Understanding students' use of learning strategies through visualizations

A usability study

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ABSTRACT

The Swedish school system is going through a digitalization process. With digitalization, a strong interest in exploring data from learners available through various digital platforms in use (e.g., learning management systems) has evolved [22]. Digital tools can be used to analyse and evaluate many learning/teaching activities performed by the school [27]. The analysis and evaluation of learning activities is a part of Learning Analytics (LA). There is no universally agreed definition of the LA term. One popular definition uses it as "the measurement, collection, analysis and reporting of data about learners and their learning environments in which it occurs" [24, p.1].

Depending on the problem to be solved, the target stakeholder (e.g., teachers, students or external evaluators) and the chosen learning context, LA can be performed differently. In some schools, like in the case of this study, students are expected to take more responsibility for their own studies without a constant presence of a teacher. This suggests that in order to succeed in their studies, these students need a high level of self-regulation in their learning. This type of learning, which is closely connected to academic achievement [32], is called self-regulated learning (SRL). When using SRL, students are expected to regulate themselves in their learning, for example by being able to set up their learning goals or to seek help when needed. Students cannot expect help from a teacher immediately when facing a problem since a teacher is not always present. SRL includes relevant skills, strategies and knowledge needed on the part of learners to be able to take control of their own learning.

SRL can be learned and taught [32]. It helps students with future studies and work [32]. The two main keys for SRL are:

1. The learners' awareness of strategic relations between regulatory processes or responses and learning outcomes [32].
2. Their use of these strategies to achieve their academic goals [32].

SRL is difficult for students, as they are not capable of accurately judging their own learning processes [6]. Without instructional support, students overestimate their understanding [1,2] and methods to reach the answer. This thesis presents design guidelines to have in consideration when designing a visualization tool in order to aid teachers in analysing students' use of SRL strategies.

Keywords

Learning strategies; Self-regulated learning; Information Visualization; Learning Analytics; Teaching and learning support

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The use of learning strategies makes a distinctive contribution to the students' achievements compared to students that do not use them [32]. Therefore, this study argues that schools that help their students to develop and apply relevant learning strategies will gain advantage compared to schools that do not. If then a school focuses students' unsupervised (by teachers) ways of study out of class - as in the case of this study - the use of SRL strategies becomes even more important.

This thesis aims to support teachers in developing student SRL strategies in educational settings. To assist teachers in this task, they need to know the students' opinions about the learning strategies that are offered by the teachers. Limited knowledge about the students' opinions might risk that the suggested strategies become an obstacle instead of a helpful tool. The present study has been conducted in a close collaboration with Kunskapsskolan in Sweden. To facilitate the development of student' SRL, teachers at Kunskapsskolan formulated a set of relevant strategies to be used by their students. However, since Kunskapsskolan has over 13,000 students, it is hard for the teachers to understand the effectiveness of such efforts; namely to understand which of the suggested strategies that are being used and are considered by students to be helpful and which not.

Students' attitudes towards the suggested SRL strategies will generate data in vast volumes which can make it hard to analyze and understand. To be able to analyse the attitudinal data from students in a more efficient way, the development and use of relevant visualizations should be considered. Several types of visualizations, such as different kinds of charts, plots, maps etc. can be employed. The most suitable depends on the data available (for more, see Section 2.5). This study thus strives to answer the following research questions:

1. How can attitudinal data from students be visualized in order to understand students' use of learning strategies?
2. How usable is this visualization tool for teachers?

2. THEORY AND RELATED RESEARCH

2.1 Learning strategies

The term learning strategies can be defined in many ways. Learning strategies in this thesis are defined as "cognitive operations sequence directed to a goal that guides students from understanding a question until make an answer" [18, p. 217]. Consequently, learning strategies can be used through the whole learning process, from getting a task to solve to delivering a solution to the task. Learning strategies can be divided into different type of strategies such as a) Support strategies (e.g., motivation and attitude); b) Processing strategies (e.g., selection and processing); and c) Knowledge personalization strategies (e.g., creative and critical thinking) [18]. The fact that multiple strategies can be used to solve the given task must be taken into consideration [18]. A student may need a motivation strategy to get motivation to use a processing strategy that directly helps the student with the task.

