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PLSpath Modelling of Various Factors' Influence on Students' Knowledge of Informatics

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Abstract. The article presents results of the national survey on teaching and studying informatics at Grades 11 and 12 in the Lithuanian secondary school. This study explores the influence of different factors on students' achievements in informatics. The purpose of this work is to study the interaction between various characteristics of student, teacher and school, and factors of studying and teaching informatics and their joint influence on students' achievements in informatics. In addition, the article explores and contrasts the casual influence structures on the students' knowledge of two different branches of informatics: computer application and programming. To explore these interrelations, PLSpath analytic procedure has been used.

Key words: structural equation modelling, PLSpath analysis, knowledge of informatics, secondary education.

1. Introduction

Several reasons inspired investigation of various factors' influence on student's knowledge of informatics. (1) Different aspects of information technology implementation into comprehensive education have been extensively examined during the past three decades. However, teaching and learning the subject of informatics and student's knowledge of informatics (especially programming) has been little investigated. Thus, the lack of research on teaching and studying of informatics in a comprehensive school was the first stimulus for this study. (2) Nowadays the learning process is perceived as a complex phenomenon and the effectiveness of education depends on various factors and their interaction. Recently the focus of studies shifted from the narrow investigation of isolated factors to the extensive exploration of a whole complex of factors of learning environment. The review of previous research reveals a big gap between research aims and methods. Simple univariate and bivariate statistical techniques are usually applied for the investigation of casual relations between different factors in most studies. The number of educational studies which employ more advanced statistical techniques and explores causal relations between many factors is too small. The inadequacy of contemporary research aims and methods was the second rationale for conducting this multivariate analysis.

2. Structure of Survey and Data Analysis

Data of the national survey "Computers in Lithuanian Schools" were employed to investigate students' knowledge of informatics in the secondary school in Lithuania. This survey was conducted in the academic year of 1996–1997. Instrumentation of this survey was adapted from the IEA international study "Computers in Education" (see Pelgrum *et al.*, 1993; Markauskaitė, 1997). The survey was targeted at the investigation of various aspects of computer use in schools, assessment of students' informatics knowledge, their background characteristics and attitudes, collection of data on teaching the subject of informatics. The survey was conducted in two stages.

Target population of the first stage (school survey) were secondary (i.e., upper comprehensive) schools. All secondary schools, except art gymnasia and boarding schools, were invited to participate. The completed questionnaires were received from 73.4% of respondents. According to international criteria (Pelgrum *et al.*, 1999) the achieved response rate is sufficient and the data collected in the school survey can be generalised for the target population.

Target population of the second stage (classroom survey) were students of Grades 11 and 12. Students and their teachers of informatics were surveyed. The sample was taken from those secondary schools where the language of instruction was Lithuanian. Students were obliged to perform computer application and programming tests and answer questions about themselves. Teachers were asked to complete the questionnaire on teaching informatics in the target class and to provide information on their personal background and characteristics.

Complex sampling design was applied to the classroom survey. The sample was stratified (stratification was based on the school type and availability of IBM-type computers) and clustered (all students from the sampled classes were surveyed). Two-stage sampling was used (at the first stage schools and at the second classes were selected). The selection procedure applied at the first stage was proportional to the population size (PPS). In total, one Grade 11 and one Grade 12 from 201 schools were included in the sample. The majority (97.5%) of selected classes participated in the survey, and more than 85% of sampled students (6 975) completed questionnaires. The weights have been calculated in accordance with the sample design. Therefore, the results can be generalised to the target population (i.e., Grade 11 and 12 students who attended schools with the Lithuanian language of instruction). All the analyses reported below are weighed in accordance with this sample design.

The students performed computer application and programming tests. The percentage scores for these two tests separately and the joint score have been calculated. The average students' score in the computer application test for the total sample was 66%, in programming test: 42%, and the joint score in informatics was 55%. To determine the quality of computer application and the programming tests, reliability analysis has been carried out. Reliability coefficients for both tests (71 items), computer application test (38 items) and programming test (33 items) were sufficiently high (0.94, 0.85, and 0.85, respectively) and acceptable for the analysis purposes (Thorndike, 1992). The score in the computer application test assesses students' ICT functionality (further: computer application knowledge), the programming test evaluates their algorithmization and problem solving abilities (further: programming knowledge), and the joint score indicates a general competence in the field of informatics (further: informatics knowledge).

This article analyses the survey data on different student's, teacher's and school characteristics and studying of informatics. The study focuses on the investigation of casual relations between different factors (and indicators) and students' knowledge of informatics, computer application and programming.

3. Hypothetical Model of Students' Informatics Knowledge Dependency upon Various Factors

To conceptualise the factors which might influence on students achievements in informatics and how they are interrelated among themselves, a hypothetical model of dependency of students informatics knowledge upon various factors has been developed. On the one hand, teaching and studying informatics, like any other school subject, has similar features. Thus, students' knowledge of informatics could depend upon the same factors as knowledge of other subjects. On the other hand, information and communication technology (ICT) is the object of informatics subject, and its teaching is inconceivable without computers. Therefore, the efficiency of teaching and students' knowledge of informatics could be influenced by factors, which determine the efficiency of ICT implementation. In view of this, the research literature on both teaching informatics and implementing ICT has been analysed. On the grounds of this analysis, the main factors were picked out and the hypothetical model of dependency of students' informatics knowledge upon different factors has been constructed (see Fig. 1) having generalized theoretical models proposed

