UNDERSTANDING SEGREGATION: UPPER SECONDARY SCHOOL STUDENTS' WORK WITH THE SCHELLING MODEL

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There are few research studies focusing on how humans can better understand segregation using mathematical models. In this paper, we explore how upper secondary school students work with the Schelling model using a computer game that was purposely designed for this study. The students were then allowed to run the model themselves. The results show that it was difficult to anticipate the degree to which segregation is generated within the model. The students mainly gave two types of explanations for the results. The first one was based on human psychology and the other was based on the mathematical principle that underlie the utility function of the model. The results are discussed from a perspective that illustrates the complexity of the subject, rather than as a measure of the teaching intervention.

INTRODUCTION

Segregation is a strong and a widespread phenomenon in society. There is segregation by, for instance, sex, age, income, or religion (Schelling, 1971). A common research area to study patterns of segregation is in choice of residential area, but the core mechanism works for other areas as well, such as school choice (Spaiser et al, 2018). We can see the results of segregation for instance in students choosing between different schools and how it affects teachers' choices of workplace (e.g. Bertilsson, 2014). Sweden is an interesting case since it is a country that is part of the so called Nordic model with a century of policy making based on equity and equality:

> Structurally, the Nordic model consisted of a public, comprehensive school for all children with no streaming from the age of seven to sixteen years. The overarching values were social justice, equity, equal opportunities, inclusion, nation building, and democratic participation for all students, regardless of social and cultural background and abilities. (Imsen, Blossing & Moos, 2017, p. 568).

The history and these norms are visible in the curriculum and the various syllabi for Swedish schools. For instance, in the curriculum for the upper secondary school, it is stipulated that,

> According to the Education Act, the education should be carried out in accordance with fundamental democratic values and human rights, covering the inviolability of people, the freedom and integrity of the individual, the equal value of all people, gender equality and solidarity between people. (Skolverket, 2013, p. 10)

Furthermore, we can read that all students should "consciously determine their views based on knowledge of human rights and fundamental democratic values, as well as personal experiences" (Skolverket, 2013, p. 10) and that all who work in the school should "actively promote equality of individuals and groups" (Skolverket, 2013, p. 10). Teachers have the responsibility to educate the students about these norms and they should

> "make clear the fundamental democratic values of Swedish society and human rights, and together with the students discuss conflicts that can occur between these values and rights and actual events" (Skolverket, 2013, p. 11).

Even in mathematics education the social perspective is visible; for instance, it says that one of the aims of mathematics is to help students to understand society with the help of mathematics. There is an increasing emphasis in Swedish policies saying that education should focus on diversity and inclusion (Imsen et al, 2017). At the same time, segregation is increasing in society (Spaiser et al, 2018).

The mechanisms generating segregation make it a far trickier subject to tackle than just educating people about equity and equality. Several modelling studies have shown that segregation can occur even when people prefer diversity (Pancs and Vriend, 2007; Tsvetkova, Nilsson, Öhman, Sumpter & Sumpter, 2016). Although sharing the same values and norms as the other countries described in the Nordic model, Sweden has a high level of school segregation (Spaiser et al, 2018). One conclusion is that public policies are not enough to improve integration (Pancs & Vriend, 2007). Hence, we need to study individuals and how they understand segregation, especially if they have had a chance to understand the mechanism behind it. At the same time, most policy making is based on the predictions of a segregation model, the Schelling model. Segregation is then viewed as a mathematical phenomenon, in the sense that individuals follow predefined rules about where to live based on their neighbours. These rules are then implemented in the form of a mathematical model (Schelling, 1971).

Looking at research, not many studies have focused on the predictions of the Schelling model from an empirical point of view (Tsvetkova et al, 2016), and so far, there appears to be only one study, by Tsvetkova et al (2016), looking at students' interaction with the Schelling model. Here, we present further analysis of data, and the focus is to study in what ways students, after interaction with this particular mathematical model through a computer game and a short lecture about segregation, will be able to make reasonable guesses about the levels of segregation and perceived happiness. This is the aim of the study. The research questions posed are: (1) How do upper secondary school students' guesses differ from the modelling results when working with the Schelling model? and, (2) What are their explanations of these differences based on?

THE SCHELLING MODEL

The starting point for looking at segregation is the study of collective behaviour: the idea that there "is a curious mathematical consistency among certain human activities" (Davis & Sumara, 2008, p. 168). It has been concluded, based on the work of Schelling, that segregation is not necessarily the result of one particular individual's actions and choices, or desires and attitudes (Davis & Sumara, 2008). It is more about a chain of reaction in a collective group. The Schelling model is a mathematical model that translates unorganized individual behaviour into collective behaviour. By using the squares on a checkerboard to represent, for instance, individual houses in a neighbourhood and tokens of two colours to represent two different groups of people, the model starts with a fully integrated society with the tokens randomly distributed over the board (Schelling, 1971). A series of simulations can then be made using various assumptions. The basic idea is that each individual of one group has a set tolerance level for the share of the other colour token in a neighbourhood. If the number of the other colour is in excess of the tolerance level then the individual moves to a new location. The model shows that even when groups are reasonably tolerant, segregation happens quickly and inevitably.