2.2 Learning analytics

The reasons for conducting LA should always be to improve students' performance, to support teaching and/or to provide learning support. This can be done in several ways, such as refining pedagogical strategies or discovering students that might be struggling with one or another subject [15]. Since the aim of this study is to understand how learner data concerning students' use of learning strategies can be visualized, the focus of the study is on the reporting part of LA. It specifically focuses on visualising students' attitudinal data about their use of the offered learning strategies, with the primary aim to support teachers.

Decisions taken on further actions at an initial stage of a LA process will have a profound effect on the following stages. The data collected from the capture stage will influence the shape of the prediction and actions that can be made. Thus, the data collection process and methods should be well planned to ensure that nothing has been missed (see more in section 2.3).

2.3 Data based decisions

Is it reasonable to make decisions about learning activities based on the analysis of collected data about such? Schildkamp et al. [21] argue that teachers and school leaders are required more and more to make their decisions based on the analysis of digital learner data as part of an increasing international focus on holding schools accountable for the education they provide and decisions need to have good arguments for why they are made [21]. If a school has data about, for example, how good a certain teaching or learning strategy works in a certain subject, they can make well-grounded decisions on which strategy should be used. It will also be easy to explain the decisions to the parents if the school has well-grounded arguments to do so. However, Schildkamp et al. [6] highlight that it is important that the data has high quality and is not based on untested assumptions. Just because the data tells that a strategy works good in one subject does not mean that it will work good in every subject. For example, a second language teacher sees that students that use a certain strategy get higher grades on tests than students who do not use that specific strategy. The teacher tells the principal that the students should use the strategy in every subject since the students get higher grades in his class. Now, the principal must proceed with caution. The principal must know what this strategy is aimed at exactly. If the intention of the strategy is to help students to remember words and grammar, that strategy becomes quite useless in for example Math.

2.4 Usability

Advanced LA tools exist, but there seems to be very few that have focused on the evaluation of their usability. They rather focus on the data that should be in the tool (e.g., the number of learning activities or time spent doing them) [16] and/or present a tool with a system where the user can leave feedback on the usability perspective [22]. Such tools frequently display pure quantitative data, such as a number of activities and time spent on such activities; it seldom includes students' opinions in regard to the offered support. The Swedish National Agency for Education states that students have rights to have influence on their education [25] and therefore, it is of importance to analyse students' attitudes towards the specifically formulated learning
strategies aiming to support students in regulating their own learning.

Earlier research results show that existing LA tools have been often directed towards adult students and/or teachers in higher education [30]. There is unfortunately a lack of relevant LA approaches and tools to support teachers and students in K-12 education. Thus, this study aims to fill in this gap by focusing on supporting teachers in secondary education.

Since there is a need for a higher digital competence on the part of educators, including their technical knowledge [27], the proposed LA tools should be usable for a teacher to use.

### 2.5 Visualisation tools

Since data has never been generated in the vast volumes as it does today, exploring and analysing these growing volumes will be more and more difficult [13]. In order to manage these high data volumes, visualization and visual data mining have been shown to be helpful [13].

One important aspect of the LA research is to empower teachers and learners to make informed decisions about the learning process [12] and provide systematic feedback [29]. This can be achieved by visualising the collected learner data through for example, learning dashboards. A learning dashboard refers to “a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance” [20, p.1].

Visualizing information can be done in many ways, such as charts, maps and bubbles with different sizes etc. However, the basic principle of all these ways can be described with what is called Shneiderman’s mantra: “Overview first, zoom and filter and then details on demand” [23, p. 129]. This means that the user firstly needs to get an overview of all the data. In this overview, the user finds the parameter(s) or pattern(s) that s/he is interested in and focuses on that/those. In order to analyse these pattern(s), the user must act, for example by clicking on it or scrolling to zoom [13]. Several studies on information visualization pinpoint the importance of Shneiderman's mantra [e.g., 5, 8, 11, 13, 23], suggesting that the implementation of a visualization tool should be done in a way that comforts Shneiderman's mantra. The implementation will differ depending on what type of data to be visualized.

