Context factors associated with ICT use by mathematics teachers[1]

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Abstract

SITES 2006 was an international assessment of pedagogy and ICT use. The study was conducted in 22 education systems and consisted of data collection at the national, school and teacher level. The main aim of the study was to investigate to what extent and for which pedagogical practices mathematics and science teachers were using ICT. The descriptive results of the study as well as first exploratory analyses were reported by Law, Pelgrum & Plomp (2008). A main observation from this study was that education systems differed substantially in terms of the extent to which ICT was used frequently by mathematics and science teachers (Voogt, 2008). For policy makers and researchers it is important to acquire a better understanding of why these differences exist. In order to throw more light on this issue, in this paper national and school context factors will be compared between education systems with relatively high versus low use of ICT in mathematics.

Keywords: secondary analysis, educational policies, ICT use, mathematics, pedagogy

Introduction

In many education systems throughout the world ICT has been introduced already since the mid 1980s. An observation from earlier international assessments of IEA (e.g. Pelgrum & Anderson, 1999) as well as many national assessments was that the infusion of ICT in the daily learning practices of students is progressing very slowly and sometimes even stagnating. For policy makers, who invested huge budgets in making ICT available for schools, a major question is why this progress is so slow and which barriers have to be removed in order to stimulate teachers to use new technologies as a tool in their educational practices (next to other instructional tools). The adoption of such a tool is an educational change. Theories about educational change (e.g. Fullan, 1993) have postulated a number of conditions that need to be satisfied in order to successfully implement changes (leadership visions, support, staff development, etc.).

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Voogt (2008) showed that large differences existed between education systems in the extent to which mathematics and science teachers used ICT frequently (at least once a week) for teaching/learning purposes. The focus of this paper is on mathematics teachers. In some education systems the frequent use of ICT by math teachers was low (Chinese Taipei-7%, Japan-3%, Slovenia-7%). This group of education systems will further on be called LOMA, while in other education systems this was much higher (HIMA): Chile-37%, Canada-Ontario-43%, Canada-Alberta-30%.

Although in the SITES 2006 final report consequently the term education system is used (because some countries participated that had more than one education system, e.g. Canada-Ontario and Canada-Alberta), for the sake of convenience we will use in this paper the term 'country'.

In SITES 2006 a large number of constructs were used (most of which were derived from educational change theories), such as:

- National policies (demographics, structure of education systems, pedagogy, ICT related policy and activities).
- School leadership activities (encouragement by school leaders of particular pedagogical practices, technical and pedagogical support, available ICT infrastructure, staff development requirements).
- Curriculum goals of teachers, assessment practices, availability and participation in professional development courses, perceived impact of ICT.

These constructs were operationalized in indicators that were measured via questionnaires, which were administered to national research coordinators (national context questionnaire), school authorities (school leaders and technology coordinators) and teachers. Overall, the questionnaires contained more than 600 items. Twenty two education systems participated in SITES 2006, in which responses were collected from a total of nearly 9000 schools and 35000 teachers.

The research question to be addressed in this paper is to what extent and on which characteristics the HIMA countries differ from the LOMA ones. This question is relevant for several educational actors, policy makers as well as academics for acquiring more insight in potential causes of stagnating integration of ICT in existing school subjects. In the remainder of this paper, first the methodology for addressing this research question will be explained. This is followed by a description and discussion of the findings. The final section concerns conclusions and reflections about implications of the findings.

Methodology and Data Sources

The data sources that will be used for this paper are the international data bases from SITES 2006 which are available through the web site of the IEA Data Processing and Research Centre.

In order to investigate the research question that was formulated above, the two groups of countries that were mentioned above (HIMA and LOMA) will be compared. For this purpose an open, explorative approach will be used, that will minimize restrictions on measurement characteristics of the data and definitions of constructs.