In Tsvetkova et al (2016), we used four different assumptions for utility functions, all representing different preferences. Here, we analyse one of them – the Same and Diverse game (c.f. Pancs & Vriend, 2007). In this game, individuals strive for similarity up to a certain level in combination with a preference for some diversity. It has been concluded that such a function has practical implications regarding equity and equality (seen as preference for some level of diversity) and can be taught in school and implemented in policies (Tsvetkova et al, 2016). This is in line with the idea of the Nordic education model where schooling was thought of one important part of educating the members of the society into openness and flexibility (c.f. Imsen et al, 2017).

METHODS

First, we describe the data collection including how the computer game was designed, and then how data were analysed.

Data collection

One conclusion that was made in Tsvetkova et al (2016) was that most game experiments found in our literature review did not allow communication. Since we wanted the students to be active and engaged, we set up a different design. The aim was to have a game that was simple, intuitive, and engaging. The solution was a two-dimensional Schelling game using a six-by-six square grid using two colours of tokens, blue and yellow. The colours were chosen as neutral colours (that also happen to be the colours of the Swedish flag).

In total, 20 upper secondary school classes participated with a total of 399 participants. They were from all three grades meaning that the students age span was 16-19. Each class had between 13 to 25 students and they came from different educational programmes, both vocational and programmes preparing for university studies. The classes came from three different regions in Sweden (east, middle and west). Each student was assigned a number and colour and they borrowed a surf tablet to use as game controller. The game was then projected on a screen so everyone could see their own movement on the checkerboard as well as their neighbours' movement. They could move their avatars to an empty spot, but only up, down, left, or right, not diagonally. The students played four games with different scoring rules that were equivalent to the four utility functions. (For a more detailed description of the interpretation of the Schelling model into computer game, see Tsvetkova et al, 2016.)

Utility functions	Simulation Outcomes	Experiment Outcome
Same	84.2	100
Diverse	51.9	41.7
Same and Diverse	72.9	62.2
Same or Different	8.3	63.4

Table 1: The different functions and outcomes, results are proportion of same type neighbours in percentages (%).

The students also answered one questionnaire before the game and one after the game, both questionnaires were about background information such as gender, residential status and grades. After playing the game the students listened to a short lecture about segregation, how it works and how the game they just have played describes different aspects of segregation. As the final step, the students were asked to run the model themselves and write down answers to a series of questions on a worksheet. In total, the lesson was planned and timed to be one hour long. As it was planned, the students were considered both as learners but also future communicators about segregation, as well as research colleagues since they participated in generating results for the modelling. They participated in not only the games, but also running the modelling themselves and in both situations they needed to communicate and negotiate the meaning of their movement on the board but also interpreting the results when running the model. This is in line with previous work described by Lerman (2001).

As discussed in Tsvetkova et al (2016), during the game itself, very few groups managed to achieve a global coordination although most groups had high level of

communication. The game was very dynamic with an average of 3.8 moves per second.

In this paper, we analyse a subset of the data generated by 14 of the 20 classes. The reason for this was that for the first five groups, we tried a different worksheet that focused more on the use of, rather than the understanding of the model. One group was excluded since they did not have the time to complete the worksheet. In the end, 272 of the total 399 students' worksheets were analysed. Of these 272 responses, 267 had filled in all the information which gives a response rate of 98%. Although running the models themselves on the surf tablet, they were allowed and encouraged to discuss the matters with their neighbours. The reason for allowing collective reasoning was the principle of wisdom of the crowd (c.f. King, Cheng, Starke & Myatt, 2011).

In the present paper, the focus is on the first question. The information given to the students was the following:

> To run the simulation, first you need to adjust the parameters and then select the model. Then you can start the actual simulation. When the simulation has stopped, you write down the final average percentages for similar neighbours and the final perceived happiness/ content. Repeat the simulation 3 times for each model in order to arrive with reliable results.
>
> **Task 1.** Which level of segregation do you get when individuals prefer both mono-culture and diversity, i.e. you are happy both with neighbours that are similar to yourself and neighbours that are different?
>
> Before you run the simulation, guess the results.

At this point in the intervention the students had experienced playing the game, which involved interacting according to the utility function, and experiencing seeing their own points changed as their numbers of neighbours changed.

