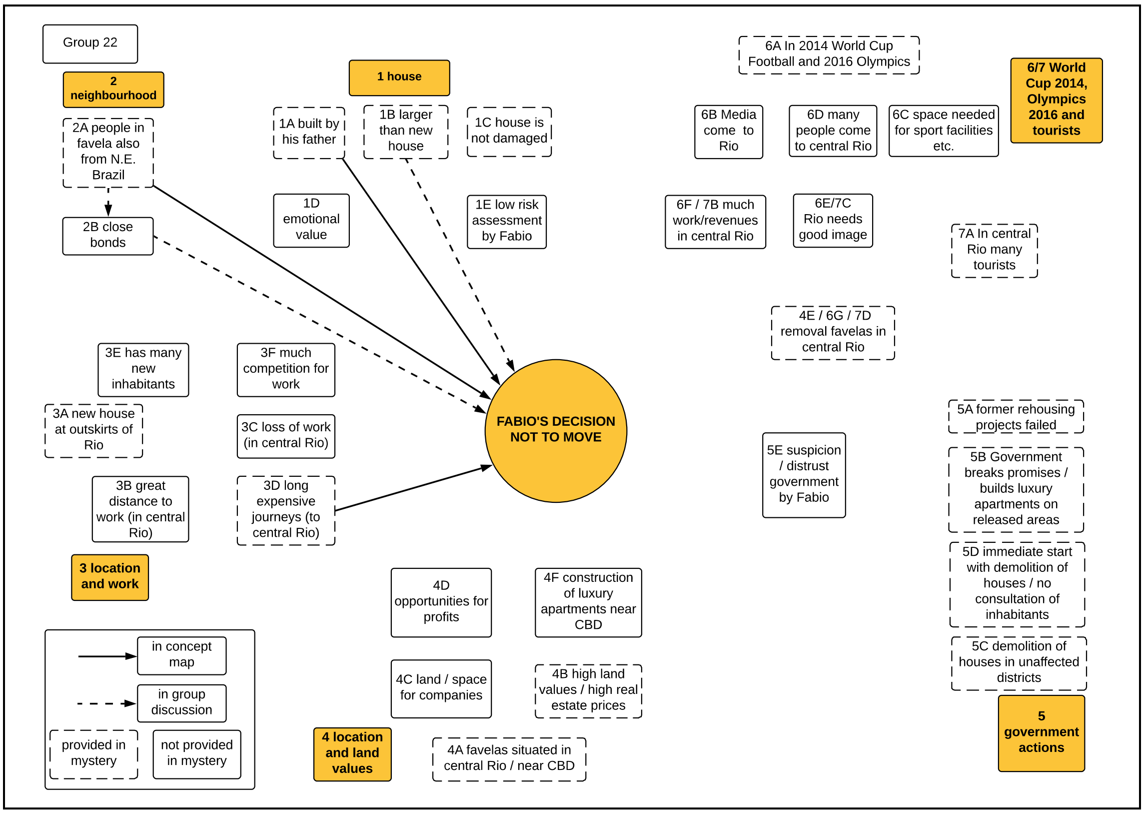

Figure 1: Propositions from concept map and group discussion of group 22.

The second example is group 64 (see Figure 2). This was a low-ability group from a fifth-year VWO class. The group consisted of two girls that belonged to the lowest thirty per cent of their class as regards their mean geography grades and one boy from the highest thirty per cent. The students were 16-17 years old. This group had problems constructing a representative concept map, so most propositions were added from the group discussion. They also had an on-task discussion but this took much longer than the first group: they started their concept map after 27 minutes of discussion. Figure 2 shows that this group was able to establish a cross-link between two factors: governments' building activities in former released areas and Fabio's risk assessment for his favela. The group used three factors to explain Fabio's decision. However, one factor, "World Cup, Olympics and tourists", with some correctly formulated propositions, was not connected to Fabio's decision and therefore not integrated into their explanation. With only two factors correctly connected to Fabio's decision and one cross-link, the outcome is on the transitional level between multicultural and relational. The group gave an integrated, albeit narrow, explanation for Fabio's decision. Their total score was 18.

