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The physical classroom environment – roles, conceptions, and preferences

Magnus Fahlström

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Prologue

In the beginning the idea was to measure air quality in classrooms and use student achievement or time on task as response variable. The idea to address air quality originates from my previous experience from working as a teacher of mathematics and computer science in upper secondary school in Sweden. Every now and then, I could experience impaired thinking capacity from declining air quality in the classroom. My students often expressed similar sensations in these situations. Consequently, I started to read literature and reports in the area of indoor air quality, and primarily in school buildings. Quite soon I understood that the air quality consists of several components that by themselves or as a combination affect humans. From that insight it was not far to realize that the physical environment as a whole has to be addressed or controlled if you try to link parts of it to learning outcome, student achievement, or what we want to call it. Now the insights had made this project too big it seemed. That is, if I were to address or control "all" aspects of the physical environment in classrooms. Ok, - is there a single factor that I can do something with instead, I asked myself? I had just moved to the office closest to the copying machine. When people swore at the machine or just closed the paper tray after refill I could not help noticing that these sounds caught my attention. Now a somewhat similar process as the one in the beginning with poor air quality started. Only this time it was noise. Noise is defined as unwanted sound. Ok, so now I started to read research on noise and acoustics in general and in school settings in particular. This might get a bit predictable now and it partly is. Noise and acoustics are also very complex fields and especially when you try to predict the effect on human behaviour. An important discovery was made though. Similarities in circumstances when people get affected or not from noise or poor air quality are greatly dependant on affective aspects. Let's take an example with air quality: If you experienced poor air quality in a room you will be more alert for it the next day in the same room and thereby more likely to be affected just because your senses are calibrated for it. The same goes for noise. For instance, if you are interested in motorbikes and you hear one pass by on the road outside, it is more likely that you pay attention to the appealing sound than a person to whom it was just normal ambient traffic noise. At this point I had some knowledge in two fields and a general idea about where my project was going.

CONTENT

LIST OF PAPERS

This thesis is based on the following papers:

Fahlström, M. (in press). Mathematics teachers' conceptions of the classroom environment. In C. Andrà, D. Brunetto, E. Levenson, & P. Liljedahl (Eds.), *Teaching and learning in math classroom.* Springer.

Fahlström, M. (review process initiated with international journal). Stated Preference Method in School Context - examining usability of conjoint analysis with teachers' stated preferences for the physical classroom environment.

Fahlström, M. & Sumpter, L. (submitted to international journal). The role of the physical environment in mathematics education.

Note: With respect to the agreements made with each publisher, not to publish elsewhere, the papers listed above are not appended to the published online version.

THE PHYSICAL CLASSROOM ENVIRONMENT – ROLES, CONCEPTIONS, AND PREFERENCES

ABSTRACT

The problem addressed in this thesis is that a considerable proportion of students around the world attend school in inadequate facilities, which is detrimental for the students' learning outcome. The overall objective in this thesis is to develop a methodology, with a novel approach to involve teachers, to generate a valuable basis for decisions regarding design and improvement of physical school environment, based on the expressed needs for a specific school, municipality, or district as well as evidence from existing research. Three studies have been conducted to fulfil the objective: (1) a systematic literature review and development of a theoretical model for analysing the role of the physical environment in schools; (2) semi structured interviews with teachers to get their conceptions of the physical school environment; (3) a stated preference study with experimental design as an online survey. Wordings from the transcripts from the interview study were used when designing the survey form. The aim of the stated preference study was to examine the usability of the method when applied in this new context of physical school environment. The result is the methodology with a mixed method chain where the first step involves a broad investigation of the specific circumstances and conceptions for the specific school, municipality, or district. The second step is to use the developed theoretical model and results from the literature study to analyse the results from the first step and transform them in to a format that fits the design of a stated preference study. The final step is a refined version of the procedure of the performed stated preference study.