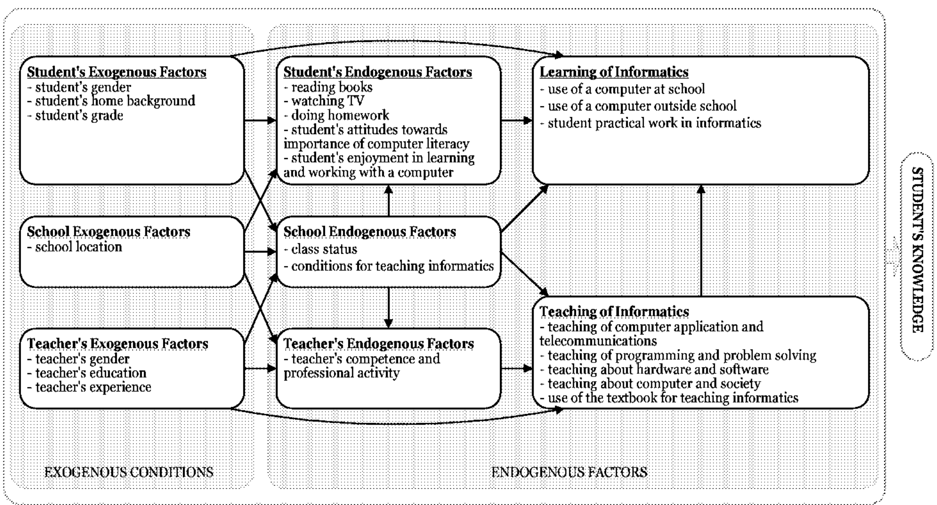

Fig. 1. Hypothetical model of students' informatics knowledge dependence upon various factors.

in various related studies (Cheung, 1993; Janssen Reinen, 1996; Scheerens *et al.*, 1997; Tujinman *et al.*, 1993).

The system of education can be decomposed into hierarchical levels (e.g., school, teacher, and student). According to the stability, the factors at each level may be grouped into exogenous (that cannot be influenced by various change activities) and endogenous (that can be influenced and changed). Casual paths in the hypothetical model are based on two general assumptions: (1) the exogenous conditions may directly or indirectly influence the endogenous factors, but the endogenous factors cannot affect the exogenous conditions; (2) all higher levels of educational system can influence the lower levels but not vice versa. The review of literature on the educational reform in Lithuania confirms that the latter precondition corresponds to the structure of comprehensive education and meets the nature of educational reform in the country (Želvys, 1999). The structure of the model was influenced to some extent by the amount of available information in the survey database since it was considered irrational to hypothesise relations that cannot be explored due to a lack of data.

4. Explanation of PLSpath

In order to explore casual relations among the set of different factors and to find out how these factors influence on the students' results directly and indirectly (via other factors), the PLSpath analytic procedure has been applied.

PLSpath is a "prediction-oriented" structural equation modelling technique for analysing multivariate relationships among sets of factors. It estimates path models involving latent constructs and multiple indicators using the Partial Least Squares (PLS) technique developed by H. Wold (see Noonan *et al.*, 1988; Sellin, 1990; 1992).

PLSpath models involve observed and unobserved or latent variables. The PLSpath model is formally defined by two sets of linear equations: inner and outer model. The outer model specifies relations between the observed variables (indicators) and the latent variables (constructs or factors). The inner model specifies the structure of hypothesised relationships among the latent variables. Basic PLSpath designs assume recursive inner structures (i.e., casual influences are assumed to be one-direction). Exogenous and endogenous variables are used in the inner model. An exogenous variable is a predetermined variable the causes of which remain unexplained, unanalysed and outside the scope of a model. An endogenous variable is a variable the variation causes of which are represented in the model.

The model is tested to determinate the extent to which it accounts for the covariation between the observed measures. The least squares regression procedures are used to maximise the explained variance. The PLSpath estimation of latent variables, the inner model coefficients and other model parameters is carried out in two basic steps. The first step involves the iterative estimation of latent variables as linear composites of their associated observed variables. The estimation of the weights defining estimates of latent variables could be done by means of factor or regression analysis. Distinction between these two estimation modes corresponds with the differentiation between formative and reflective indicators. Formative indicators are assumed to "produce" a latent factor; whereas reflective indicators are assumed to "reflect" a latent construct.

The second step involves the non-iterative estimation of inner and outer model coefficients. These coefficients are estimated by means of least squares methods. As the procedure aims at optimal least squares prediction of latent and observed endogenous variables, the PLS technique is characterised as "prediction- oriented" approach.

In this study the preference was given to PLSpath over the other better known structural equation modelling techniques (e.g., LISREL, EQS) due to several reasons. (1) A lot of dichotomous and ordinal variables are used in the survey. PLSpath employs the least squares method to obtain parameter estimates and, as a consequence, only minimal demands in measurement scales and residual distributions are required (Sellin, 1990). (2) This study was conducted and the hypothetical model was developed *post hoc*, thus philosophical considerations and the nature of the analysis prompted to apply exploratory (prediction-oriented) rather than confirmatory (theory testing) methods of structural equation modelling (Chin, 1997).

5. Model Construction

The PLSpath program (Sellin, 1989; 1990) was employed for modelling. Since this software is designated for only random samples, additional manipulations have been done to accommodate parameter estimation procedures to the complex design of the survey sample. In this study, all PLSpath estimations were adapted for the complex design of the survey sample. The jackknife procedure was used to estimate standard errors of path coefficients. VesWarPC (Brick *et al.*, 1997) software package has been used to obtain these estimates.

To investigate casual relations between various factors and students' knowledge of informatics, the data collected in the classroom survey have been used (i.e., variables included in the model come from students and informatics teachers questionnaires). Data were obtained from 6 975 students and 394 teachers. These two databases were combined together and record of each student was supplemented with information from teachers' database. The combined database included 510 (7.3%) records with missing information from teachers' database. PLSpath program allows of no missing values. For that reason, the cases with missing teacher's information were removed from the data set. Other missing values in the database were replaced by the median values of the class (for students' data) or region (for teachers' data). Thus, the database used for the investigation included 6 465 records.