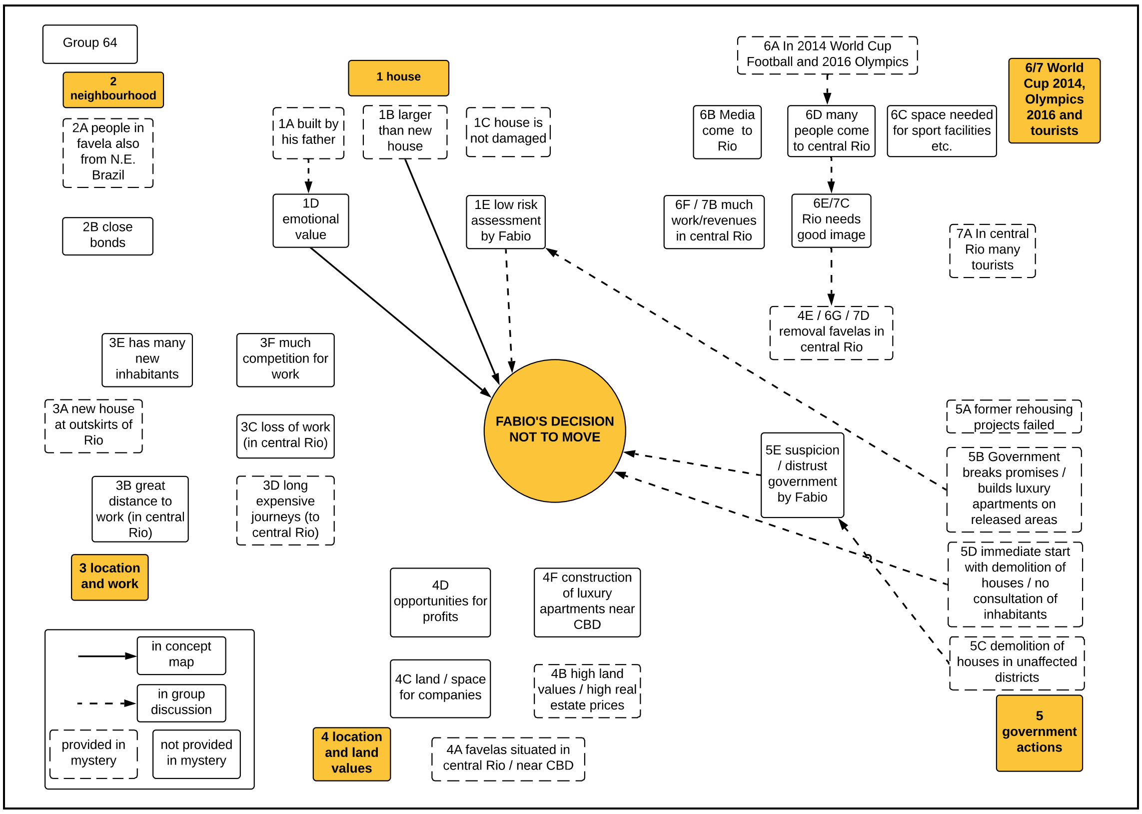

Figure 2: Propositions from concept map and group discussion of group 64.

The third example is group 33 (see Figure 3). This was a low ability group from a fourth-year VWO class: the students, three girls aged 15-16 , belonged to the lowest thirty per cent of their class as regards their mean geography grades. They had an extensive on-task discussion and started with their concept map after 29 minutes. As can be seen in Figure 3, their explanation is more extensive and coherent than the other groups: they established more propositions, used more factors and established three cross-links, illustrating their understanding of the interrelationships between factors. They established the interrelationship between the opportunities to gain high profits by building luxury apartments on the future released area and Fabio's distrust of the intentions of the government. Another interrelationship they identified was between the opportunities to gain profits and the construction of luxury apartments on released areas near the CBD. The third cross-link was between governments' building activities in former released areas and Fabio's risk assessment for his favela. Their discussion was limited to the problem of the mystery and no transfer to other contexts or generalisations were made. The group outcome is therefore on the relational level. The group concluded that Fabio's distrust of the government was crucial to understanding his decision not to move. Their total proposition score was 36.