When creating a visualization tool, it is important to make the tool feel intuitive [16]. In order to do that, one needs to think about what is intuitive for humans. How it should be implemented depends on how the core of the visualization is made. For example, humans tend to see cues that tell them what to do with an object [31]. A door handle that sits on most of the doors in a home environment invites a human to grab it and pull it down [31]. This means that when creating a visualization tool, one needs to create design elements that are intuitive. For example, if an element is clickable, give a hint in some way, for example, change the background colour when hovering. In order for individuals to remember how things work, they must also be introduced to all the necessary functions in an effective way. If they are not, the users will probably forget something since the short term memory is very limited [31] and if it should be transferred into the long term memory, users either have to use the functions repeatedly or connect it with something they already are familiar with. Based on previous experience, people will create different mental models on how the interaction in a visualisation will work [31]. If the user never has seen a visualisation before, his/her mental model will differ from a user that has seen a visualisation. In order to design a tool as well as possible, all different types of mental models must be taken into consideration. People tend to defend their own ideas very hard and developers/designers should not spend time trying to change those [31].

### 3. CASE DESCRIPTION

The work presented in this thesis has been conducted in a close collaboration with Kunskapsskolan (Sweden), a company that runs 29 elementary schools, 7 high schools and one school for students with special needs in different locations in Sweden. In its pedagogical approach, Kunskapsskolan focuses on students’ self-studies rather than on more commonly encountered joint teacher-led classroom learning and teaching activities. The students are expected to plan their studies on a weekly basis as well as on an annual basis, which requires a certain level of SRL knowledge, skills and strategies, including students' time management strategies. To aid students in their SRL activities, Kunskapsskolan offers a number of digital tools, including Loggboken, i.e., a digital calendar where students fill in what they plan to study during the up-coming week.

Kunskapsskolan has digitalized almost everything that can be digitalized, including learning tasks and the presentations of these tasks. In the language subjects (Swedish, English, German etc.) and math, students do all the work via a learning management system called Kunskapsporten [14]. All the learning materials including learning tasks and learning goals are available in a digital form at Kunskapsporten, which opens up access to learner data that can be analysed in order to improve students’ conditions for learning. The subjects are divided into 35 to 45 steps to be achieved at the end of the secondary school education. Each step is centred around several learning goals. When the student think s/he has fulfilled relevant goals, s/he can book a time with a teacher to prove it.

### 3.1 Earlier Work

Kunskapsskolan has earlier attempted to motivate its students to formulate their own learning strategies to be used while studying on their own (see Figure 1). After a period of time teachers realised that this tool - which was integrated into Kunskapsporten - was not used by the students as it was intended [3]. The textbox was either totally ignored by the students or used to write down when to do what during the week.

![Figure 1. The text box where students are supposed to write down their own strategies.](image)
Considering the importance of the learning strategies' use, Kunskapsskolan has in Fall 2018, started to work on assisting their students in their use of learning strategies when studying. In particular, a number of teachers at Kunskapsskolan's schools have formulated a set of relevant (to their knowledge) learning strategies to be used by the students. For example, Minnespromenaden (method of loci) is a strategy that can help students to remember things. Another strategy is Baklängesplaneran (back-wards planning) which aims to help students to break down a big task into more concrete pieces. Based on the availability of these strategies, a prototype of a recommendation system was built by students at KTH during the Fall of 2018 to encourage students to be more aware of how they learn best (the prototype is available at https://felixnoren.com). When the KTH students got the formulated strategies from Kunskapsskolan, they were all categorised. A few examples of these categories were “Hitta motivationen” (find the motivation) and “Planera ditt lärande” (plan your learning). Each step in each subject were then, categorised by the KTH students to be able to match the strategies with the steps. In Appendix A, the first view of the prototype where students choose strategies is seen. The prototype is built to look as similar to Kunskapsporten as possible. In Appendix B, the button Lägg till strategier (Add strategies) has been clicked on and the students gets a list of recommended strategies to choose from. In this view, they can also see bookmarked strategies and strategies chosen in the past. The strategies are recommended by matching the categories from the steps with the categories from the strategies. For example, if step 26 in math is categorised with “plan your learning” and “find the motivation", the strategies that appear for step 26 in math are tagged with “plan your learning” and/or “find the motivation”. Besides the matching tags, the recommended strategies are also generated based on ratings from previous students. The star in Appendix B, indicates that the strategy is hand-picked by a teacher. After a week the students evaluate the strategies used with their mentor during a weekly private conversation. In Appendix C, students have chosen their strategies and are directed back to the first view. Pay attention to the right side compared to appendix A and see that two strategies have been added. Presently, when evaluating the suggested strategies, the prototype prompts the students to choose between three alternatives; thumbs up, thumbs down or have not used (see Appendix D) [3]. In this view, students can also bookmark chosen strategies if they want to. This thesis has a particular focus on supporting teachers through the visualization of learner data available from the students' evaluation of the learning strategies used. This data was chosen through a suggestion from Kunskapsskolan. Since they rather recently made an investment in developing SRL strategies and values students' opinions, they wanted to be able to analyse and evaluate the students' opinions in order to know how they should proceed with the development of SRL strategies.