Given the exploratory character of the approach used in this paper, we do not want to be constrained by theoretical concepts and derived composite variables that were used in the SITES 2006 report (Law, Pelgrum & Plomp, 2008). We will use a singleton approach by focusing on questionnaire items rather than composites. A main reason for using this singleton approach is that composite variables sometimes hide interesting phenomena that can be observed when examining the items underlying the composite. The following example may help to illustrate this point. Pelgrum (2008) used a composite variable called 'presence of emerging pedagogy', consisting of a score based on 6 questionnaire items, reflecting independent and autonomous learning by students. It was observed that interesting differences existed when comparing the mean score per country between 1998 (SITES Module 1) and 2006, for instance in some countries the score declined substantially (e.g. Denmark and Norway), while in other countries substantial increases were observed (e.g. Hong Kong and Lithuania). However, when the comparison was done for each of the underlying items separately, it appeared that quite different patterns showed up, e.g. whereas the composite score for Denmark decreased a substantial increase showed up in one of the underlying items (about information handling).

For the analysis of differences between the two groups of countries in principle all questionnaire items from SITES 2006 will be used. A number of SITES 2006 variables will not be included, because they are considered not to be relevant for the purpose of this paper. The set that is used for the analysis covers nearly 90% of all SITES 2006 variables. A number of items first had to be recoded, for instance:

- A question in the technical questionnaire about the availability of technology applications, for which the answer options were: 'available', 'needed but not available', 'not needed and not available'. The codes for these answer options were recoded in order to reflect a distinction between available and not available.

- A question in the teacher questionnaire about participation in professional development activities, for which the answer options were: 'No, I don't wish to attend'; 'No, I would like to attend if available'; 'Yes, I have'. The answer codes were recoded in order to reflect a distinction between 'Attended' and 'Not attended'.

For interpreting the size of differences between the two groups of countries we will use a statistics that is known as the 'effect size'. This statistic was introduced by Cohen (1992) and is calculated as follows (copied from Wikipedia):

$$d = \frac{\text{mean}_1 - \text{mean}_2}{\sqrt{(\text{SD}_1^2 + \text{SD}_2^2)/2}}$$

Cohen (1992) tentatively provided the following guidelines for the interpretation of effect sizes: small effect (0.2 or less), medium (0.5) and large (0.8 or more). This means that roughly 1 standard deviation difference (as compared to the average standard deviations in both groups) is considered to be a substantial difference. For the purpose of this article we will use effect sizes larger than 0.5 or lower than -0.5 for qualifying differences between the two groups as meaningful.

The second step in our exploration will be to compare country profiles. This will be done by identifying a small set of school context factors that are considered potential levers for educational change. Once the items with meaningful effect sizes are identified, it will depend on the number of items which next step will be performed in the analysis:

1. When the number of school level items with meaningful effect sizes is relatively small (roughly 10 or less) and if there are no clear indications of redundancy in this set, the profile analysis will be based on these items.

2. When the number of items is large, we will investigate (via factor analyses) if a meaningful (that is, interpretable) data reduction of this set is possible.

Findings and Discussion

With regard to the national context indicators that were presented by Anderson & Plomp (2008), no systematic differences were found between the HIMA and LOMA countries.

The effect size for each of the questionnaire items were calculated according to the method that was presented in the previous section. For this purpose SPSS 16.0 was used.

The overall result for 550 questionnaire items is shown in Figure 1, in which each bar represents one item.

[Take in Fig 1 about here]

From Figure 1, we can infer the following:

- The effect sizes of a large number of items are meaningful according to the criterion that was mentioned in the previous section (=-0.5 or =0.5). This concerns 158 of the 550 items (29%).
- Positive effect sizes are outnumbering the negative ones (26% versus 3%). 35 items showed large positive effect sizes (=0.8). Large negative effect sizes hardly occurred.
- The following are a few examples of items for which relatively large effect sizes were observed:
    - o School leaders inform teachers about pedagogical changes taking place in the school (d=0.9)
    - o School leaders motivate teachers to critically assess their own educational practices (d=1.1)
    - o Teachers use ICT for extended projects (d=1.1)
    - o Teachers indicate that their priority in the next years is to involve students in extended collaborative projects (d=1.1)

The following narrative contains a more extensive description of all observed differences.