INTRODUCTION

The problem addressed in this thesis is that a considerable proportion of students around the world attend school in inadequate facilities, and that is detrimental for the students' learning outcome. We live in the physical world. Everything we do take place in a physical environment. Our educational system is predominantly arranged in built school environments. Based on the body of research addressing school facilities and physical environment it is safe to say that the condition and quality of school buildings have a direct effect on the educational outcome (e.g. Earthman, 2004; Higgins, Hall, Wall, Woolner, & McCaughey, 2005). There is also enough evidence to state that the physical environment that students spend a significant part of their life in, trying to learn, is not always adequate and that it is a problem big enough to address (e.g. Earthman, 2004; Higgins et al., 2005). According to a large synthesis study of over 800 meta-analyses, teachers, and most important, how they teach, are one of the most important influences over students' learning in schools (Hattie, 2008). How well teachers can teach is dependant of the status of the teaching facilities and the flexibility and control over the physical settings in the classroom (Uline, Tschannen-Moran, & DeVere Wolsey, 2009). To take it further, Uline, Wolsey, Tschannen-Moran, and Lin (2010), found positive effects from being involved in the process of school renovation, among both teachers and students. This is also supported by other research (e.g. Higgins et al., 2005). As a novel approach to involve teachers to address the problem addressed in this thesis the overall objective is as follows:

Objective and research questions

The overall objective in this thesis is to develop a methodology, with a novel approach to involve teachers, to generate a valuable basis for decisions regarding design and improvement of physical school environment, based on the expressed needs for a specific school, municipality, or district as well as evidence from existing research.

To fulfil this objective three studies have been conducted. The first study is the role study, which has a research question and an aim that addresses: *evidence from existing research,* in the objective above. It is formulated as follows:

- What is the *role* of the physical environment in mathematics education? The second aim of the paper is to build a theoretical model for the analysis of the different roles the educational environment can play in mathematics education.

The second study is the conceptions study, which aims at: *involve teachers* and *expressed needs*, in the overall objective. The research question posed is:

- What factors can be identified and what are their effects, when studying mathematics teachers' *conceptions* of the physical classroom environment's impact on their students' learning in mathematics?

The third study is the preferences study, where the formulations: *generate a valuable basis for decision* and *the novel approach of involving teachers*, are targeted from the overall objective. The objective is:

- The objective of this study is to use previously identified and well established factors to examine the usability of a stated *preference* method. The factors used are: lighting, ventilation, temperature, inner classroom acoustics, external noise proofing, and spaciousness and freedom of movement.

With these three objectives and research questions, the three studies target different parts of the overall objective. Taken together they cover the whole overall objective.

THEORY AND DEFINITIONS

There are two main concepts that have been used in all three studies: *physical environment* and the link between *teaching, learning, and education*. These concepts have been used differently in the three studies, depending on their different objectives. The usage of these concepts and other theories and definitions will be explained in this section in relation to each study.

Physical environment

Physical environment does not have an absolute definition. Physical environment can mean a number of things, such as a sense of place in time and space, as in Tuan (1979), a single factor like air quality, or a few similar basic factors. When addressing the physical school or classroom environment, it has to be defined in each case, as Gump (1978), points out.

In order to answer the research question concerning the role of the physical environment, the concept of physical environment is first problematized in relation to different research in the area. Then, with a start in the general definition from Tuan (1979), physical environment is narrowed down in three ways. The first way is that it is only physical and does not include social climate or other non-physical aspects e.g. discourse. The second delamination is to exclude situations where it is only equal to learning material or manipulatives. This does not exclude situations when the physical environment is used as learning material. The third way is that the focus is in on indoor environment where most of the education takes place. In this study, role is defined as the purpose or influence of someone or something in a particular situation, here mathematics education. Role is considered as an ongoing dynamic process, compared to more definite ones, such as impact.

To fulfil the objective of the second study, the conceptions study, a broad and inclusive definition of the concept physical environment is used. In contrast to the first study where the definition excluded possible aspects of the concept, the definition used in this study aims to capture anything the concept might encompass. In this study, the physical environment includes any object or sensation related to something in the physical world found in the teachers' conceptions. This is combined with the wide definition of conception: "a general notion or mental structure encompassing beliefs, meanings, concepts, propositions, rules, mental images, and preferences" (Philipp, 2007, p. 259). With these broad definitions there are no distinctions made between strong beliefs or weak attitudes expressed by the teachers.

In the preference study, the third study, a very specific definition is applied. Physical aspects of fictive classrooms are described with qualitative levels from the six factors: *lighting, ventilation, temperature, inner classroom acoustics, external noise proofing, and spaciousness and freedom of movement*. These factors are chosen for their known importance so that the objective of testing the usability of the method can be reached. The concept preference is connected to *stated preference theory* which relates to properties of things, such as value or utility. This means that, to state preference, is to elicit perceived value or utility for some entity (Louviere, Hensher, & Swait, 2000). Unlike the definition of conception above, where preferences are included, this definition explicitly targets the expressed value or utility. In the overall objective, and implicitly in the objective of the preference study, the aim as to obtain a base for decision. The circumstance for that decision base is as in *basic economic theory*, where the work of Marshall (1920) is a cornerstone. The assumption is that decisions are made to optimize utility or value under the condition of limited resources.