At the beginning of the analysis, all variables that might conceptually characterise any factor, included into the hypothetical model, were selected. The first step was to cluster conceptually similar measures into constructs and to reduce the quantity of data. The variables grouped into disjointing clusters by their meaning and using factor and scale analyses. Each cluster formed a separate construct and manifested a different factor.

In some cases a construct was comprised of only one indicator (e.g., student's gender), in other cases – of several (2–12) variables (e.g., construct "student practical work in informatics" was made up of two indicators: the number of developed programs and the number of other practical tasks done by a computer). In total 24 constructs were made up of 89 indicators. An overview of all variables included in the analyses is given in Appendix 1.

The second step was taken to simplify the modelling and reduce the quantity of constructs. The correlation of each indicator with scores of informatics was calculated. Where correlation of all indicators was insignificant (level of significance: 0.01), these constructs were no longer considered. According to this criterion, 4 constructs (i.e., school location, doing homework, teaching about hardware and software, teaching about computer and society) were excluded. In addition, construct on teacher's education was eliminated from the analysis as almost all teachers (96%) had university education. Finally, the construct on reading books was excluded as the t-test and correlation analysis of associated indicators provided inconsistent and irregular results on the relation between the students' score and the number of books read.

From the rest 18 constructs (formed from 76 indicators) using the PLSpath analytic procedure, the model of student's knowledge of informatics was constructed. The 'reflective' approach was chosen for defining estimates of latent variables. Preference was given to the factor estimation mode rather than regression estimation mode in order to avoid possible influence of multicollinearity of indicators, to maximise the reliability of the construct and to increase the validity of latent variables.

The point of departure for the investigation of casual relationships between factors was the correlation matrix of latent variables. To obtain initial estimates of inner and outer model coefficients and to calculate the correlation of latent variables, the starting inner model was defined by one equation: the student's score of informatics was specified as the dependent variable and all other factors were independent variables. Then on the basis of initial correlation matrix (see Appendix 2), possible significant interrelations between latent variables were determined and described by a set of equations (see Appendix 3). The expected directions of relations between latent variables were derived from the hypothetical model. Some significant correlations between latent variables were not described in the inner model due to low semantic feasibility of causal relationships between these factors (e.g., correlation between watching TV and teacher's experience).

Three criteria were applied to the inner modifications subsequently. Certain paths were considered for removal if: (a) signs of the path coefficient and the correlation between two latent constructs were contrasting; (b) path coefficients were insignificant at 5% level of significance; (c) path coefficients were insignificant at 1% level of significance. Changes in the inner structure after each step are marked by a respective letter (see Appendix 3). Fig. 2 presents the main results of the modelling (see Appendix 4 for direct, indirect and total effect of latent variables. Due to big extent and complexity of the outer structure, the detailed information on the outer model is not provided here).

To explore direct and indirect influence of factors on students' knowledge of different informatics branches, following the same PLSpath analytic procedure, special models for students' knowledge of computer application and programming have been constructed. The final PLSpath models for the students' knowledge of computer application and the programming are presented on Fig. 3 and 4.

6. PLSpath Model for Students' Knowledge of Informatics

The PLSpath analysis accounted for 22% of students' informatics score variance (Fig. 2). Total influence (direct and indirect) of the following constructs was the greatest: the class status (on average, students from gymnasia schools, gymnasia, exact and natural types of class were scored higher than the rest of their coevals), student's gender (boys achieved higher results than girls), student's home background (a higher academic level of home background resulted in higher students' scores in informatics), student's enjoyment in learning and working with a computer (students' enjoyment and interest in computers had positive influence on their knowledge of informatics). Each of these constructs explained 2–6% of variance of the informatics score. Eight constructs exerted direct effect on students' achievements. Direct influence of class status, student's practical work in informatics, teaching computer application and telecommunication, teaching programming and problem solving, and student's enjoyment in studying and working with a computer

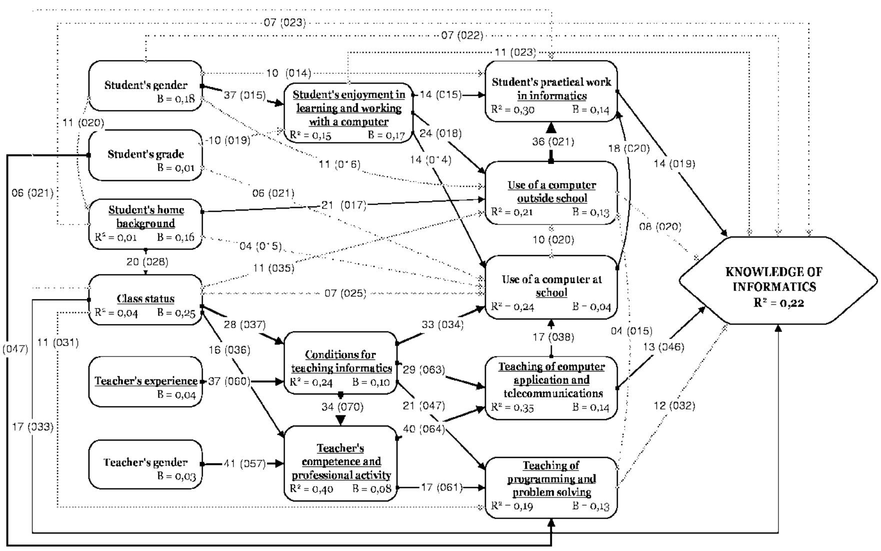

Fig. 2. PLSpath model for students' knowledge of informatics.