First a description will be given of how HIMA and LOMA countries differed in terms of school level conditions (as reported by school leaders and technology coordinators). This is followed by a summary of differences that were observed at the teacher-level.

From the 284 school level items that were included in the analysis 53 showed meaningful effect sizes. School principals in HIMA countries were more inclined to perceive that active student learning is taking place in their schools, in particular with regard to the following items:

- Students developing abilities to undertake independent learning.
- Students learning to search for, process and present information.

- Students learning and working during lessons at their own pace.

The school leaders in the HIMA countries were more inclined to encourage teachers to cover the prescribed curriculum content and to prioritize resource allocations to improve students' ICT skills. They were also more inclined to actively monitor and evaluate the implementation of pedagogical changes and to encourage teachers to assign production projects to students.

School leaders in HIMA countries were much more active in undertaking communicative activities to support the change process. Items with effect sizes larger than .8 were:

- Informing teachers about pedagogical changes taking place in the school.
- Informing teachers about educational developments outside the school.
- Motivating teachers to critically assess their own educational practices.
- Discussing with parents and students the pedagogical changes taking place in the school.

Maybe as a result of this active engagement they assigned higher priorities to acquire, as school leaders, competencies with regard to:

- Explaining teachers the relevance of encouraging students to be responsible for their own learning and outcomes.
- Identifying best practices existing outside the school regarding the integration of ICT in learning.
- Promoting collaboration between teachers of different subjects.
- Managing the adoption of ICT-supported methods for assessing students progress.
- Promoting the integration of ICT in the teaching and learning of traditional subjects.

They also encouraged teachers to use particular forms of assessment, such as:

- Written tests/examinations
- Written tasks/exercises
- Oral and/or written group presentations.

With regard to the organization of learning, school leaders in HIMA countries reported more often that students work in different groups according to the projects that they are taking, but they also indicated that changes to the usual time schedule occurred if students needed time to complete their projects. On the contrary, school leaders in LOMA countries indicated more often that students were following their lessons according to a fixed schedule. With regard to background characteristics of schools it appeared that absenteeism of students in HIMA countries was slightly higher than in LOMA countries. Finally, in HIMA countries school leaders reported more often that they used ICT for communication with teachers and parents, and also for budgeting, monitoring and controlling expenses and/or time tabling.

Consistent with the group categorization for the selection of countries that were involved in the effect size calculation, is the observation that technology coordinators in HIMA countries indicated more often that their school had integrated ICT in most teaching and learning processes. They indicated that in particular ICT was used for the learning of mother tongue, mathematics and social sciences. On the contrary in the LOMA countries ICT seems to be more frequently used by students in a separate ICT-subject. Also computers are, according to technology coordinators, more often available in most classrooms.

HIMA and LOMA countries hardly differed in terms of obstacles that were perceived as hindering the schools' capacity to realize its pedagogical goals, except that in HIMA countries it has been more often reported that there were insufficient numbers of computers connected to the Internet.

Whereas above mainly a description was given of the items on which the HIMA countries scored higher (with here and there some mentioning of the LOMA countries), it further appeared that the LOMA countries scored higher on the following items:

- Providing teachers with laptop computers and/or other mobile devices.
- Encouraging teachers to involving students in self-accessed courses and/or learning activities.
- Encouraging teachers to collaborate with teachers from other countries.
- Teachers, parents and/or students initiated changes that were considered highly satisfying by school leaders.
- Availability of (non-ICT) equipment and hands-on materials.
- Maintenance of hardware by external companies hired by the school.
- Computers available in some classrooms.
- Teachers acquired knowledge and skills in using ICT via reading professional journal and/or similar publications.