Teaching, learning, and education

The link between teaching, learning, and education is not obvious and varies depending of theoretical view point. That is why it has to be stated. In the first study, the role of the physical environment in mathematics education is analysed. For that purpose and to build the theoretical model, a clear and established definition of mathematics education, was needed. From the work about milieu by Chevallard and Brousseau the concept of a learning situation, a didactical situation, is used (see Schoenfeld, 2012). The didactical situation has three actors: student/learner, teacher, and content. In this case content is

mathematics, which means that mathematics education is defined as the didactic situation with student, teacher, and mathematical content as actors.

In the conceptions study the objective was to find factors and effects in mathematics teachers' conceptions of the physical environment's impact on their students' chances for learning. For that objective, and as inclusive as the rest of the study, an open-minded definition of the concept learning is used, despite its complex nature. Learning here is considered to be the intended outcome of the activities the teachers engage their students in. These activities are considered to be conscious decisions made by the teachers though, which can be linked to the basic assumptions, as in Marshall (1920), about how decisions are made.

To fulfil the objective in the preference study, teachers give a rating of their perceived adequacy for teaching or teaching utility for a set of fictive classrooms. In analogy with the conceptions study, it is left to teachers to decide what teaching means to them, when adequacy for teaching, i.e. teaching utility, is to be rated.

METHODOLOGY

Data collection

To answer the research question of the role played by the physical environment in the first study, a structured literature search was performed with the search words: 'physical', 'environment', and 'mathematics' (or math or maths). The data were peer-reviewed journal articles from the ERIC database, May 2015. After the search, a first elimination was done by reading abstracts and exclude hits that did not concern physical environment or mathematics education as defined in this study. This resulted in 14 remaining articles. As a second step the whole articles were read, which resulted in another eight that could be identified as not relevant for the study. These eight could not be removed based only on the information in the abstracts, for instance one of the papers contained physical environment in the abstract, but nowhere else in the paper. The findings in the six remaining articles constitutes the data to be analysed with the developed model.

In the second study, semi structured interviews were performed to answer the question of factors and their effects in teachers' conceptions. To fulfil the objective, it was important to get teachers' own words of teaching situations where the physical environment played a part. With the wide definition of conceptions in mind the choice of semi structured interviews seemed natural in that sense that structured interviews might miss important aspects and unstructured interviews might wander away from the subject of physical environment entirely (cf. Bryman, 2015). In the interviews the teachers were asked to tell about specific situations in relation to disturbance or distraction, a question aiming to produce narratives related to the objective of the study. To balance the questions about disturbance or distractions, the teachers were also asked to tell about successful teaching situations where there was no disturbance or distraction. Besides balancing, the reason for this is that other factors and effects may arise in conceptions of non-disturbing/-distracting situations compared to the first phase concerning disturbance/distraction. The participating teachers were purposely sampled to cover different student age levels. The teachers who agreed to participate during the data collection period of this study all came from small or middle sized towns in the middle parts of Sweden. The participating teachers taught students in the age interval from 10 to 19 years. The interviews took place in neutral places at convenience for the interviewees.

To be able to achieve the objective of the third study and determine the usability of conjoint analysis the procedure was applied as an online survey. In this study teachers rate profiles, fictive classrooms, on a scale from 1 to 5 for their perceived adequacy for teaching, i.e. teaching utility. The driving force in conjoint analysis is that the rater, evaluator, has to make tradeoffs between competing qualitative levels for the different factors. The data collected is interval data at the respondent level since there is no natural zero point in this case. The development of the level descriptions and the survey form was done in an iterative process where different approaches were tried before reaching the final solution, which

was an orthogonal design with eight profiles, i.e. fictive classrooms. Orthogonal design meaning the correlation matrix for the profiles is the unity matrix and that there are no correlations between the factors built in to the design pre survey. In Table 1 the level descriptions for the first profile can be seen. The descriptions for current level are in bold font.