Notes: (1) R^2 – proportion of explained variance of a latent variable; (2) B – total effect (direct and indirect) of a latent variable on students' knowledge of informatics; (3) Underlined latent variables are composed of several observed variables, non-underlined are composed of a single observed variable; (4) significant paths are represented by arrows, path coefficients (multiplied by 100) and jackknife standard errors (multiplied by 1000).

was most notable. Student's gender and conditions for teaching informatics had the most considerable indirect effect on students' knowledge of informatics.

7. PLSpath Model for Students' Knowledge of Computer Application

The PLSpath analysis accounted for 20% of students' computer application score variance (Fig. 3). The following constructs affected on computer application knowledge most: student's gender (boys scored higher in computer application than girls), teacher's competence and professional activity (those students, whose teachers are more competent in informatics and pay more attention to their own professional improvement, scored higher in computer application), class status (students from gymnasia schools, gymnasia, exact and natural type of class scored, on the average, higher than the rest of their coevals); student's enjoyment in learning and working with a computer (students enjoyment and interest in computers had positive influence on their knowledge of informatics). Each of the enumerated constructs elucidated 3–4% of the total variance of the computer application score. Eight constructs had significant direct influence on the students' computer application score. Teacher's competence and professional activity, student's enjoyment in learning and working with a computer, student's gender, and class status exerted the most significant direct influence. Student's gender and conditions for teaching informatics had the most significant indirect influence on the computer application score.

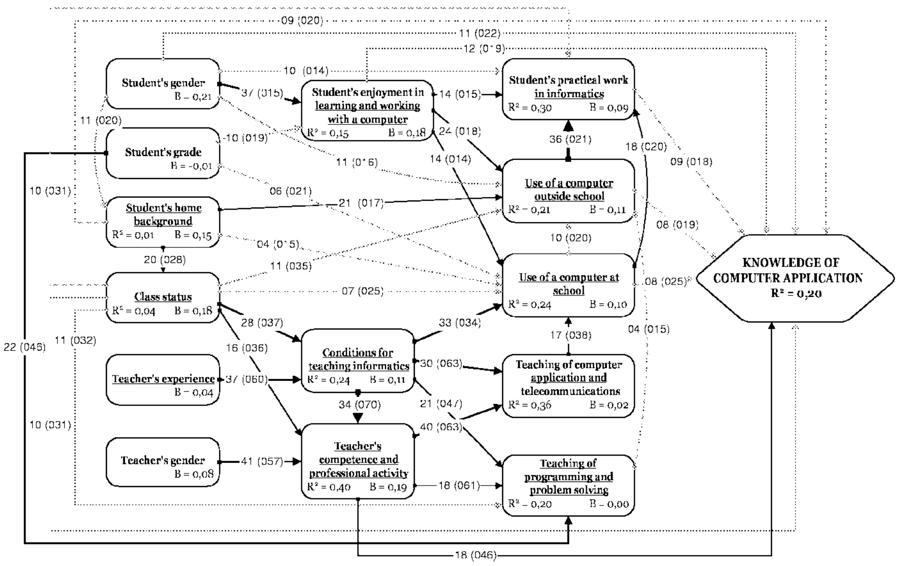

Fig. 3. PLSpath model for students' knowledge of computer application.

Note: See notes for Figure 2 for the description of the legends.

8. PLSpath Model for Students' Knowledge of Programming

The developed PLSpath model accounted for 16% of variance of the students' programming score (Fig. 4). Class status exerted the greatest influence on programming knowledge: it explained more than 8% of variance of students' programming results. Other constructs that substantially influenced the students' score in programming were: teaching of programming and problem solving (students who learned more topics in programming and used the Pascal programming software achieved higher results); student's practical work in informatics (students who did more programming and other practical tasks by computer scored higher in the programming test). Each of these constructs accounted for about 2% of the total variance of the programming score. Only four constructs had significant direct influence on students' programming results: class status, teaching programming and problem solving, student's practical work in informatics, and student's enjoyment in learning and working with a computer. The indirect effect of all constructs was very low: the influence of student's home background was most notable.

9. The Analysis of Causal Relations

The analyses showed that 3 constructs: *watching TV*, *student's attitudes towards the importance of computer literacy*, and *the use of the textbook for teaching informatics* did not (neither directly nor indirectly) influence students' scores. The relationship between these factors and students' scores is artificial because they correlate with some other factors.

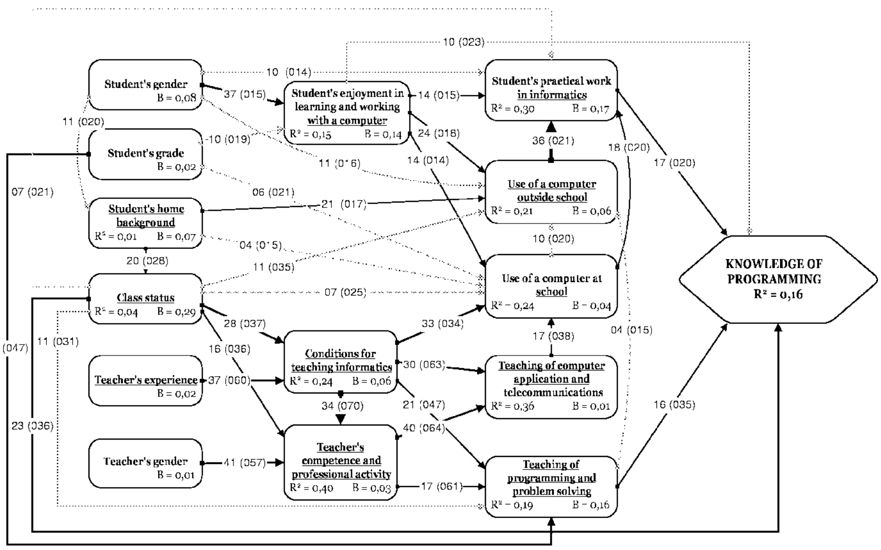

Fig. 4. PLSpath model for students' knowledge of computer application.