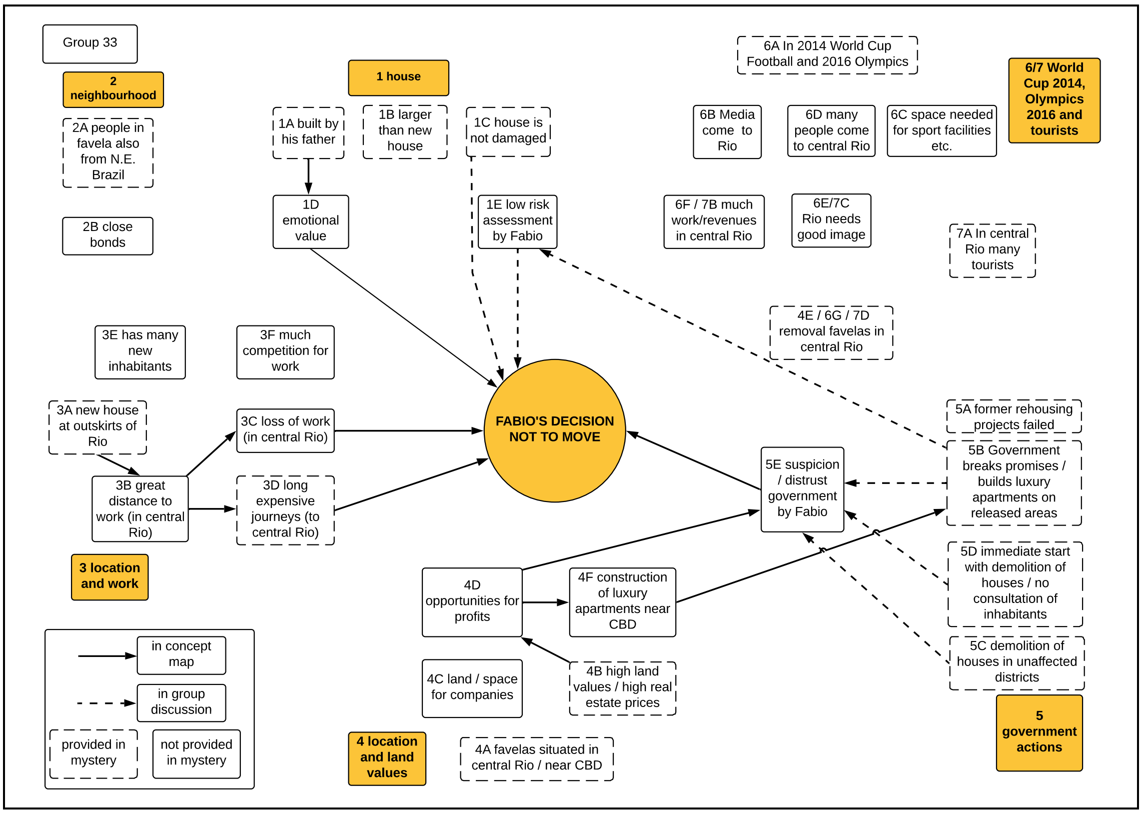

Figure 3. Propositions from concept map and group discussion of group 33.

Comparison of Figures 1 - 3 shows the differences between the groups in their geographical relational thinking skills. Whereas group 22 was able to formulate only simple, linear relationships to explain Fabio's decision, group 33 showed an ability to reason with more complex relationships to explain his decision. They clearly provided a more integrated, coherent explanation.

Differences in Relational Thinking between the Two Mysteries

Table 3 shows that the distribution of the student groups on the SOLO levels was similar for the Jakarta and Rio mysteries. Table 4 shows the differences between the mysteries on the other three indicators of relational thinking. The number of propositions students formulated was significantly lower in the Rio mystery than in the Jakarta mystery ($t(67) = 2.72$; $p = .008$; Cohen's $d = .66$). With respect to the number of factors used, the difference between the two means was also significant ($t(51.29) = 6.67$; $p < .001$; Cohen's $d = 1{,}61$). No difference between the two mysteries was detected with respect to the number of cross-links ($t(67) = 1.01$; $p = .32$; Cohen's $d = .25$).