	Level 1	**Level 2**
Lighting	Only fluorescent lights in the ceiling, no directed board lighting, varied daylight	**Fluorescent lights in the ceiling, directed board lighting and glare free daylight**
Ventilation	**Non satisfactory at full occupancy**	Satisfactory - good air quality even at full occupancy whole day
Temperature	Uneven - weather dependent	**Smooth - for classroom individually controlled temperature**
Inner classroom acoustics	**Non satisfactory - noise escalate in group discussions**	Satisfactory - the noise level is pleasant even in group discussions
External noise proofing	**External noise, such as from the corridor or outdoors, often interfere**	External noise seldom or never interferes
Spaciousness and freedom of movement	**Limited - cannot freely reach all students**	Good - can easily reach all students

Table 1. Level descriptions for profile 1

The participating teachers came from 6 out of 29 randomly selected Swedish municipalities. The survey was completed by 47 teachers, representing the major teaching subjects and student ages from 7 to 16 years. Their teaching experience ranged from less than 1 year to more than 40 years. Considering the variation among the teachers it is argued that the objective can be fulfilled despite the low participation rate. The argument is that the possible bias from the teachers representing a specific sub category of teachers with specific preferences for the physical environment is avoided with this variation. A link to the online survey was distributed in the participating municipalities via their internal e-mail or message systems. A follow letter giving a description of the survey and information about voluntary participation together with an instruction how to fill in the form was also distributed with the link. The survey lasted from December 2015 throughout January 2016.

The choice of these different methods for collecting data in the three studies have been steered by the different objectives and research questions. This have resulted in three different types of data.

Data analysis

Since the three studies had different types of data, three different types of methods for analysis were needed. In the first study the ambition was to reach beyond a summary of findings. The concept of role is closely related to actors. No theory where the physical environment was considered as an actor was found. Consequently, a theoretical model for the analysis was developed, describing the different actors and relations between these actors in a didactical situation. The model is based on the didactic triangle and inspired by others who have expanded the didactic triangle (e.g. Rezat & Sträßer 2012). The physical environment was added as an actor in the didactic situation described by the didactic triangle (see Figure 1).

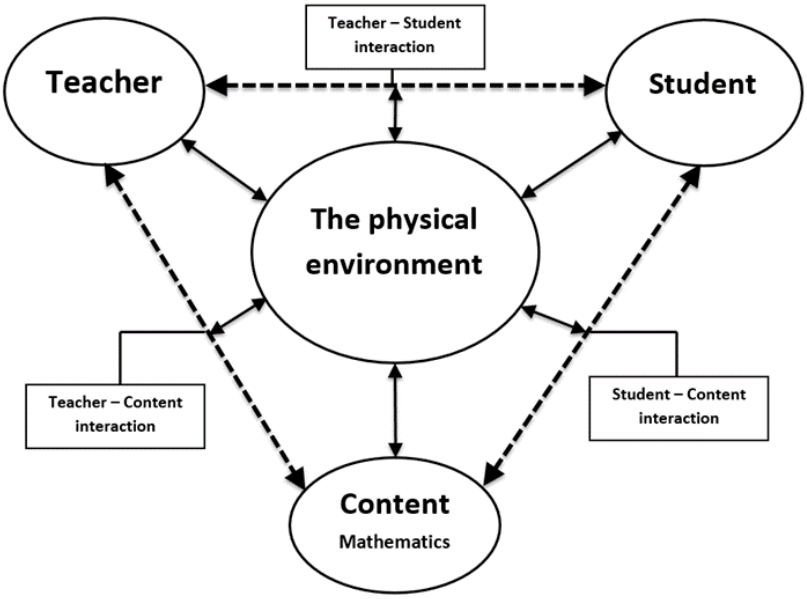

Figure 1: model of the physical environment in a didactical situation

There are six interactions that the physical environment in the model can have: with the teacher, the student, and the content together with the interactions between them: student – teacher, teacher – content, and student – content, where the physical environment can play a role in the model (marked with solid arrows in Figure 1). The result sections of the selected articles were then analysed with respect to these six interactions in the model. In the first phase, the interactions were identified and coded with one of the interactions. In the second phase of the analysis, the direction of each interaction were analysed, i.e. determine if the attention of the interaction is to or from the physical environment. The results were structured in one table for each interaction, divided in two parts, depending on direction of attention.