Note: See notes for Figure 2 for the description of the legends.

PLSpath models not only show the influence of factors on students' scores but also reveal casual relationships within the set of factors. The latter dependencies predetermine the indirect effect. Exploration of interrelations of various factors reveals the following dependencies:

The student's gender influenced student's enjoyment in learning and working with a computer: boys were more favourably disposed to computer use than girls. Boys also used computers more frequently outside school and performed more practical tasks.

Student's class was directly related only with teaching programming and problem solving: Grade 12 students learned more programming topics than 11^{th} grade students did.

Student's home background had the most significant influence on the use of computers outside school and class status. Students with a more favourable academic home background tended to use ICT at home or elsewhere outside school more frequently, they also studied at schools and classes of a higher academic level.

Class status directly influenced seven endogenous constructs. The most notable were a direct connection between the class status and conditions for teaching informatics as well as teacher's competence and professional activity: the ratio of computer to student was more favourable during informatics lessons of gymnasia and exact and natural type of classes. The students involved in these classes had more hours for the subject of informatics and more of these lessons took place in a computer classroom. Teachers who taught these children informatics had higher competence and were more engaged in professional activities. The students from lower academic level schools and classes learned informatics from the textbook more frequently, compared with their coevals from gymnasia schools and classes.

Gender of informatics teachers was directly related to their competence and professional activity: male teachers gave themselves a higher self-rating with regard to informatics knowledge and they were more actively involved in various professional activities than their female colleagues. Regarding the use of the textbook at informatics lessons, it was found out that female teachers tended to use it more often, compared to male.

Teacher's experience was directly related only to the background of teaching informatics: students who had more experienced teachers had more favourable conditions to learn this subject at school, too. The teacher's experience was related to many endogenous constructs indirectly.

Conditions for teaching informatics did not directly influence the students' informatics, computer application, or programming scores. Indirectly, students' knowledge depended upon this construct: conditions had notable influence on all constructs of teaching informatics and the use of a computer at school. Conditions for teaching informatics were positively related with the teacher's competence and professional activity. There was negative dependence of the usage of the textbook upon conditions of teaching informatics. This finding might indicate that less favourable conditions to learn informatics by applying computers forced to study this subject from the textbook.

Competence and professional activity of informatics teachers exerted strong influence on teaching computer application and telecommunications, but influenced less on teaching programming and problem solving. More competent and professionally engaged teachers tended to teach a greater number of different computer application topics and to employ a greater variety of software.

Student's enjoyment in learning and working with a computer was positively related with all constructs of studying informatics: the students who enjoyed using computers, worked with them at school and outside it more frequently and performed more practical tasks in informatics.

The constructs of informatics teaching had but a slight influence on other endogenous constructs: students who learned more about computer application and programming, applied computers at school and elsewhere more frequently, respectively.

The use of computers at school was related with its use outside school and the amount of practical work in informatics: the students who used computers at school for various purposes, applied it outside school more frequently and performed more programming and other practical tasks.

The use of computers outside school was related to the student's practical work in informatics: the students who applied computers for various purposes outside school more frequently, tended to perform more programming and other tasks with ICT.

The PLSpath model for students' computer application knowledge accounted for a greater variation of scores than the model for programming knowledge. The comparison of the developed PLSpath models for the computer application and programming scores showed that some factors exerted different influence on students' knowledge of these two branches. The class status, teaching of programming and problem solving, and students practical work in informatics had more notable influence on the programming score than on the computer application score. Student's gender, home background, conditions for teaching informatics, teacher's gender, teacher's competence and professional activity, use of a computer at school and outside it exerted more notable influence upon the computer application than upon the programming result. Student's grade, his enjoyment in learning and working with a computer, teacher's experience, teaching of computer application and telecommunications almost equally acted on computer application and programming knowledge.

10. Discussion and Recommendations

Overall findings of the survey indicate that the influence of various factors on students' knowledge of computer application and programming is different. Knowledge of computer application is under strong influence of student's, teacher's and school exogenous and endogenous factors, while programming knowledge comes under the notable impact of factors of teaching and studying informatics. These results suggest that programming knowledge might be improved by enhancing teaching and studying of programming topics, while better computer application skills might be achieved by adjusting the influence of various exogenous conditions and endogenous factors (e.g., student's gender, student's home background, teacher's competence).

Student's gender. The topics of programming were extensively included in the secondary school curricula of informatics when the survey was carried out. The difference between the dependence of student's gender on programming score and computer application score allows us to infer that the contents of informatics curriculum might be an important precondition which predetermines all students' equal level of knowledge. This suggests that improvements in girls' knowledge of computer application might be achieved by including more computer application topics into the compulsory informatics curriculum. Gender differences that deal with the access to computers could be compensated by creating exclusively favourable conditions for girls to use ICT at school (e.g., by assigning special hours in a computer room solely for girls, by including girls into ICT-related extracurricular activities).

Student's home background. The survey data indicate that comprehensive school does not ensure equal opportunities to become computer-literate for all students in Lithuania and does not compensate for the lack of opportunity to work with computers outside school. The results show that student's home background is interrelated with an opportunity to work with a computer outside school and has considerable influence on student's knowledge of computer application. From these findings, one may infer that a shift towards computer application in the compulsory informatics curriculum and creation of necessary conditions for acquiring practical ICT-related skills could reduce undesirable influence of home background (e.g., compensate the lack of chances to use ICT at home and elsewhere outside school).