The students were now asked to guess both the average of similar neighbours and the average percentage of happiness. Then they were instructed to run the models (see Figure 1).

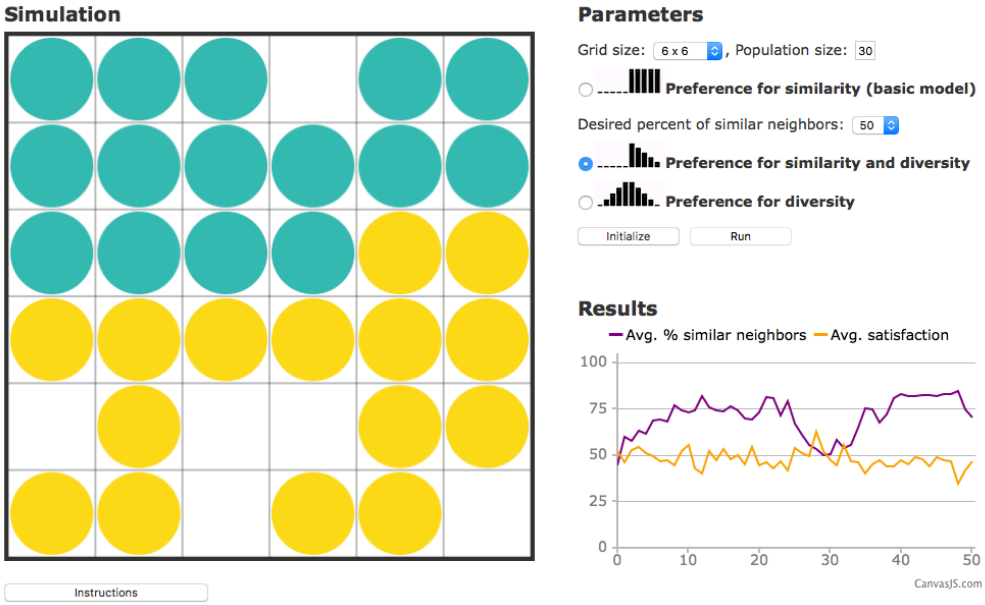

Figure 1: The Schelling model as presented to the students.

Lastly, they were asked to comment on their guesses in relation to results from the simulation. The formulation was the following:

> Now you compare your guesses with your results. Any difference? In what way? What do you think is the reason for the results of the simulation?

The questions were aimed to focus on how quickly segregation is created even though people prefer both colours, i.e. the Same and Diverse game.

Method of analysis

The data were analysed by summarising all the guesses from the students and calculating the average. The guesses were compared to the modelling outcome. The simulations were run for 100,000 time periods and replicated 1,000 times. Since the research question is about how students' guesses differ and not a question whether they are significantly different, we use only descriptive statistics such as mean and mode. The written comments from the students were analysed using thematic analysis (c.f. Braun & Clarke, 2006) looking for patterns in the responses. A first analysis showed that there were mainly two types of comments: comments on how close/ far away their guesses were from the simulation outcomes, and comments that contained some information about how the students interpreted the situation. Only the latter group was analysed using thematic analysis. The responses were grouped looking for patterns (similarity and difference) and as a second step, the themes were controlled against each other but also back to the original data. The reason for the second step is because themes had to "cohere together meaningfully, while there should be clear and identifiable distinctions between themes" (Braun & Clarke, 2006, p. 91). Here, the focus is not how many responses falling into the different categories,

but to present the themes. The data were collected and handled according to the ethics stipulated by the CODEX given by the Swedish Research Council.

RESULTS

The results are divided into two parts. In the first part, we have the descriptive statistics of the guesses made by the students and the outcome from the modelling. The second part is the results from the thematic analysis.

Students' guesses and modelling outcome

The results from the students' guesses and the simulation are presented in Table 2:

	Students' average guess	Modeling outcome
Similar neighbour	65.76	79 ± 1.3
Happiness	64.08	47 ± 2.6

Table 2: Students' guesses and simulation results given in percentages (%). Numbers in parentheses indicate standard deviations in simulation outcomes.

As we can see in Table 2, the average guess differs as the students underestimated the degree of segregation and overestimated the degree of happiness. However, looking at the mode of students' guessing about similar neighbour, the most common guess was 70, which is closer to the modelling outcome. The range of the responses was 90. The mode for happiness was 50, which is close to the outcome from the model, and the range was 94. This variation is reflected in the students' comments.

Students' explanations

When analysing the students' responses, some students commented on how different the results were compared to what they expected. Some students just stated 'it was different' or 'it was x % off'. Such responses were left without further analysis. One example was the following (where S and number indicate the response):

> it was opposite what I thought it should be. [S264].