With regard to the items at the teacher level, it appeared that 40 % of the 266 items had meaningful effect sizes. This number is too large for a detailed description as was given above for the school level items. Therefore, we will provide a more global summary. For the interested reader Table 1 in Annex 1 is included, showing the items (with variable names used in the SITES 2006 data base) that had absolute effect sizes >.5. In the description below, we will focus only on the non-ICT variables. The reason is that the HIMA and LOMA groups are not independent with regard to these variables. What appears from an inspection of the non-ICT items is that in HIMA countries:

- The number of mathematics lessons per week was higher.
- The absenteeism of students was higher (consistent with what school leaders reported).
- Teachers assigned more importance to life long learning activities.
- Students were more engaged in determining their own content goals, explaining and discussing own ideas with teachers and peers, and self and/or peer evaluation.
- There is more flexibility in terms of the locations where students work.
- Teachers also reported (consistent with what school leaders indicated) that the vision of the school staff was to constantly motivate teachers to critically assess their own educational practices and to think about the vision and strategies of the school. They also felt that they could influence innovation plans in the school and that they were able to implement innovations in their classroom according to their own insights and judgments.

According to the methods-section above, the next step of the analysis depends on the number of school level items that showed meaningful effects sizes. As described above, it appeared that 53 items showed absolute effect sizes that were larger than .5. Hence we explored whether this set could be reduced in a meaningful way. Via factor analyses (including all SITES 2006 countries) it appeared that a set of 5 interpretable factors could be identified. These factors (and a short description of the underlying items) were labeled as follows:

I. Active communication, consisting of items, such as: informing teachers and parents about pedagogical changes, discussing with teachers and students about teaching and learning.
II. Priorities for school leadership development, consisting of items indicating priorities for the school leadership to acquire skills in change management.
III. Assessment orientation, that is school leaders encourage teachers to use different types of assessment of student progress.
IV. ICT use of school leader, for communication and administrative activities.
V. Bottom up change-orientation, that is satisfying changes in the school were

initiated by teachers and/or students.

Factor scores were generated and used to perform a number of comparisons of country profiles, namely between pairs of HIMA and LOMA countries and between countries that one would expect to be culturally comparable.

Below we will describe the outcomes of these profile analyses and their potential implications for policy-making.

[Take in Fig 2 about here]

Figure 2 contains the profile of a HIMA country (in this case Chile with 37% mathematics teachers using ICT frequently) and a LOMA country (Chinese Taipei, 7% frequent use).

From Figure 2 one may infer that in Chinese Taipei, in comparison with Chile, school leaders are less active in communicating about pedagogical changes and also have lower priorities for developing their change management competencies. On the other hand it seems that they leave the initiative for realizing changes much more to teachers and/or students. It is not known whether these different profiles result from differences in national strategies for integrating ICT in teaching and learning. Nevertheless, it seems warranted to advise policy-makers in Chinese Taipei to reflect further on these strategies and to determine whether something can be learned from the strategies applied in Chile.

Another illustration of a profile comparison of a HIMA (Canada-Ontario with 30% frequent use) and a LOMA country (Japan with 3% of frequent use) is shown in Figure 3.

[Take in Fig 3 about here]

The profiles in Figure 3 are quite different from the ones in Figure 2. Canada-Ontario stands out in terms of active communication of school leaders about pedagogical changes and the use of ICT by school leaders is much higher than in Japan, but also the need for school leadership development is substantially higher.

Important for policy-makers, when using these kind of profile analysis, is to first determine which countries are relevant to compare with. Arguments like economical competitiveness might for instance play a role in such deliberations. Next, the analysis might be used for generating ideas on potential levers for change.

Whereas the profiles in the comparison above are quite different, it is interesting to explore whether more similarity appears, if the comparison is done for countries that are more or less culturally comparable. For this comparison two systems from the same country (in this case the Russian Federation and Moscow, Figure 4) are compared as well as two different countries from the same region (Denmark and Norway, Figure 5).