Before the analysis in the second study could be carried out the interview recordings were transcribed verbatim. The analysis was done in three steps. The first step consisted of several read thru and coding of keywords related to the physical environment as defined for this study, i.e. any object or sensation related to something in the physical world. This first step can be seen as directed content analysis, as in Hsieh and Shannon (2005), where the coding is based on prior theory or definitions. The second step was narrative analysis were the sections around the coding from the first step were analysed looking for stories, as in Andrews, Squire, and Tombouko (2008), of cause and effect. For instance, the factor poor acoustics, has the effect of disturbing noise. The third step consisted of data driven conventional content analysis, where the results from the different transcripts were grouped in themes (Hsieh & Shannon, 2005). These themes then became the structure of the result section.

In the third study the collected interval data from the teachers' stated preferences for the presented fictive classrooms were analysed. The main part of the analysis was done using the Conjoint() function in the Conjoint R-package by (Bak & Bartlomowicz, 2012). The model used with dummy variables can be expressed as:

$$U_s = b_{0s} + b_{1s}X_{1s} + b_{2s}X_{2s} + b_{3s}X_{3s} + b_{4s}X_{4s} + b_{5s}X_{5s} + b_{6s}X_{6s}$$

Where U_s represents total utilities stated by respondent number *s*, $b_{0s}$the intercept for respondent *s*, $b_{1s}, \dots, b_{6s}$ the parameters of the regression model which are the part-worth utilities for each factor for respondent *s*, and $X_{1s}, \dots, X_{6s}$ are the so called dummy variables for respondent *s*. The output from running the Conjoint() function on a sample in R consists of intercept and coefficient means, standard errors, t-values, p-values, and significance codes. The output also contains residual standard error, R-squared, adjusted R-squared, F-statistics, and degrees of freedom. The manual analysis conducted was to interpret this output in relation to the objective of the study, i.e. did the coefficients representing the

factors chosen for their importance turn out significantly non-zero? The argument for this is that if a quantified factor turns out zero it means that it is not important. In this case, where the factors are to be significantly non-zero, this means that the probability that a factor is zero anyway is very small.

Ethical considerations

The approach and treatment of persons and organizations was done so that they can stay anonymous and participate voluntary. That means no naming of municipalities, single schools, places, or persons in my writing or presentation. This sometimes meant removing information that could lead to identification. There have been only adult participants in the studies. It should be noted that in the interview study the possibility of receiving information about under aged persons had to be considered and prepared for. In all contact with respondents, care was taken to inform and remind of the possibility to "un participate" at any time. When recruiting participants, I actively chose to not contact people I knew personally or from work in order to avoid conflicts of interest.

When data collections were closed the ethical awareness concerned staying true to data, procedures, and references. This means no inappropriate tidying of data, describe procedures and actions when transforming and analyzing the data correct and as detailed as possible. This last effort also depends on my capability to do so, but has meant doing it as well as my capacity allows. The last item in this section about staying true to references, means reading the original source and not rely on someone else citing them and read properly and not only the parts that suits the point to be made. When it came to presenting results from the interviews, care had to be taken so that no one was shown in a bad light, but still stay true to the data and procedure of analysis.

RESULTS

The results will be presented for each study and then summarized in relation to the overall objective.

The roles of the physical environment

The question posed was: What is the role of the physical environment in mathematics education? It turns out that the physical environment can play several roles in mathematics education. That was realized early in this study and that is why the theoretical model for the analysis was developed. A summary with representative examples from the results of the analysis can be seen in Table 2 below.

Direction of attention and interaction	**Examples of roles played by the physical environment and connotations attached**
Towards teacher	Secure in - positive Restricted by – negative Inspired by - motivational
From teacher	Pride of – positive Command over - influence
Towards student	Freedom to move about – positive Claustrophobic - negative
From student	Belonging to – positive Adapt to - negative
Towards content	Vertical writing surface – designated to
From content	Scale – represented by
Towards student-teacher	Mediating, enhancing – positive Preparing - neutral Obstructing, limiting - negative
From student-teacher	Violation of [physical] personal space - negative
Towards student-content	Become the content, affect time on task
From student-content	Display student work – designated to
Towards teacher-content	Increase cognitive demand – negative

	Affect hearing or view – positive or negative
From teacher-content	Be considered when teachers plan – setting the frame

Table 2. Representative examples of the roles played by the physical environment

As seen in Table 2, the roles of the physical environment have shared characteristics in the interactions with: teachers, students, student-teacher, student-content, and teacher content. These characteristics can be summarized as affecting the conditions for the interactions in a positive or negative way with emotional or motivational associations. Depending on the direction of attention the roles have different time character. In the direction towards other interactions the roles are active *during* the interactions. When the direction is from the interactions the time characters are different for the different interactions. For teacher-content interaction there is a *pre* character, mainly when teachers plan for their teaching. For student-content interaction the roles of the physical environment have a *post* character, mostly in displaying student work. The roles in relation to content is neutral, with no emotional associations, and have an *ongoing* or *during* time character in both directions of attention.