4. METHOD

4.1 Visualization tool

A visualization tool was developed. The aim of the tool was to visualize the students' evaluation of the learning strategies they have used. Since the prototype mentioned in section 3 is not implemented into Kunskapsporten, the visualization has been created with dummy data (see section 6.1). The dummy data was created with help of a random number generator (available at https://www.random.org/integers/). For this prototype, random numbers between 1 and 30 was generated to represent answers from the evaluation mentioned in 3.1. This data is multi-dimensional. For example, when students evaluate a strategy, there are three options, i.e., “helpful”, "unhelpful" and “have not used” which creates three dimensions, i.e., a number of answers for each option. Every strategy is also connected to the school the student studies at and in what subject the student has used the strategy. Visualizing multi-dimensional data creates challenges in terms of the tool's usability from the teachers' perspective.

The visualization tool (available at https://felixnoren.se/thesis) is based on parallel coordinates [10] and shows how a certain strategy in a certain subject has been evaluated by the students at a certain school. Parallel coordinates is a visualisation type that is able to visualise high dimensional data in a geometry shape. To show data in N dimensions, N axes is drawn. A point of data is then represented by a line that vertices the axes. For example, if a data point has the coordinates (5,10,15) in a three-dimensional space, the line cuts the first axis at five, the second axis at 10 and the third axis at 15. The filtrations are based on schools, categories (i.e. the tags used in the prototype described in section 3.1), subjects, strategies and the number of answers on each option from the evaluation. To filter based on schools, the user clicks on a school and then only data from that school is visible (Appendix E and F). If the user wants to have data from two schools visible, s/he clicks on another school and the data from that school will be visible as well. To filter based on categories, subjects or strategies, the user can either click on an item in the list below each header or s/he can search for it with the search bar. If the user hovers over an item below the strategy header, that strategy will be highlighted in the canvas where the visible lines can be seen (see Appendix G). Each line has numbered values connected to three axes: helpful (corresponds to the number of students that clicked the "thumbs up" button; Appendix D), unhelpful (corresponds to the number of students that clicked the "thumbs down" button; Appendix D) and unused (corresponds to the number of students that clicked the "Har inte använt" button; Appendix D). To filter based on these numbered values, the user drags the mouse over the axes s/he wants to filter on. If the user wants to see all the strategies where, for example, 10-16 students have evaluated the strategy to be helpful (i.e., clicked the "thumbs up" button), s/he then drags the mouse between 10 and 16 on the helpful axis. The result from this example filtration can be seen in Appendix H. The span can be adjusted and moved. It is also possible to use the filter at multiple axes at the same time. This last type of filtering explained is called "value filtering".

The filters can be combined if the user wishes to do so. If the teacher wants to see, for example, strategies that his/her students have used in their specific subject, or if the teacher wants to see which strategies that are the most up-voted and at the same time, least down-voted at one specific school, it is possible. The colour coding is based on schools, which means that all the strategies from one school has one specific colour assigned to them.

In Appendices E-G, five headers (i.e., Lärstrategier, Alla skolor, Kategorier, ämnen and Strategier) can be seen at the bottom. The one to the far left presents user instructions and next to that, there is a list with all the schools ("Alla skolor") that are visible in the tool. The numbers presented in the column "Alla skolor" show how many lines the school is represented by on the canvas. When the filter from Appendix H (i.e. 10 to 16 students have considered the strategy helpful) is applied, the user can directly see how many strategies each school have where 10-16 students have considered the strategy as helpful. For a comparison between the overview where no filter has been applied and the view where the filter from Appendix H has been applied, see Figure 2.
4.2 User test

To understand the perceived usability of the designed visualization tool, eight teachers were introduced to it. They got the visualization in front of them on a Mac computer and were given relevant tasks to test the tool. They included the following tasks: "Which strategy/strategies is/are most popular one in Nacka?" or "How many math strategies have 20 or more students from Lund said that it is unhelpful?" (see Appendix I for the full questionnaire). When teachers performed the relevant tasks, the screen was recorded in order to be able to afterwards see how they interacted with the visualization tool. Afterwards, the teachers filled in a System Usability Scale (SUS) [17].