Table 4

Means and standard deviations of three indicators of relational thinking for both mysteries

	Jakarta	Rio
N	34	35
Total proposition score		
Mean*	26.59	20.83
St. deviation	7.62	9.82
Min	15	8
Max	49	49
Number of cross-links		
Mean	1.18	0.91
St. deviation	0.99	1.15
Min	0	0
Max	4	4
Number of factors used		
Mean*	5.24	3.74
St. deviation	0,61	1.17
Min	4	2
Max	6	6

*Differences are significant (2-tailed)

Table 5 shows the correlations between these three indicators of relational thinking for the two mysteries. In the Rio mystery (the shaded cells below the diagonal), the three indicators were positively correlated. Thus, for the Rio mystery, groups that established one or more cross-links, also formulated more correct propositions obtained from more factors, while groups who did not establish a single cross-link, usually formulated fewer propositions. This could be an indication that higher scores for the Rio mystery were obtained by a more integrated understanding of the mystery problem. For the Jakarta mystery the scores obtained for the three indicators of relational thinking were less correlated.

Table 5

Correlations between the three indicators of relational thinking for the Jakarta mystery (above the diagonal) and the Rio Mystery (below the diagonal).

		Jakarta (N=34)		
	Indicator	Proposition score	Cross-links	Factors used
Rio (N=35)	Proposition score		0,261	0.481*
	Cross-links	0.625**		0,079
	Factors used	0.804**	0.464*	

$^{*}p \leq .05$ $^{**}p \leq .01$

Group Characteristics, Group Behaviour and Relational Thinking

The results of the regression analyses for each of the four indicators of geographical relational thinking are summarised in Table 6. The only significant predictor of the standardised total proposition score in the final regression model was the on-task behaviour of the students (β = .43; sr^2 = .16): the number of on-task words they used before they started to construct their concept map. This model explained significantly 13% of the variance in the total proposition score (F = 2.63; p < .05). For the number of cross-links, again the only significant predictor in the final regression model was students' on-task behaviour (β = .26; sr^2 = .06). The proportion of variance in the total number of cross-links explained by the final regression model (5%) remained statistically non-significant. In the final regression model, there were no predictors significantly explaining differences in the standardised total number of factors groups used. Finally, we performed a hierarchical multiple regression analysis for the variance in the SOLO levels of the groups with the same predictors and found no different results: again only the number of on-task words uttered prior to the construction of the concept map was a significant predictor in the final model (β = .39, sr^2 = *.13*). The final regression model did not significantly explain the variance in the SOLO levels of the groups.

Table 6
Results of the final regression models of four Hierarchical Multiple Regression Analyses predicting the standardised total proposition score, total number of cross-links and the standardised number of factors used to explain a mystery, by group characteristics and group effort (N=68).

Dependent variables	*Total proposition score*		*Total number of cross-links*		*Total number of factors*		*SOLO level*	
Predictors in final model	β	sr^2	β	sr^2	β	sr^2	β	sr^2
Educational level	-.001	.00	-.075	.00	.070	.00	-.138	.01
School year, dummy, 5,4=0	-.062	.00	.111	.01	.019	.00	.036	.00
School year, dummy, 6,4=0	.092	.01	.177	.02	-.153	.02	.116	.01
Mean geography grades	.063	.00	-.073	.01	.187	.03	.099	.01
Proportion of off-task words	-.034	.00	-.219	.04	.138	.02	-.079	.01
Number of on-task words	.431	.16***	.259	.06*	.152	.02	.391	.13**
Adjusted R^2	.127		.047		-.006		.090	

*$p \leq .05$ **$p \leq .01$ ***$p \leq .001$

Discussion

With respect to the first research question, we found substantial differences between groups with respect to their relational thinking skills. Many groups had serious difficulties with relational thinking: nearly 40% of the groups operated on the multistructural level or lower, so they were not able to give an integrated, coherent explanation. Yet almost half of the groups operated on the relational level or higher: they were able to establish one or more cross-links and gave an integrated, coherent solution. The difficulty that many groups had with relational thinking is in line with the findings of the studies on geographical relational thinking we described in the introduction section.