The responses that had some information about how the students interpreted the situation were grouped into themes. Two themes were the result of this analysis. One theme was explanations based in the psychology of people:

> Perhaps it is because people are never content. [S54]; Slightly less average percentages (similar neighbours) and a big difference in average happiness. You rather want to be

surrounded with people that are similar then different. [S85]; People want more segregation than I thought. [S107].

The argumentation does not separate between human behaviour and the mathematical modelling, as if the students see the tokens as humans just as when they themselves played the game. Some students even gave the tokens human feelings, here illustrated by the following response:

> The degree of happiness regarding culture should be 100% since you have no problems. The model is based on parts more than how complex feelings are. [S224]

Some students anticipated the high degree of segregation and the low level of happiness and provided some explanations using human behaviour:

> Not such mega difference compared to my guess. You don't want to be someone who is against the stream, most people don't anyway [S261]

It is not clear whether these students had understood the difference between the mathematical model and the application of the model. Since we do not have further information about how to interpret these statements, whether there is a deeper understanding that lies behind these comments, the conclusion drawn here is that it appears that some students did not make the distinction between the simulation and when they played the computer game, the latter being the case when the tokens did represent a specific person.

The second theme appeared in students' responses that referred to the mathematical principle behind the utility function:

> The players want to have a security to still have more than 50% of similar neighbours even though one neighbour is moving and then you could have lower degree of happiness in order to gain more security. [S258]; "The tokens" want to be sure to have more than 50% of their own colour. [S224]; the neighbours are more similar to each other in the simulation compared to my guesses and the degree of happiness is lower. Everyone could probably not get 50% independent how they move as long as they are not collaborating. [S187].

These students appear to have understood the fundamental principle of the model and the predicted outcome. Some commented on the complexity of segregation as described by the computer game the students just played. Here, this is illustrated by the following two responses:

> Even if they wanted diversity, they were attracted to each other. Domino effect. |S13]; When someone is dissatisfied, they move and that ruins it for their neighbours. When everyone is ok happy, it stops. [S47]

Several students mentioned the domino effect, the chain of actions that is created when one token moves. Based on these comments, we see that some students appear to understand the model and how quickly segregation is created even though preferences allow both similarity and diversity.

DISCUSSION

The aim of the paper was to study upper secondary school students' guesses about the level of segregation after participating in a class designed to stimulate understanding of segregation using the Schelling model. As described earlier, the Same and Diverse game which is in focus here, is of special interest since it has practical implications and is thought of as being able to be taught in school and through policies (Tsvetkova et al, 2016). In regard to the curriculum and norms and values such as inclusion, equity and equality, the design did allow the students to "discuss conflicts that can occur between these values and rights and actual events" (Skolverket, 2013, p. 11). Looking closer at the students' explanations to outcomes in relation to their guesses, there are two main themes besides the answers that just on a superficial level commented on how far/ close they were in their guesses. These two themes were 'psychology of people' and 'the mathematical principle of the model', where the first indicates a struggle to separate between the model and the computer game and the other indicates that some students understood how the game worked, including the chain of actions (c.f. Schelling, 1971).

Although using the possibility of collective reasoning, in line with the idea of wisdom of the crowds (King et al, 2011), the results illustrate how hard it is to understand exactly how quickly segregation is created even in the most beneficial circumstances such as in the Same and Diverse game. However, using similar reasoning as Lerman (2001), the written texts are not end results but more tools for learning. Therefore, we don't see the guesses as a measure, although relatively close, of how effective the lesson design was, but more an indication of how complex this area is. Davis and Sumara (2008) use Schelling's work as an example of sociological work that is also connected to psychology and human behaviour. We think the results from our study function as a further illustration, now with an educational perspective. Some of the comments from the students support this conclusion: although the mathematical model and its tokens do not have any emotions, they describe and model on group level individuals who do have emotions and desires.

One possible implication would then be that this is a complex topic, but one way to fulfil the norms described in the Nordic education model (c.f. Imsen et al, 2017), norms that are embedded in the Swedish curriculum (c.f. Skolverket, 2013), is to talk about this also from a mathematical point of view, using the computer game that we designed. Although the results from our study show that some students do struggle to transfer from the computer game situation to the modelling situation, we think the tool offers a starting point: the incredible activity of the students that was measured (Tsvetkova et al, 2016) suggests that it is a good way of initiating a conversation. However, we also understand that although we designed a lesson where the students participated in many different educational tasks, one hour of active work appears not enough to tackle such a complex topic. Also, we did not offer what a teacher could: a follow up class where potential misunderstandings can be dealt with. Therefore, we

think this is a good topic for further elaboration, especially when considering that this is a research area that has just started.

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