When a person answers a SUS s/he answers a Likert scale with 10 questions in a 1-5 scale where 1 corresponds to do not agree at all and 5 to completely agree. When s/he has answered, a score between 0 and 100 is calculated. With help from data from over 10 000 responds and hundreds of products, the score can be meaningfully interpreted [17]. A score above 68 is above average. There is also grade scale (A-F) where the score can be translated into a grade (see Table 1).

Table 1. SUS Grades [17]

<table>
<thead>
<tr>
<th>Grade</th>
<th>Score</th>
<th>Adjective</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>84.1-100</td>
<td>Best Imaginable</td>
</tr>
<tr>
<td>A</td>
<td>80.8-84.0</td>
<td>Excellent</td>
</tr>
<tr>
<td>A-</td>
<td>78.9-80.9</td>
<td></td>
</tr>
<tr>
<td>B+</td>
<td>77.2-78.8</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>74.1-77.1</td>
<td></td>
</tr>
<tr>
<td>B-</td>
<td>72.6-74.0</td>
<td></td>
</tr>
<tr>
<td>C+</td>
<td>71.1-72.5</td>
<td>Good</td>
</tr>
<tr>
<td>C</td>
<td>65.0-71.0</td>
<td></td>
</tr>
<tr>
<td>C-</td>
<td>62.7-64.9</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>51.7-62.6</td>
<td>OK</td>
</tr>
<tr>
<td>F</td>
<td>25.1-51.6</td>
<td>Poor</td>
</tr>
<tr>
<td>F</td>
<td>0-25</td>
<td>Worst Imaginable</td>
</tr>
</tbody>
</table>

The participants were also asked to offer feedback on visualization of their choice by a) Fill out a separate questionnaire or b) spontaneous thoughts when they tested the visualization.

5. RESULTS

5.1 Usability Score

The average score on the SUS questionnaire is 75 which suggests that the tool is approved from a usability perspective (a score above 68 is above average), which according to table 1, is a B. The median score 80 is, according to table 1, an A-. However, a closer look at the scores offered by the participants reveals that there is a quite big variation. The highest score was 100 and the lowest 47.5.

Of the eight teachers that scored the visualization tool, one was 35-39 years old, one was 40-44, two was 45-49 and four was 50+ years. Grouped by age, the people that was older than 50 years was the group that scored the tool highest by an average of 86 compared to the certain younger group of 45-49 that scored the tool 70 on average. The men of the test group tend to see the tool more usable than women. Men's average score in the SUS was 78 while the women's ditto was 73.

5.2 Discoveries during the tests

While the participants tested the visualization tool, a pattern amongst the participants that do not use Apple computers on a daily basis was visible; they had problems with how to interact with an Apple trackpad. Another pattern discovered was that the participants tend to interpret all axes in the same way. When a data point is high on the axes, most of the test participants interpret it as good, but that is not necessarily true. If a strategy contains many unhelpful answers (i.e., lays high on the unhelpful axis), the intention was not to interpret it as good. It was also discovered that the value filter tended to be hard to aim at an exact spot. A vast majority made a more generous filtration and then adjusted it afterwards.

5.2.1 Value filtering or hover over lines

Answering the first question, "Which strategy/strategies has/ve been most helpful in Linköping?", most of the participants understood that the lines could not be hovered over and used the value filter straight away. This may be caused by the instructions they were given before the test started, as it was not mentioned that the lines could not be hovered over in order to get more information. However, some comments were made at the topic, suggesting that it would be a good feature to implement (read more in Section 6).

5.2.2 Accuracy when using the value filter

When answering the second question, "Which school(s) has most strategies where 25-30 students considered the strategy as
unhelpful?”, none of the participants had problems with filtering these strategies (except from the trackpad troubles mentioned above). However, everyone had problems with finding the schools right away, since they were ordered alphabetically and not by the amount of visible strategies.

5.2.3 Come across the answer in different ways Question number 3, “How helpful is the strategy "byt format" when students in Täby studies German as a second language?”, participants came across the answers in one of three different ways:

1. First filter on the school, then on the strategy "byt format" and then realized that the only subject the students in Täby used the strategy in was German as second language
2. First filter on the school, then on German as second language and last, the strategy "byt format"
3. First filter on the strategy "byt format", then filter on the school and realized that the only subject the students in Täby used "byt format" in was German as second language.