Student's enjoyment in learning and working with a computer. Enjoyment to use a computer is an important factor, which is closely related with students' achievements in informatics. The review of literature revealed that there are no obvious efficient inexpensive measures to induce students' interest in ICT. A combination of the survey findings and the world know-how suggests that student's predilection for computers could be increased by creating favourable conditions to study informatics and to practice with ICT in other situations.

Class status. From the survey data one might infer that a higher programming score of students from gymnasia schools, gymnasia, exact and natural type of classes was predetermined by classical factors that cause higher achievements of these students in all other academic areas. A higher score in computer application was influenced by the same classical factors and more favourable conditions to study informatics. Taking into account emerging tendencies of the society, the following conclusion could be drawn: differences in the students' programming score from different classes reflect specific features of the educational system (i.e., heterogeneity of curricula) and are admissible, but notable differences in the basic knowledge of computer application are hardly acceptable as all students, irrespective of their interest and class type, should learn to use ICT and acquire computer literacy. Therefore, more attention and financial resources should be allocated to ICT implementation (establishment of necessary ICT infrastructure, training of informatics teachers, etc.) in schools and classes of lower academic levels; dissimilarities in students' needs and interests should be taken into account when preparing informatics curriculum, educational standards, textbooks, and other learning materials.

Conditions for teaching informatics. As indicated above, the conditions for teaching informatics exert only indirect influence on students' scores, but the influence of this factor on studying and teaching informatics is fairly notable. In general, the survey results allow us to state that students' knowledge of computer application depends on the opportunity to practice with ICT, which is less important for teaching programming skills. Therefore, the main step towards enhancement of positive influence of conditions for teaching informatics could be an arrangement of computer rooms fitted for studying this subject. One may note that due to scarcity of proper conditions to learn informatics, the efficiency of other learning tools (e.g., textbook) becomes of utmost importance. Therefore, the textbook for the compulsory informatics course should fit the learning process of this subject without possessing enough computers.

Teacher's competence and professional activity. The influence of teacher's qualification on students' knowledge of informatics and, in particular, on knowledge of computer applications reveals an important role of the teachers' training system. More attention and time should be allotted to both teachers ICT competence and didactical aspects of ICT integration in training courses; employing new communication and information exchange tools and new learning methods, the system for permanent qualification development should be established.

Teacher's experience. The survey findings show that students' scores are not related with the teaching experience of an informatics teacher, however the results significantly correlate with the teacher's experience in teaching by computers. A deeper investigation of the latter relation reveals that there is a significant difference between the results of those students whose teachers have a fairly long experience in using ICT and those who have no experience at all. The latter finding reveals the importance of minimal conditions for every informatics teacher to use ICT for teaching his subject.

Teacher's gender. Male teachers over-scored female teachers in self-rating of ICT-related knowledge. In addition, males were engaged in a greater number of professional activities than females. This points to the need of additional means for improving female teachers' professional skills and involving them in various ICT-related activities.

Use of the textbook for teaching informatics. The results indicate that students from lower academic level classes use the textbook more frequently. Therefore, authors of textbooks should take into consideration a suggestion that a textbook for the compulsory course should be targeted at a mediocre student who is less interested in exact sciences. The survey also shows that students who lack opportunities to learn informatics in full value (e.g., due to the lack of computers at school, low teacher's competence, etc.) use the textbook more frequently than others do. This proves that the textbook is applied as an alternative means of learning informatics when a school is short of computers or other necessary conditions to teach this subject.

Use of a computer at and outside school. The majority of students use computers only at school, but even at school ICT is accessible not for all children. The survey findings indicate that teaching informatics influences its learning and the use of ICT outside school is connected to its use at school. This allows us to think that the main actions should be aimed at changes in school and class rather than the student's level, as changes in teaching might have a positive effect on learning, too.

Student's practical work in informatics. Practical experience in computer application has a powerful influence on student's informatics knowledge and skills. This finding corroborates the given recommendation to provide students with opportunities of practising with ICT as much as possible (for self-study purposes, optional courses, extracurricular activities, etc.).

Appendix 1. Summary of Constructs

Name of latent variable: construct	Number of indicators: description of indicators
A1: Student's gender	1: [1= girl; 2 = boy]
A2: Student's home background	3: Level of education of student's father and mother [1 = lower secondary; 2 = secondary; 3 = vocational or college; 4 = university]; number of different types of books at home [range 0–3]
A3: Student's grade	1: [1= 11^{th} grade; 2 = 12^{th} grade]
B1: School location	1: [1 = country; 2 = suburb; 3 = city]
C1: Teacher's gender	1: [1= female; 2 = male]
C2: Teacher's experience	2: Number of years of teaching informatics [range 0–30]; number of years of using a computer for teaching of informatics [range 0–23]
C3: Teacher's education	1: [1 = secondary; 2 = vocational or college; 3 = university]
D1: Class status	3: Type of school [2 = gymnasia; 1 = other]; type of class [2 = gymnasia; 1 = other]; profile of class [2 = exact and natural sciences; 1 = other]
D2: Conditions for teaching informatics	3: Total number of informatics hours per school year [range 0–144]; number of informatics hours during which students are using computers per school year [range 0–101]; computer to student ratio at informatics lessons [range 0–1]
E1: Reading books	4: Number of read books of different genres: belles-lettres; social and humanitarian sciences; exact and natural sciences; other [range 0–21: 0 = none; 21 = 21 or more]
E2: Watching TV	1: Hours daily spent by students on watching television [range 0–8]
E3: Doing homework	1: Time (minutes) daily allotted for doing homework [range 0–480]
E4: Student's enjoyment in using and working with a computer	9: All 9 items on students interest to use ICT [four point Likert scale: -2 = strongly disagree; 2 = strongly agree]
E5: Student's attitudes towards importance of computer literacy	5: All 5 items on students disposition towards importance of ICT [four point Likert scale: -2 = strongly disagree; 2 = strongly agree]
F1: Teacher's competence and professional activity	7: 4 indicators on teacher's skills to program, to operate a computer, to maintain a computer, and to use telecommunications. 3 indicators on teacher's involvement in professional activities, self-development, and practical use of ICT
G1: Teaching computer application and telecommunications	12: 6 indicators on teaching various topics of computer application (e.g., word processing; spreadsheets, databases) and telecommunications [0 = no; 1 = yes]; 6 indicators on the use of general purpose software [0 = no; 1 = yes]
G2: Teaching programming and problem solving	6: 5 indicators on teaching topics of programming [0 = no; 1 = yes]; 1 indicator on frequency of use of Pascal programming software [1 = never; 2 = every term; 3 = every month; 4 = every week]
G3: Teaching about software and hardware	3: All 3 indicators on teaching purely theoretical topics about software and hardware [0 = no; 1 = yes]