Teachers' conceptions of the physical environment

The research question asked for factors and their effects in teacher's conceptions. The results are arranged in the themes: mathematical activity, internal factors, and external factors. The results are summarized in Table 3.

Theme	**Factor**	**Effect**
Mathematical activity	Poor acoustics	Disturbing external noise when the mathematical activity is performed in silence and disturbing internal noise when the mathematical activity is the primary sound source
	Tidiness	Calming
	Messy	Disturbing
	Poor lighting	Impaired vision
	Good layout of front of classroom	Aiding teachers and students
Internal factors	Poor acoustics	Disturbing related to activity outside the classroom
	Generous classroom size	Flexibility and control over seating, activity, and movement in the classroom
	Cramped classroom size	Restricted movement, seating flexibility, and activity alternatives, together with risk for poor air quality.
	Daylight	Overall positive effect
	Ergonomic furniture	Minimizing discomfort
External factors	School location	Determines amount of external sound proofing
	Visual distraction	Need for privacy window tints
	Direct sunlight	Blinding light – need for sun protective films on the windows
	Sun heat radiation	Uncomfortable temperature raise

Table 3. Summary of factors and their effects grouped in themes

As seen in Table 3 above there are several factors that have both positive and negative effects depending on the quality of the factor. The type of mathematical activity is important. If it consists of communicative interactions there are different issues compared to silent individual activities. Some factors are also connected so that they affect each other such as school location that can have visual distraction as an effect which in itself is a factor.

Teachers' stated preferences for the physical environment

The objective with this study was to examine the usability of conjoint analysis of teachers' stated preferences for the physical classroom environment. Previously identified and well established factors were chosen for their known importance so that the usability can be tested. Results from running the Conjoint() function on the full sample in R can be seen in Table 4.

Coefficients:	**Estimate**	**SE**	**t-value**	**Pr(>|t|)**
(Intercept)	2.47074	0.04153	59.487	< 2e-16 ***
factor(x$lighting)	-0.24734	0.04153	-5.955	6.06e-09 ***
factor(x$ventilation)	-0.26330	0.04153	-6.339	6.74e-10 ***
factor(x$temperature)	-0.19415	0.04153	-4.674	4.14e-06 ***
factor(x$inner.acoustics)	-0.36968	0.04153	-8.901	< 2e-16 ***
factor(x$ext..noise.proof.)	-0.26330	0.04153	-6.339	6.74e-10 ***
factor(x$space.and.movement)	-0.34840	0.04153	-8.388	1.06e-15 ***
Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Residual standard error: 0.8054 on 369 degrees of freedom				
Multiple R-squared: 0.4377, Adjusted R-squared: 0.4286				
F-statistic: 47.88 on 6 and 369 DF, p-value: < 2.2e-16				

Table 4. *Results from running Conjoint() function in R*

To conclude the output, the intercept is 2.47 which is the overall mean rating given for all eight profiles by the 47 responding teachers on the 1 to 5 scale. The teaching utility value for the factors are: lighting 0.25, ventilation 0.26, temperature 0.19, inner classroom acoustics 0.37, external noise proofing 0.26, and spaciousness and freedom of movement 0.35. The produced standard error for all coefficients is 0.04. Since there were only two levels for each factor the level utilities are either positive or negative. All factors are significant at the highest level with regards to them being non-zero. This can be rephrased so that the probability that the factors found here are zero, and thereby not important in the end, is less than 0.001.

Summary

The results from the three studies aimed at covering different parts of the overall objective. The results from the first study shows that there is evidence from existing research that the physical environment plays a role in all interactions defined in the theoretical model developed. These roles often have a positive or negative connotation, such as hindering or enabling. In the second study teachers were involved and told stories of teaching situations related to the physical environment. In these stories, where the teachers' conceptions of factors and their effects emerged from the analysis, specific needs

where expressed. These effects were either positive or negative depending of the qualitative level of the factors. In the third study the results showed that the chosen factors and the attached qualitative level descriptions made the factors turn out significant. If the qualitative level was poor the coefficient for that factor was negative and vice versa. This third study addresses novel approach in the use of a stated preference study and valuable basis for decision.