This indicates that the participants filtered their answers in different orders. In this case, way 1 and 3 were the most effective one since the strategy was only used in one subject and thus it was only necessary with the two filtrations done in way 1 and 3. If the system is going to be implemented, the strategy may be used in multiple subjects. If that happens, the teacher has to filter on not just the two filters mentioned in way 1 and 3, but also filter the subject header.

5.2.4 Filter by eye Question 4, “How many math strategies have 20 or more students from Lund said that is unhelpful?”, the intention was to see if the participants used the value filter as soon as they had filtered off everything except math strategies from Lund. There was shown that it was not necessary since there were quite few strategies visible when the filtering was done (see Appendix J). That could have been necessary if there were more strategies evaluated by students from Lund.

5.2.5 Teachers’ interpretation of data In the question “which strategy is most popular in Nacka?”, there was room left for interpretation. The participant had to define the term “popular" by themselves. The majority of the participants defined a strategy as popular if it had a high amount of “helpful” answers and a low amount of “unhelpful" answers. Some of them just looked at the amount of helpful answers. No one considered the amount of “unused” values.

5.2.6 Getting close to the answer The question, “At which school(s) is the strategy "kontrollera dina tankar" (i.e. "control your thoughts") most unhelpful?”, a similar pattern to the pattern in question 4 was discovered. When the participants had made the necessary filtration, everyone saw the line that was the answer. However, since the line was not hoverable, it was hard to get the answer right away. Some of the participants solved this by applying a value filter so just the particular line was visible. Others hovered over the strategies in the list below the canvas until they saw which school it belonged to. It turned out that some of the colours looked quite similar so the participants that chose the "list way" had a hard time to find which colour in the list that corresponds to which colour in the canvas.

5.2.7 Recognising all the information The numbers beside the school (see figure 9) tended to not be fully understood. When finding the answer to Q2, every participant used it as it was intended while when finding the answer for Q7, “how many different strategies in French as a second language have students in Katrineholm evaluated?” no one realized they could just have filtered out everything except the strategies connected to French as a second language and that the number beside Katrineholm would have revealed the answer immediately. Instead, everyone filtered in both French as a second language and the school of Katrineholm and started counting the number of lines on the screen. Some of them realized after a while that the number beside Katrineholm existed.

5.3 Summary of the results According to the results presented above, individuals tend to use different methods in order to get to the same answer. Some users filterate on schools first and then strategies, while others filtrate the opposite way. Some users liked to use the value filter and some just want to hover on the strategy header to see which strategy belongs to which school.

6. DISCUSSION The aim with this study was to see how learner data can be visualized in order to understand students’ use of learning strategies and how usable the visualization tool is as experienced by the teachers. There are probably many more ways of how such data can be visualized, but the results of the user tests show that parallel coordinates is one way to do it. When looking at the SUS results, the tool can be considered as helpful, at least from the usability perspective, which probably means that the tool included the triggers necessary for the participants to interact with it in the way they wanted to. Most of the people have similar triggers where they are told what to do without knowing it. For example, when the mouse pointer turns from an arrow to a hand with the index finger up, it triggers users to click.

To visualize the data, parallel coordinates was chosen because the data was multi-dimensional and there are few other ways to visualize such data in a geometry shape. Since the visualization is going to be used on a computer screen, it would be a bad idea to have some kind of 3D figure as the visualization. Shneiderman's first part of the mantra, overview first, would be "broken" since the user is not able to see all the data in a 3D figure on a 2D computer screen and there would have to be other elements of interaction (rotate around axes and such) that can be avoided with parallel coordinates. If another type of data was to be visualized, there may be other better ways to visualize that than with parallel coordinates, but the more dimensions the data that should be visualized have, the stronger becomes the arguments for parallel coordinates.

The interpretation of the axes was, as said, treated equally. This was, of course, not intended. However, it means that people tend to see patterns, where a line at the top is interpreted as something to seek for. The goals for Kunskapsskolan in this case are to have a big amount of helpful answers while at the same time have a low amount of unhelpful and have not used answers. This kind of problem could be resolved by inverting the unhelpful and the unused axes.