Name of latent variable: construct	Number of indicators: description of indicators
G4: Teaching about computer and society	3: All 3 indicators on teaching about social aspect of ICT [0 = no; 1 = yes]
G5: Use of the textbook (Dagiene et al., 1991) for teaching informatics	1: Percentage of informatics lessons, in which the textbook was used [1 = 0–25%; 2 = 26–75%; 3 = 76–100%]
H1: Use of a computer at school	8: All 8 indicators on intensity of computer use for various purposes (e.g., programming, practical tasks, word processing) at school [range 0–10; 0 = do not use; 10 = 10 or more times per year]
H2: Use of a computer outside school	10: Availability of a computer at home [0 = no; 1 = yes]; hours weekly spent by students on working by computer [range 0–40]; 8 indicators on computer use for various purposes (e.g., programming, practical tasks, word processing) outside a school [0 = do not use; 1 = use]
H3: Student's practical work in informatics	2: Number of developed programs; number of other practical tasks done by computer [range 0–11; 0 = none; 11 = 11 or more]
REZ: Student's knowledge	1: Student's score in informatics [range 0–100]

Notes: (1) all nominal scales have been checked for consistency and rearranged in the ascending order (with respect to student's score of informatics) before the analysis; (2) standardized values of all indicators were used in the PLSpath analysis.

Appendix 2. Initial Correlations between Latent Variables

	A3	A1	D1	A2	H2	E2	H3	H1	E5	E4	G1	G2	F1
A1	-0.05*												
D1	-0.02	0.07**											
A2	0.01	0.11**	0.20**										
H2	-0.01	0.24**	0.19**	0.28**									
E2	-0.13**	0.09**	-0.13**	-0.13**	-0.06**								
H3	0.02	0.26**	0.18**	0.18**	0.47**	-0.06**							
H1	0.05*	0.08**	0.24**	0.12**	0.19**	-0.03	0.29**						
E5	-0.03	0.02	0.03	0.06**	0.10**	-0.03	0.10**	0.05**					
E4	-0.11**	0.37**	0.01	0.07**	0.31**	0.03	0.31**	0.11**	0.41**				
G1	0.00	0.02	0.30**	0.08*	0.05	-0.06**	0.12**	0.34**	0.00	-0.02			
G2	0.22**	0.01	0.23**	0.09**	0.10**	-0.08**	0.10**	0.20**	0.00	-0.04	0.23**		
F1	-0.01	0.01	0.32**	0.14**	0.10**	-0.06**	0.12**	0.31**	-0.03	-0.07**	0.52**	0.27**	
C2	0.02	0.02	0.13	0.07	0.04	-0.08**	0.07*	0.22**	-0.02	-0.06*	0.19**	0.06	0.26**
D2	0.01	0.02	0.33**	0.13**	0.08**	-0.09**	0.13**	0.44**	-0.01	-0.06*	0.41**	0.30**	0.42**
G5	-0.03	-0.05*	-0.22**	-0.11**	-0.09**	0.03	-0.10**	-0.25**	0.00	0.00	-0.35**	-0.14*	-0.37**
C1	0.00	0.01	0.13	0.04	0.03	-0.03	0.07**	0.11*	-0.02	-0.02	0.29**	0.04	0.48**
REZ	0.02	0.22**	0.23**	0.20**	0.26**	-0.07**	0.27**	0.24**	0.12**	.22**	0.26**	0.22**	0.26**

	C2	D2	G5	C1
D2	0.40**			
G5	-0.24**	-0.31**		
C1	0.08	0.11	-0.20**	
REZ	0.15**	0.22**	-0.17**	0.14**

Note: ** – correlation is significant at 1% level of significance; * – correlation is significant at 5% level of significance.

