INTEGRATING SCHOOL AND WORK PERSPECTIVES ON STATISTICS IN VOCATIONAL LABORATORY EDUCATION

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The research reported here took place at the boundary between school and work so we could study how students in work placement (apprenticeship) can be helped to integrate different perspectives. The intervention consisted of five one-hour meetings with three students aged 19 and followed a boundary-crossing approach, stimulating students to make connections between school and work perspectives on statistics. The main question was how well they learned to integrate these perspectives during the intervention. Using a hierarchy of integration levels, the analysis shows that students' improvement in level of integration was statistically significant and with moderate effect size. This suggests that boundary-crossing approaches are worth exploring further to help students integrate school and work perspectives.

Key words: *boundary crossing, integration, vocational education, workplace mathematics*

THE PROBLEM AND PURPOSE

The mathematics of school and work differ drastically, as researchers have shown over the last 25 years (e.g., Lave, 1988). It is therefore not surprising that many people find it hard to make connections, and use 'school mathematics' fruitfully at work (Nunes, Schliemann, & Carraher, 1993). The same situation exists for statistics. For example, statistical process control is very common in companies (Bakker, Kent, Derry, Noss, & Hoyles, 2008) but hardly ever taught in schools. In the context of laboratory education, the typical school perspective on statistics includes concepts and measures such as arithmetic mean, standard deviation, correlation and regression, which students learn in the first two years of secondary vocational laboratory education. A work perspective, however, is mostly concerned with stability and reproducibility of measurement and the linearity of machines that are compared: measurements of the same substance need to be stable, and they need to be reproducible by different people and on different days. Moreover, if two machines measure the same substances, they ideally produce the same values (y=x); in practice a correlation coefficient of .99 is satisfactory.

Method comparison is a common work task for many students in clinical chemistry education, which involves a lot of statistics. The core of the comparison is pair-wise comparison of patient blood in both machines, leading to paired data to be represented in a scatterplot (Figure 1). Correlation and regression are applied to measure the degree of correlation (here $R^2 = 0.9634$) and, more importantly, the slope of the regression line (here 0.7464). However, lab technicians typically think in terms of linearity (is the correlation coefficient close to 1.000?), bias (does the slope deviate from 1.0?), stability and reproducibility (measured with the variation coefficient). What is not clear for most students are the connections between school-statistical concepts and techniques such as variation coefficient, slope, correlation and regression on the one hand and lab technical concepts such as stability, bias and linearity on the other. Lab technicians often consider these last concepts also as 'statistics' because they are measured with statistical measures (variation coefficient etc.).

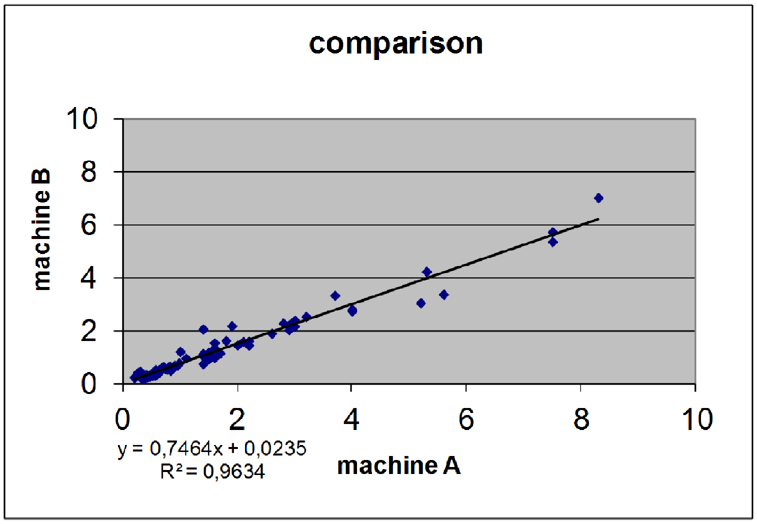

Figure 1: Comparison of machines A and B

We present an example from out research to show how these perspectives can be inseparable in concrete examples. Assume a new machine, such as B in Figure 1, is going to be used because it is reliable (assuming $R^2 = 0.9634$ is fine), faster and cheaper than machine A, but systematically measuring lower than machine A. The slope of 0.7464 suggests that the bias is about -25.4%. What should the lab technicians decide? One option is to build in a correction factor (of 1/0.7464 = 1.34) into machine B's software so that measurement values are pretty much the same as before with machine A. Another option is to tell medical specialists that the values have gone down systematically. If a reference value of 0.5 mg/L of a particular substance (here a specific protein) in blood used to be the critical value for checking a particular disease (here thrombosis), the new reference value would become 0.7464* 0.5= 0.37 mg/L. Both options have advantages and disadvantages. In the first option, specialists do not have to get used to new reference values, but there is a risk in a reboot of the machine or installation of updated software that the correction factor is not carried over or that users are not aware of a correction factor being built in. In the second option, specialists will get confused because they have a sense of which concentrations of substances in blood are of clinical significance. If these values change because of one machine measuring differently, they will not be pleased. Moreover, comparison across labs or hospitals will become impossible.

Given such different perspectives on statistics, the question arises how students can be helped to integrate these school and work perspectives. To this end we have designed an intervention in vocational laboratory education for students in work placement (apprenticeship without payment) who come back to school once in two weeks. The purpose of this paper is to evaluate how this intervention helped these students integrate school and work perspectives on statistics. Insight into this process is also relevant to statistics educators in general education who want to help students ‘apply’ their school-informed statistical knowledge.