As stated earlier, the participants defined the term “popular” themselves during one of the questions and that most of the them defined it as a strategy with many answers on helpful and few answers at unhelpful at the same time. Most of the teachers did not mentioned the unused axis at all. This may be because all of
the other questions did not require to take the unused axis into consideration which means that they never got introduced to it properly which meant that they had not the unused axis in mind.

The colour coding in the tool was based on schools. This makes it easy to compare strategies across different schools. If the user of the tool wants to compare different strategies from one school, the colour coding is of no help since all the lines will have the same colour. The problem could be solved in several ways but the most important thing to think about is what the main reason for the tool is. Is it to compare strategies across schools or is it to compare one school across different strategies? If the main reason is both of them, it can be a good idea to either make a new colour coding when strategies from only one school is visible or let the user choose what to base the colour codes on manually. There needs to be further research done in order to see whether a new colour coding based on strategies will make users confused or not since there are no kind of confirmation done by the user and it can be hard to keep track of the line the user looks at if it suddenly changes colour. If there was an option for the user to change the colour coding manually, it might be a little too much of interactions in order to make the tool good in the perspective of usability since there would be another interaction for the user to have in mind. Since the short-term memory is limited [30], the less the user needs to keep in mind the better.

Instead of just visualise the data that already exists and hope that it can lead to something, it is better to plan what data that needs to be visualised. Then, there are bigger possibilities that the teachers can draw conclusions that can help the students. The choice of data to visualise was chosen together with Kunskapsskolan. In order to make the visualisation as meaningful as possible, it is of importance that the visualised data is well planned and that a thought about what data that should be used. In this case, Kunskapsskolan wants to know what students think about the offered SRL strategies, and therefore they need to have data on what students think about the strategies. The next step is to investigate in how this data can be achieved and if there is a need for additional data (such as which school the student studies at). When that is done, the visualisation can take shape.

As stated, different users tend to use different methods in order to get to the answer. This was made on purpose since the human mind tend to create mental models of how the interaction works. These models can variate and therefore, it is good to not force the user into a specific method. However, it is easier to force the user into one specific method. If a developer chooses to do so, only one method needs to be designed and there is no need to look if different methods interfere with each other, but that might lead to a big change in their mental model, which is something that should be avoided.

6.1 Ethical considerations
The visualization was created based on dummy data, since there are no real data from students yet. If/when the implementation is done, one needs to cautiously proceed with the data since the students are underaged. Data that can be linked to a specific under-aged person is considered to be particularly valuable since they cannot always see the risks of disclosing the data and understand what protection they have right to have [4]. Thus, to collect and show the data to all the teachers, one need to have a consent from parents or collect the data in a way that it cannot be traced to one specific person [4]. Most schools probably already have that consent from parents but a double check on that may have to be done.

6.2 Method critique
If the tests were to be done again, an external mouse would have been brought instead of testing with a trackpad. Both ways have their pros and cons. Testing with trackpad could be a way to ensure that the tool is "trackpad friendly" but since that was not the intention, there would be better with an external mouse if the intention was to get a higher usability score. One could do the tests twice, one time with a trackpad and one time with the external mouse or divide the test participants where one half do the tests with a trackpad and the other half with an external mouse.

As mentioned, the lines on the canvas could not be hovered over to get more information about the specific line. The main reason for that was that the technology used to draw the lines makes every line into one single element. This results in that the data connected to each line is not bound to the data it holds. The reason for using this technology is performance. There are over 2000 lines only in this prototype where every strategy appears one time for each school. If this is going to be implemented, each strategy can possibly appear several times for each school since they can be used in several subjects. If the prototype had lines where a strategy appears two times for each school, there would be nearly 5000 lines, which makes the performance issue even bigger. It is possible to solve by calculating the positions of the lines and compare those with the mouse's position on the screen, but that was not done due to time restrictions. However, it would be very hard, if not impossible, to hover over a specific line in the overview since there are so many of them. One could have set a limit so that when, let us suggest, 100 or less lines are visible, the hover function is enabled. If time had existed, that would have been implemented.

The overview of the visualisation could have been made differently in order to get some kind of information besides the fact that it is a lot of data. One could have created some kind of statistics over every school. An example could be that the visualisation could have shown the total amount of answers for each option and/or show the percentage for each option.

6.3 Future work
This research is limited to the development of a visualization tool for teachers since they have the responsibility to help students and this tool can help them to do so. There is a need to research the area further with more participants to validate this study's results. This would be of interest for the developers that are going to build the real tool in order to see which functions that are necessary to implement and which functions that not need to be implemented.