With respect to the differences in relational thinking between the two mysteries (research question 2), we found that the Rio mystery was more difficult for students than the Jakarta mystery, based on lower mean scores overall. The problem of the Jakarta mystery was probably more familiar to Dutch students, because floods and hydrological systems are common topics in geography lessons in lower and higher secondary education in the Netherlands. Moreover, our analysis revealed that the design of the Rio mystery was more complex for students, because it required them to think more in terms of interconnections between factors. Most groups that made connections between different factors to explain the Rio mystery also established more relevant and correct propositions and used more factors. The information strips on Jakarta contained more pieces of information that were relatively easy to connect linearly to floods: heavy monsoon rains, a lot of waste in the rivers, smaller riverbeds, slums in riverbeds and a rising sea level. It was therefore easier to obtain a relatively high total proposition score without establishing the interconnections between factors. These findings suggest that the design of a mystery affects the level of relational thinking.

Concerning the third research question, we found that the only significant predictor that explained a small proportion of the variance of three indicators of relational thinking was students' on-task behaviour during the group discussion: the amount of on-task discussion they had on the problem of the mystery before they started to construct the concept map. More extensive discussion on the different aspects of the problem before integrating these relationships into a concept map seemed to be more fruitful than quickly starting with the construction of the concept map. Leat and Nichols (2000, 2003) also found that groups that were willing to rework their first constructed web of relationships integrated more information into their explanation. Unlike previous studies on geographical relational thinking in secondary education, we did not find significant correlations between educational level, grade or previous achievement in geography and relational thinking. A possible explanation could be that the studies we reviewed gathered their data from individual students whereas our study used data from small groups. There is a lot of evidence that group interaction, the strategy groups employ or the quality of the talk in the discussion affect the outcome and therefore could also account for part of the variance of the total score (see for example: Barron, 2000; Goos, Galbraith & Renshaw, 2002; Mercer, Wegerif & Dawes, 1999; Mortimer & Scott, 2003; Ruiz-Primo et al, 2001). A qualitative analysis of the group discussions might deepen our understanding of geographical relational thinking in small groups.

Limitations and Future Research

This research study consisted of a relatively large-scale quantitative investigation of relational thinking by students working together in collaborative groups to solve a mystery. A limitation of our study was the small sample size. Sixty-eight groups in a multiple regression analysis with more than two predictors does not allow firm generalisations to be made. Either large-scale quantitative research or qualitative research on group discussions of students working in small groups to solve mysteries would be future directions to be taken to gain further insights into students' geographical relational thinking.

We found a first indication that different designs of mysteries may result in different levels of relational thinking. We recommend more research on the relationship between the particular design of a mystery and the level of relational thinking produced. This could give insights into how to design mysteries more effectively to foster relational thinking.

More in general we recommend research on students' relational thinking in secondary geography education in a wide range of countries, not only to get more evidence on students' relational thinking skills, but also to facilitate international comparison and to learn from each other's practices.

Conclusion and Recommendations

The difficulties that many groups from the six schools in the Netherlands had with geographical relational thinking point to the need for more exercises in Dutch geography lessons that practise this thinking skill. The absence of any significant relationship between educational level, school year or students' geography grades and indicators of relational thinking might mean that relational thinking needs to receive much more attention in Dutch geography classes. Although our study was limited to Dutch secondary geography education, the (scarce) evidence we found on students' relational thinking in the earth sciences, geography and biology suggests that relational thinking, often mentioned as a core geographical thinking skill (e.g. International Geographical Union, 2016; Lambert, 2004; Uhlenwinkel 2014), also might need more attention in geography lessons in other countries.

To foster students' relational thinking in geography lessons, exercises and assignments that present complex regional problems to students and not only linear relationships are needed. This would be a promising shift of focus, because most studies we reviewed provided evidence that an explicit focus on relational thinking fosters students' thinking in interconnected causal relationships. Complex relational thinking exercises can also develop a "systems disposition", a set of attitudes to be focused on thinking in complex relationships (DeVane, Durga & Squire, 2010). Asking students to represent their relational thinking as a causal scheme or concept map has proved to be very helpful in getting them to think in terms of webs of relationships. Renshaw and Wood (2011) found that the concept map assignment reoriented students from linear causality chains to thinking in terms of interdependences. A whole-class discussion guided by a skilled geography teacher after each exercise in relational thinking can enhance students' understanding. Explicit attention for relationships *and* cross-links in this whole-class discussion would be helpful for a holistic, interrelated understanding of the mystery.