Appendix 3. Structure of the Inner Model for Students' Knowledge of Informatics

		A1	A2	A3	C1	C2	D1	D2	E2	E4	E5	F1	G1	G2	G5	H1	H2	H3
A2	=	A1																
D1	=	A1^{c}	A2															
D2	=		A2^{b}			C2	D1											
E2	=	A1	A2	A3			D1											
E4	=	A1	A2^{b}	A3														
E5	=		A2^{c}							E4								
F1	=				C1	C2^{b}	D1	D2										
G1	=				C1^{b}	C2^{a}	D1^{c}	D2				F1						
G2	=			A3			D1	D2				F1						
G5	=				C1^{b}	C2^{b}	D1^{b}	D2^{b}				F1	G1					
H1	=	A1^{b}	A2	A3		C2^{b}	D1	D2		E4	E5	F1^{b}	G1	G2^{b}	G5^{b}			
H2	=	A1	A2				D1	D2^{a}	E2^{c}	E4	E5^{a}	F1^{b}		G2	G5^{a}			
H3	=	A1	A2^{c}		C1^{b}		D1	D2^{a}	E2^{c}	E4	E5^{a}	F1^{a}	G1^{b}	G2^{b}	G5^{b}	H1	H2	
REZ	=	A1	A2	A3	C1^{b}	C2^{b}	D1	D2^{a}	E2^{b}	E4	E5^{c}	F1^{b}	G1	G2	G5^{a}	H1^{b}	H2	H3

Note: The latent variables indicated by marks a, b and c have been eliminated from the inner structure after the respective modifications of the model. See the text for details.

Appendix 4. Direct, Indirect and Total Effects on Endogenous Latent Variables in the PLSpath Model for Students' Knowledge of Informatics

	Effect		
	Direct	Indirect	Total
A2: Student's home background			
A1	0.11	–	0.11
D1: Class Status			
A1	–	0.02	0.02
A2	0.20	–	0.20
D2: Conditions for teaching informatics			
A1	–	0.01	0.01
A2	–	0.06	0.06
C2	0.37	–	0.37
D1	0.28	–	0.28
E2: Watching TV			
A1	0.10	-0.02	0.09
A2	-0.12	-0.02	-0.14
A3	-0.12	–	-0.12
D1	-0.12	–	-0.12
E4: Student's enjoyment in using and working with a computer			
A1	0.37	–	0.37
A3	-0.10	–	-0.10
E5: Student's attitudes towards importance of computer literacy			
A1	–	0.16	0.16
A3	–	-0.04	-0.04
E4	0.44	–	0.44

	Effect		
	Direct	Indirect	Total
F1: Teacher's competence and profesional activity			
A1	–	0.01	0.01
A2	–	0.05	0.05
C1	0.41	–	0.41
C2	–	0.12	0.12
D1	0.16	0.09	0.25
D2	0.34	–	0.34
G1: Teaching computer application and telecommunications			
A1	–	0.00	0.00
A2	–	0.04	0.04
C1	–	0.16	0.16
C2	–	0.16	0.16
D1	–	0.18	0.18
D2	0.30	0.14	0.43
F1	0.40	–	0.40
G2: Teaching programming and problem solving			
A1	–	0.00	0.00
A2	–	0.04	0.04
A3	0.22	–	0.22
C1	–	0.07	0.07
C2	–	0.10	0.10
D1	0.11	0.10	0.21
D2	0.21	0.06	0.27
F1	0.17	–	0.17
G5: Use of the textbook for teaching informatics			
A1	–	-0.00	-0.00
A2	–	-0.02	-0.02
C1	–	-0.14	-0.14
C2	–	-0.07	-0.07
D1	–	-0.11	-0.11
D2	–	-0.19	-0.19
F1	-0.26	-0.09	-0.35
G1	-0.23	–	-0.23
H1: Use of a computer at school			
A1	–	0.06	0.06
A2	0.04	0.04	0.08
A3	0.06	-0.01	0.05
C1	–	0.03	0.03
C2	–	0.15	0.15
D1	0.07	0.12	0.19
D2	0.33	0.07	0.40

	Effect		
	Direct	Indirect	Total
E4	0.14	–	0.14
F1	–	0.07	0.07
G1	0.17	–	0.17
H2: Use of a computer outside school			
A1	0.11	0.12	0.23
A2	0.21	0.03	0.25
A3	–	-0.01	-0.01
C1	–	0.01	0.01
C2	–	0.02	0.02
D1	0.11	0.03	0.13
D2	–	0.05	0.05
E4	0.24	0.01	0.26
F1	–	0.01	0.01
G1	–	0.02	0.02
G2	0.04	–	0.04
H1	0.10	–	0.10
H3: Student's practical work in informatics			
A1	0.10	0.15	0.25
A2	–	0.12	0.12
A3	–	-0.01	-0.01
C1	–	0.01	0.01
C2	–	0.03	0.03
D1	0.06	0.08	0.15
D2	–	0.09	0.09
E4	0.14	0.12	0.25
F1	–	0.02	0.02
G1	–	0.04	0.04
G2	–	0.02	0.02
H1	0.18	0.04	0.22
H2	0.36	–	0.36
REZ: Student's knowledge of informatics			
A1	0.07	0.11	0.18
A2	0.07	0.08	0.16
A3	–	0.01	0.01
C1	–	0.03	0.03
C2	–	0.04	0.04
D1	0.17	0.08	0.25
D2	–	0.11	0.11
E4	0.11	0.05	0.17
F1	–	0.08	0.08
G1	0.13	0.01	0.14
G2	0.12	0.01	0.13
H1	–	0.04	0.04
H2	0.08	0.05	0.13
H3	0.14	–	0.14

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Įvairių faktorių įtakos moksleivių informatikos žinioms PLSpath analizė

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Remiantis tyrimo „Kompiuteriai Lietuvos mokyklose" duomenimis, straipsnyje analizuojama Lietuvos bendrojo lavinimo vidurinių mokyklų 11 ir 12 klasių moksleivių informatikos žinių priklausomybė nuo įvairių mokyklos, informatikos mokytojo ir moksleivio savybių bei informatikos mokymo bei mokymosi faktorių. Atskirai nagrinėjama įvairių veiksnių įtaka skirtingų informatikos krypčių – kompiuterijos taikymo ir programavimo – moksleivių žinioms. Faktorių tarpusavio sąveikai ištirti naudojamas PLSpath struktūrinio modeliavimo metodas.