[Take in Fig 4 about here]

In Figure 4 it is clear that the profiles of Moscow and the total Russian Federation are almost identical. These are characterized by active communication, school leadership development needs, mediocre emphasis on assessment, and very low use of ICT by school leaders. When comparing two other systems from the same country (Canada-Ontario and Canada-Alberta) it was also observed that the profiles were nearly identical.

When comparing two different countries from the same region (Denmark and Norway) we can also observe (Figure 5) nearly identical profiles. It seems that in these two countries many school leaders use ICT themselves, but the sores on the other factors are not very explicit.

[Take in Fig 5 about here]

Conclusion and Implications

The results of the analyses presented above have shown that the differences between HIMA and LOMA countries with regard to school context factors are quite well interpretable. School leaders in HIMA are more active in stimulating the use of ICT, encouraging teachers to apply new ways of teaching and learning and in creating a school climate that supports the implementation of educational change in the school. They do not seem to give up the emphasis on covering the content of the prescribed curriculum, but rather seem to encourage new ways to realize this. The observations that were reported are consistent with theories on educational change.

The work reported in this paper is quite exploratory. Further analyses are needed to determine which refinements are desirable. Probably further fine-tuning is possible with regard to the cut-off criteria that were used for selecting items with meaningful effect sizes. We used as lower threshold an absolute effect size of .5, but maybe the results would still be meaningful and interpretable when this threshold would be lowered.

Whereas the analyses in this paper were based on mathematics teachers, future work will also be focused on investigating on which school context variables countries with frequent use of ICT in science lessons differ from countries where this is not the case. Moreover, more work is needed with regard to national context variables. Although it may look disappointing that no systematic differences could be discovered between HIMA and LOMA countries with regard to the national context variables that were collected in SITES 2006, this result is not surprising, because SITES 2006 was not specifically designed to answer the research question on which this paper was focused. What needs to be sorted out is to what extent the HIMA and LOMA countries differ in terms of specific national policies to integrate ICT in the teaching and learning of mathematics.

The comparisons of profiles between specific countries do not immediately lead to recipes for policy planning. These comparisons rather could function as lever for raising awareness at the policy level and generating questions, such as: do we think that the integration of ICT in the teaching and learning of mathematics is important and, if so, how can school leaders be activated to play a role in realizing such intentions? The analyses shown in this paper indicate that the SITES 2006 data base is useful as basis for data-driven policy making with regard to the integration of ICT in education.