Another work that could be interesting is to make a visualization tool for students in order for them to get instant feedback on things such as how they have evaluated strategies and how these evaluations corresponds to the grades they get. That may help students to realise that some strategies may be "boring" to use but that they actually help students to complete the work.

For the future, the system described in the earlier work section needs to be implemented in order to get real data and see how the visualization tool forms out. After a while, a pattern amongst the strategies will be seen, e.g. which strategies that are used within each subject and possibly steps and how much data it will be. This is interesting since the data later on can be used to pave way for artificial intelligence to recommend strategies for the students based on a personal level, like Netflix recommends movies based on what has been watched earlier. Such aspects as what strategies they like and how they perform in terms of grades when using a
certain strategy can be examined in the future. If this becomes reality, the ethical considerations must be carefully considered.

6.4 Contribution
This work contributes both to the field of research and practice. The research contribution is how visualization tools for LA can be improved from a usability perspective. The practical is to help teachers understand the use of SRL strategies among students.

7. CONCLUSION
The study aimed to see how learner data can be visualized in order to understand students’ use of learning strategies and how to make the tool usable for teachers. When designing tools with these premises, this study concludes that one needs to take following guidelines into consideration:

1. The more dimensions the data have, the stronger are the arguments to use parallel coordinates as visualization technique.
2. Take trackpads into consideration, there can be issues with dragging elements.
3. Think about how the data will be sorted. If the data is colour coded, consider from which data point the data should be colour coded depending on what the tool is meant to visualize.
4. Try to follow every mental model of how the interaction works, but make sure that different models do not interfere with each other.

More research is required to identify more guidelines and see which functions that are most necessary in a tool like the tool developed in this study to open up for more detailed design guidelines and pave a way towards the next step in the digital area the Swedish school system is facing.

8. REFERENCES
dashboard for feedback to support learning regulation.

*Computers in Human Behavior*


APPENDICES

A: The first view of the strategy recommendation prototype
B: Recommended strategies
C: Strategies added (look to the right and compare to Appendix A)
D: Evaluation view
### Lärostrategier på Kunskapsskolans visualisation overview

Detta verktyg ska du få bekanta dig med. Visualiseringstypen ovan kallas för parallelta koordinater där varje linje motsvarar en specifik strategi för en specifik skola.

#### Interagera med visualiseringen

**Flytta en axel:** Dra i texten ovanför axeln

**Filtrera på värden:** Markera intervall på den axel du vill filtrera

**Ta bort filter på värden:** Klicka på axeln utanför filtreringen

**Filtrera på skolor:** Klicka på skolan i listan

**Filtrera på strategier:** Använd sökkrutans filter

**Ta bort filter:** Klicka på rubriken på det du vill ta bort filter på.

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<th>Kategorier</th>
<th>Ämnen</th>
<th>Strategier</th>
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<td>Matematik</td>
<td>10minutersregeln</td>
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<td>86 Borås</td>
<td>Skriva</td>
<td>Svenska</td>
<td>Anteckna för att minnas bättre</td>
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<tr>
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<td>Vara innovativ</td>
<td>Matematik</td>
<td>Att bredda en diskussion</td>
</tr>
<tr>
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<td>Våga mera</td>
<td>Engelska</td>
<td>Att sammanfatta-skriftligt</td>
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<td>Tyska</td>
<td>Att undvika att bli störd</td>
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<td>Kontrollera dina tankar</td>
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<td>86 Varbergo</td>
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</table>
F: Strategies from only one school is visible
G: The look when an item below the strategy header is hovered on
H: Strategies where 10-16 students have answered “Helpful”
I: Questions asked to the test participants

1. Which strategy/strategies have been most helpful in Linköping?
2. Which school(s) has/ve most strategies where 25-30 students have considered the strategy as unhelpful?
3. How helpful is the strategy “byt format” when students in Täby reads German as a second language?
4. How many strategies have 20 or more students from Lund said that it is unhelpful?
5. Which strategy is most popular in Nacka?
6. At which school is the strategy “kontrollera dina tankar” most unhelpful?
7. How many different strategies in French as a second language have students in Katrineholm evaluated?
J: The canvas when only math strategies in Lund were visible. When answering Q4, there seemed to be no need for the value filter, the vast majority could see the answer from this view.