DISCUSSION

The overall objective in this thesis was to develop a methodology, which involves teachers with a novel approach, to generate a valuable basis for decisions regarding design and improvement of physical school environment based on the needs for a specific school, municipality, or district together with evidence from existing research. In essence, the results of the three studies contributes to the overall objective, as follows: The driving force of the method in the third study are the trade-offs that have to be made by the teachers when they rate the fictive classrooms. The fact that the factors turned out significant indicate that the qualitative level descriptions in the survey form where realistic with distinct differences. These qualitative level descriptions originate from the second study and have been transformed and chosen with knowledge of existing research to fit the design of the third study. These results and the methodological experiences gained from obtaining them, leads to a proposition of a methodology that satisfies the overall objective.

The proposed methodology

The proposed methodology is a chain of mixed methods, where the first step involves a broad investigation of the specific circumstances and conceptions for the specific school, municipality, or district. From the interview procedure and the results in the conceptions study, it is concluded that semi structured interviews are a good start in getting rich and nuanced descriptions of the case at hand. From the role study it is learnt that this first step can be enhanced by including the knowledge from developing and using the theoretical model together with the roles present in the results of the analysis. The enhancement is to get more aspects out of the interviews by addressing all interactions and use the knowledge from the results when posing follow up questions during the interviews. Interviews will be performed with teachers representing all major teaching subjects.

The second step in the proposed method is to analyse the results from the first step and transform them in to a format that fits the design of conjoint analysis. This means identifying clear factors and qualitative level descriptions of these factors. From the work done in this thesis with using authentic level descriptions from the conceptions study in the development of the survey form in the preferences study it is concluded that it is a fruitful procedure. However, it has to be enhanced by identifying more than two qualitative levels for the factors. To accomplish that, the results and the model from the roles study can be used. For instance, by considering direction of attention for diversification. At this stage local constraints and legal regulations have to be considered so that no alternatives are illegal or dangerous (cf. Earthman, 2004).

The third step consists of deploying the stated preference investigation with conjoint analysis experimental design. Some of the aspects learnt from conducting the preferences study are addressed in the previous step. One important quality to improve over the conducted procedure in the preferences study is the final analysis. The standard error for each coefficient has to be calculated. In the alluded scenario background factors, such as teaching subject and student age, will be included in the regression model.

To formulate the methodology on a more general level, the target is to quantify teaching utility, stated by teachers, as a basis for decision. The process starts with a broad investigation of specific circumstances, based on evidence from existing research of the physical environment. By analysing and transforming the results from the broad investigation, diverse descriptions of qualitative levels for factors in the physical environment can be obtained. These diverse descriptions are then combined, or conjoined, to generate fictive, but realistic, classroom descriptions that teachers rate for teaching utility.

In the rating process, teachers have to make trade-offs between competing preferences, which allows for the targeted quantification.

Implications

This methodology can be used in a single school to generate a basis for decisions regarding aspect the physical environment within existing budget or in a district or municipality in a larger project with extra funding. The benefit from using this methodology is the focus on teaching utility expressed by teachers who are the ones to carry out the teaching. With the assumption that teaching utility leads to the desired educational outcome, this methodology is beneficial for students, teachers, and society in general.

Limitations

Something that is not addressed in this thesis, is that students can of course be involved in a similar way as teachers are involved and that would probably be fruitful (Higgins et al., 2005; Uline et al., 2010). Another limitation is that two out of the three studies have focused on mathematics education. Distinctions between conclusions regarding mathematics education and education in general are not clear. The overall objective aims to address all major teaching subjects in the future case. Further issues are that in the first study, no synonyms to the search words were used other than, math and maths for mathematics, which could have generated more hits. In the second and third study the participation rates are quite low, 7 and 47 respective, which makes general conclusions uncertain. The finial limitation addressed is my personal bias. I am aware of that I am a mathematics teacher and teacher educator which gives me a pre conception of the language used and issues studied. This could be a benefit when analyzing statements from teachers, students, or other stakeholders because it gives a deeper understanding of phenomena. At the same time this can be a bias in the way that things get over interpreted.

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