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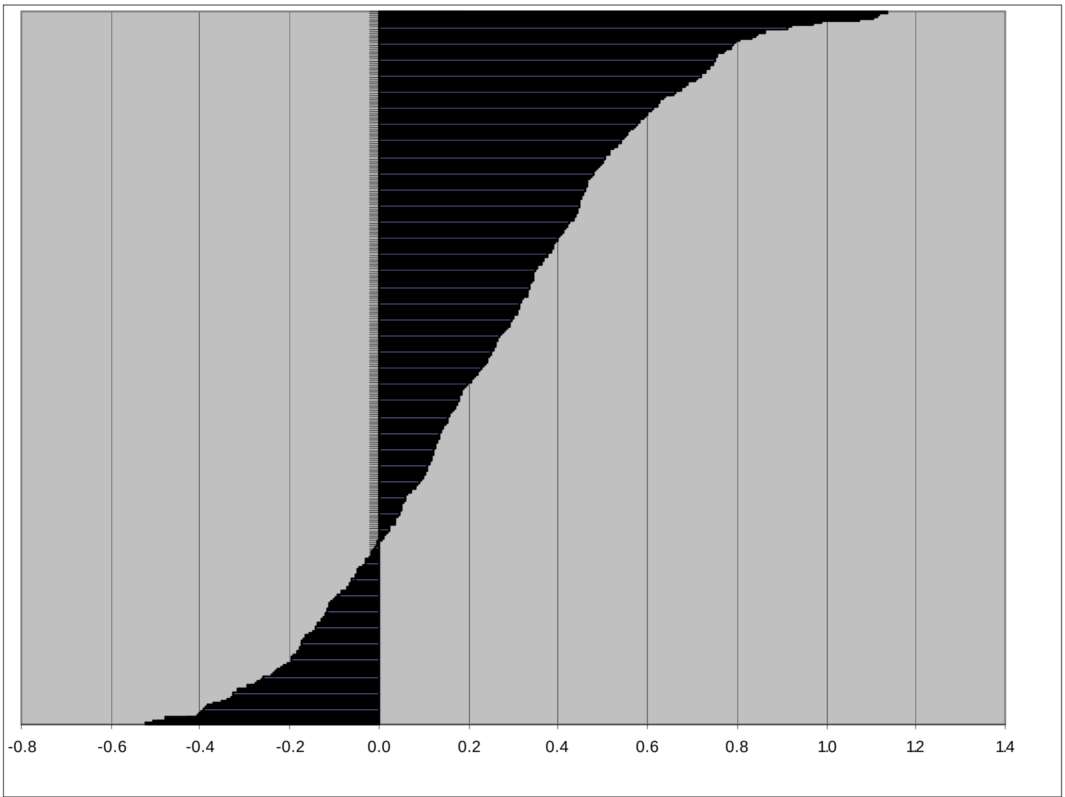
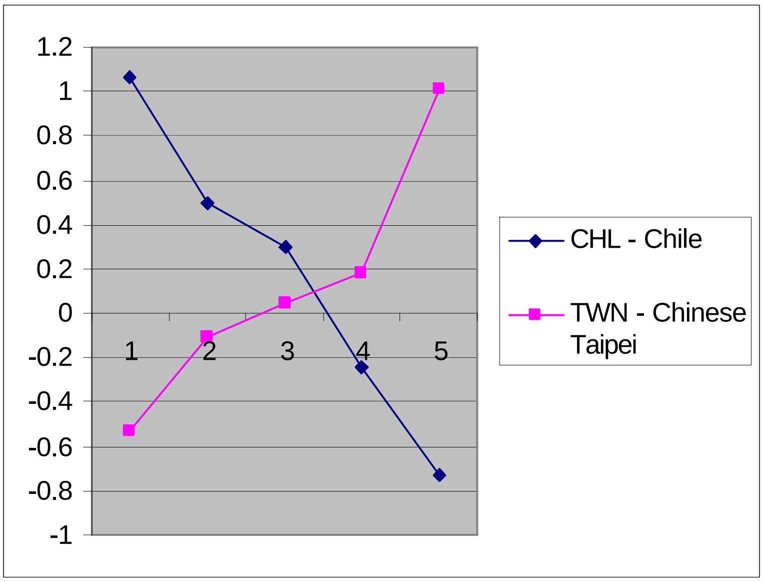
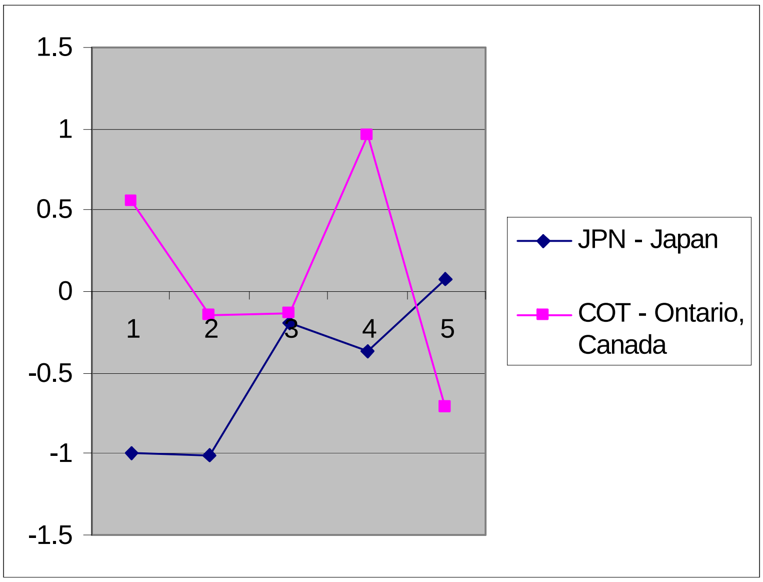