A step-by-step approach could use less complex exercises like the Jakarta mystery first to practise relational thinking and then move on to more difficult mysteries like the Rio one. These could be used as the next step in geographical relational thinking to focus explicitly on interconnections to understand a regional problem. When students have more competence in thinking in systems of relationships, analogical reasoning as described by Richland and Simms (2015) is a promising tool for geography teachers. It can deepen students' insights into how the world works, in the deeper structures of our existence on the planet.

Learning to think in systems of relationships is expected to foster students' relational understanding of their existence in this world, and would therefore be helpful in the choices they have to make to live responsible lives. If geography lessons contribute to the development of individual capabilities by delivering this powerful knowledge to our students, teaching geography will be a very relevant undertaking in secondary education.

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Biographical Statements

Jan KARKDIJK has a Master of Geography degree and teaches geography in secondary education in the Netherlands and is also PhD student at the Faculty of Behavioural and Movement Sciences at VU University, Amsterdam. His PhD research focuses on geographical relational thinking in secondary education.

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Joop Van der SCHEE After a start in 1976 as geography teacher at a secondary school in Amsterdam I became geography teacher trainer and lecturer in human geography at Vrije Universiteit in Amsterdam. At the end of the eighties I finished my PhD about map skills in secondary geography education. In 2007 the Royal Dutch Geography Society asked me to become professor for geography education in the Netherlands which was a very interesting period of 10 years. Between 2013 and 2016 this function was combined with a part-time professorship for geography education and communication at Utrecht University. After my retirement in 2016 I was visiting professor at Sapienza University in Rome, Italy. My main research focus is on map skills including GIS and on geography thinking strategies of students. See www.joop.vdschee.nl for my publications. I enjoyed very much helping to start the International Geography Olympiad of the International Geographical Union (IGU) in 1996. Not only because it was a very big success but most of all to co-operate with an inspiring international group of young geographers. I was co-chair of this organisation from 1996-2012. From 2012 until 2016 I was co-chair of the IGU Commission on Geographical Education. A key publication was the 2016 IGU International Charter on Geographical Education.

Appendix

The propositions belonging to the specific factors are incorporated into these two criterion maps (Figure A1 and A2). We left out nearly all of the cross-links, because many correct and relevant cross-links can be made and incorporating them would make the criterion maps too confusing. Only a few cross-links that are essential for a proper explanation are included.