Fig.1: Effect sizes for 550 questionnaire items



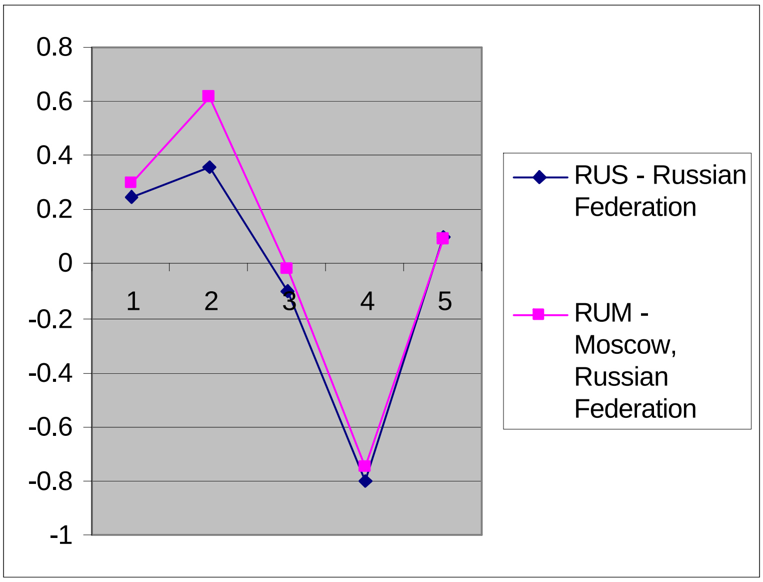
Legenda. Factor 1: Active communication, Factor 2: Priorities for school leadership development, Factor 3: Assessment orientation, Factor 4: ICT use of school leader, Factor 5: Bottom up change

Fig. 2: Factor scores for Chile and Chinese Taipei



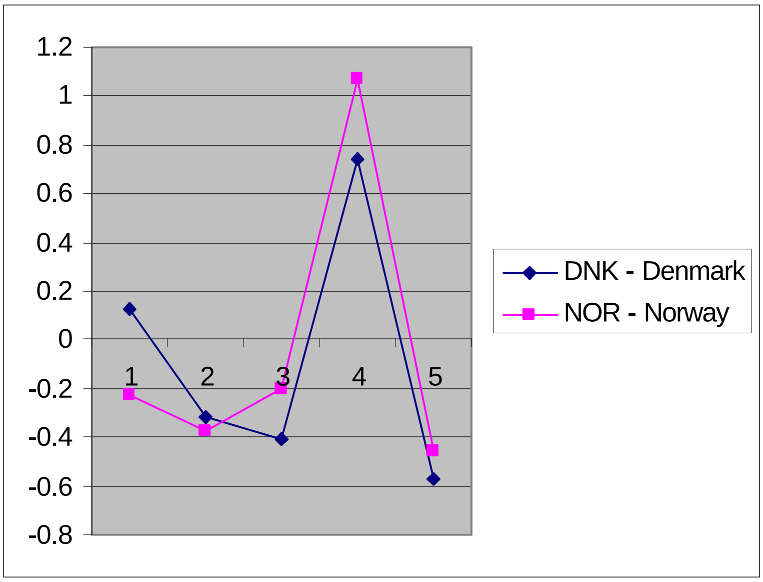
Legenda. Factor 1: Active communication, Factor 2: Priorities for school leadership development, Factor 3: Assessment orientation, Factor 4: ICT use of school leader, Factor 5: Bottom up change

Fig. 3: Factor scores for Canada-Ontario and Japan



Legenda. Factor 1: Active communication, Factor 2: Priorities for school leadership development, Factor 3: Assessment orientation, Factor 4: ICT use of school leader, Factor 5: Bottom up change

Fig. 4: Factor scores for the Russian Federation and Moscow.



Legenda. Factor 1: Active communication, Factor 2: Priorities for school leadership development, Factor 3: Assessment orientation, Factor 4: ICT use of school leader, Factor 5: Bottom up change

Fig. 5: Factor scores for Denmark and Norway

Annex 1.

Table 1. Teacher items with absolute effect sizes =.5

Var-name	Eff. Size	Var-name	Eff. Size	Var-name	Eff. Size	Var-name	Eff. Size
BTG04A1	0.5	BTG14A1	0.9	BTG17D1	0.5	BTG22G1	1.1
BTG06A1	0.9	BTG14B1	0.6	BTG17F1	0.6	BTG22H1	0.8
BTG07B1	0.5	BTG14B2	0.7	BTG17H1	0.6	BTG22I1	0.7
BTG07D1	0.7	BTG14C1	0.6	BTG18A1	0.7	BTG22J1	0.8
BTG07E1	0.8	BTG14C2	0.6	BTG19A1	0.5	BTG22L1	0.5
BTG07F1	0.8	BTG14D1	0.8	BTG19B1	0.5	BTG25B1	0.7
BTG08A1	0.7	BTG14F1	0.6	BTG19D1	0.6	BTG25C1	0.6
BTG08D1	0.8	BTG14G1	0.5	BTG19E1	0.6	BTG26A1	0.7
BTG08G1	0.8	BTG14H1	0.8	BTG19F1	0.5	BTG26C1	0.5
BTG08H1	0.6	BTG14I1	0.7	BTG19G1	0.5	BTG37A1	-0.9
BTG08I1	0.7	BTG14L1	0.8	BTG19H1	0.5	BTG39E1	0.5
BTG08L1	0.7	BTG14L2	0.7	BTG20A1	0.6	BTG39K1	0.5
BTG09A1	0.7	BTG15B2	0.5	BTG20C1	0.6	BTG40N1	-0.5
BTG09A2	1.1	BTG15C2	0.5	BTG20G1	0.5	BTG41J1	0.7
BTG09B1	0.8	BTG15D1	1.0	BTG20H1	0.7		
BTG09B2	0.8	BTG15D2	0.7	BTG20J1	0.7		
BTG09C1	0.8	BTG15E1	0.7	BTG20L1	0.5		
BTG09C2	0.7	BTG15E2	0.8	BTG20M1	0.5		
BTG09D2	0.5	BTG15F1	0.7	BTG20N1	0.6		
BTG09E1	0.6	BTG15H1	1.1	BTG21I1	0.6		
BTG09E2	0.5	BTG15H2	0.5	BTG21J1	0.5		
BTG09F1	0.5	BTG16A2	0.7	BTG21L1	0.5		
BTG09H2	0.7	BTG16B1	0.5	BTG21M1	0.5		
BTG09I2	0.5	BTG16B2	0.8	BTG21N1	0.5		
BTG09J2	0.6	BTG16D2	0.7	BTG21P1	0.9		
BTG09L1	0.8	BTG16E1	0.6	BTG22A1	0.7		
BTG09L2	0.9	BTG16E2	0.5	BTG22B1	0.6		
BTG09M1	0.9	BTG16I1	0.5	BTG22D1	1.0		
BTG09M2	0.6	BTG17A1	1.0	BTG22E1	0.7		
BTG11A1	0.8	BTG17B1	0.5	BTG22F1	1.1		