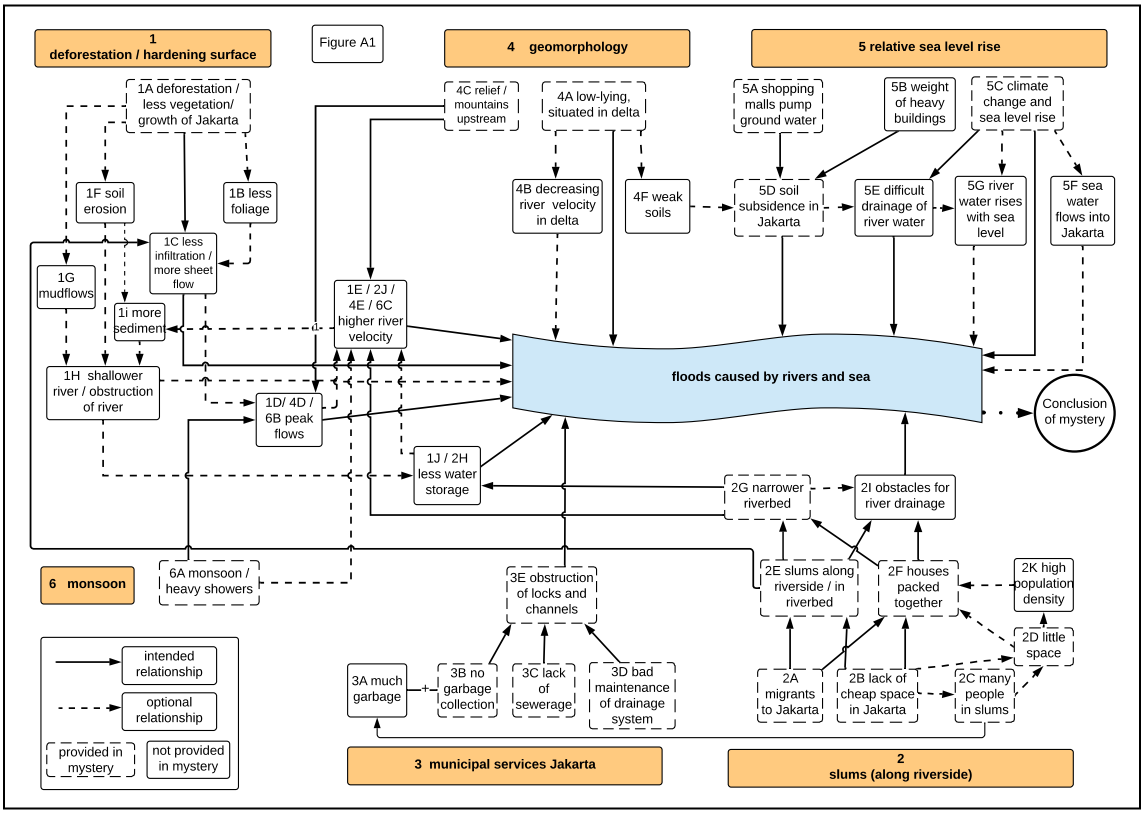

Figure A1. Criterion map of the Jakarta mystery

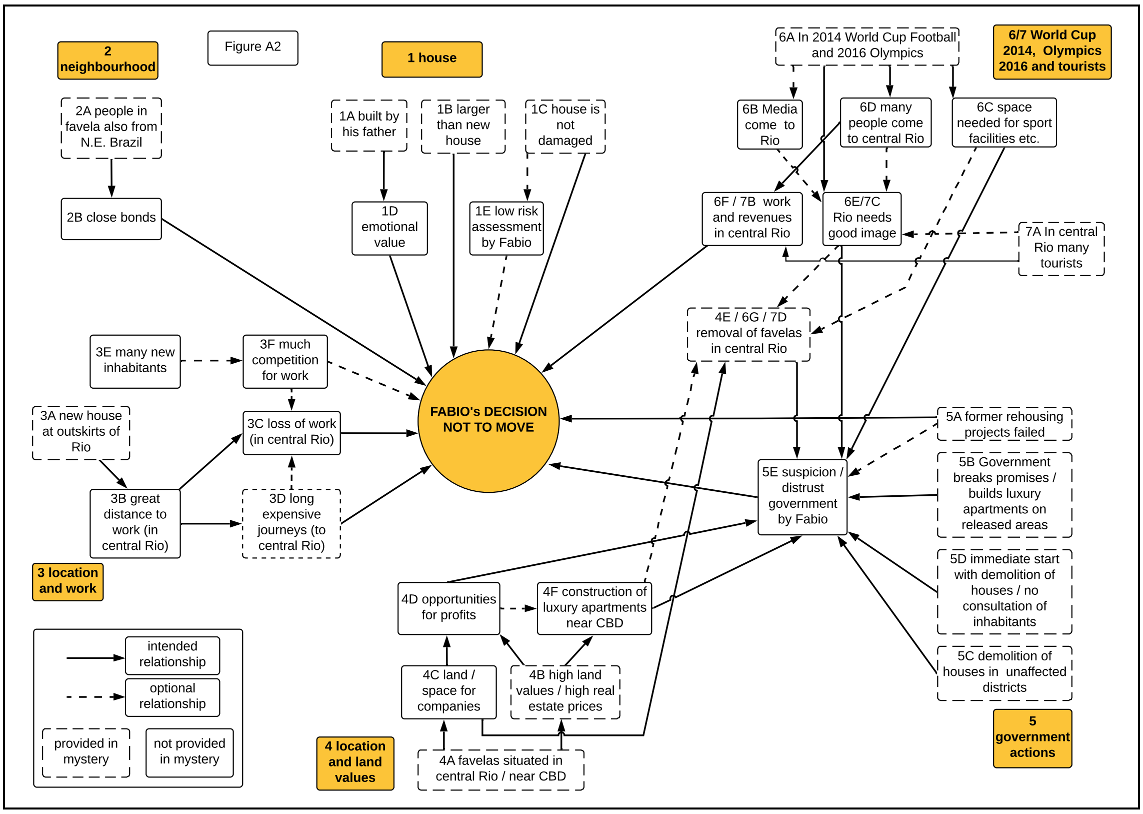

Figure A2. Criterion map of the Rio mystery