TRANSFER AND BOUNDARY CROSSING

As many scholars have argued, adopting a transfer perspective on the problem has its limitations (e.g., Lave, 1988). Transfer is mostly considered to be the application of some general principle by a person in a new situation when confronted with a task. The concept is thus unidirectional and oriented on individuals performing tasks. In sociocultural traditions (e.g., Tuomi-Gröhn & Engeström, 2003), the alternative metaphor of boundary crossing has been proposed to capture the often more complex situation that people move not only forth but also back. Boundary crossing is therefore bidirectional, dynamic, and oriented on both individual and collective. We do not wish to imply that transfer does not exist or is not worth pursuing. We only suggest that the concept of boundary crossing draws attention to a wider range of relevant processes involved in learning to integrate different perspectives.

If not just transfer but boundary crossing is to be promoted in vocational education, what would it look like? In mathematics and statistics education, several researchers have explored the potential of boundary-crossing ideas in vocational and workplace settings. Wake and Williams (2007) invited mathematics college students to workplaces and discussed what they had seen. In collaboration with companies, Hoyles, Noss, Kent, and Bakker (2010) developed an approach to designing mathematical learning opportunities along with so-called technology-enhanced boundary objects – reconfigurations of workplace artefacts that involved some mathematics or statistics. Boundary objects are objects that are functional in different communities and fulfil a need, but typically not the same for each community (Star, 2010). For statistical examples see Bakker, Kent, Noss and Hoyles (2009).

In our review study on boundary crossing, we identified different learning mechanisms potentially involved in boundary crossing: identification, coordination, reflection and transformation (Akkerman & Bakker, 2011). We also determined characteristic processes belonging to these four learning mechanisms. For example, identification can lead to ‘othering’ and legitimate co-existence. Reflection often takes the form of perspective making or perspective taking.

In this paper we apply the insights gained in workplace training and our review study to vocational education. We focused on Dutch secondary vocational education (MBO), when students are mostly between 16 and 22 years old. The first year of MBO is typically school-based, but there is a gradual shift to work placement in the final year. The day release programme of the final year, when students come back to school one day per two weeks, is a particularly interesting boundary between education and work. We were particularly interested in helping students cross possible boundaries between school and work situations. This paper studies how we can promote and study integration of different perspectives.

BOUNDARY-CROSSING APPROACH AND QUESTION

We designed an approach in which students learned to integrate different perspectives. We drew on the boundary-crossing literature (Akkerman & Bakker, 2011) as a framework for action (diSessa & Cobb, 2004) to design what we came to call a *boundary-crossing approach*. This approach in MBO laboratory education (clinical chemistry) entailed the following.

a) Students were stimulated to formulate questions at work and ask them at school, and vice versa. In this way we promoted reflection: perspective making and taking (what is an acceptable correlation coefficient? Are outlier tests really used in the labs?).

b) Workplace supervisors were invited at school to answer students' questions and tell about how statistics was used in hospital laboratories (further abbreviated to 'labs').

c) In the meetings we used software that was also commonly used in the labs (Excel).

d) A boundary object was used as the connecting thread through the meetings. In this case it was a report of a student's project of the previous school year. It was about comparing a new machine for measuring a concentration of a chemical substance with the old and reliable machine. We considered the report as a boundary object because it served different functions in different communities. Initially it was the end product of an student's project in a hospital lab (on method comparison) which contained results that were useful to the lab (whether the new machine was reliable and stable enough) and it was graded at school, so the student could get his diploma. We used it to give the next generation of students an idea of what kind of project they may be doing in their labs, to discuss the statistics needed for such projects, to stimulate students to ask questions, and for teachers and supervisors to talk about their expectations of students.

In this paper we evaluate one important aspect of our approach. We ask: *How well did the students learn to integrate school and work perspectives on statistics?*

METHOD

After ethnographic and survey research in laboratories, we designed the aforementioned boundary-crossing approach. The participants were three students (19 years old), one male, Ferdie and two female, Sylvana and Petra (all names are pseudonyms), in their fourth and final year of the highest level (4) of MBO laboratory education. The first author was their teacher for this intervention because the regular teacher did not feel comfortable enough about the statistics involved. Two supervisors from a hospital lab were invited in the third session to answer the students' questions and discuss with them what they thought was important about the statistics required for method comparison.

The following data were collected: pre-interviews with two teachers were audio recorded, all classroom interaction was video and audio recorded by the second author. A brief questionnaire was handed out beforehand and discussed with the students. All verbal interactions were transcribed verbatim.

To test if students learned to better integrate both school and work perspectives on method comparison, we developed a coding system for levels of integration (Table 1). It is based on the following assumptions:

- Involving *both* a school and work perspective on statistics in a statement or reasoning is of a higher level of integration than involving *either* a school *or* a work perspective. Hence levels 3 and 4 in Table 1 are defined as higher than levels 1 and 2.
- *Reasoning, predicting or explaining* is in general of a higher level than merely making a *statement*. A sign of reasoning is if students use if-then constructions and a sign of explanation is if cause-effect relationships are discussed. Hence level 2 is considered higher than level 1, and level 4 higher than level 3.

Level	Characterization
1	Statement about something from a school perspective *or* work perspective but without explanation, prediction or reasoning
2	Reasoning (explaining, predicting) only from a school perspective *or* a work perspective
3	Statement from both a school *and* a work perspective but without explanation, prediction or reasoning
4	Reasoning (explaining, predicting) from both a school *and* a work perspective

Table 1: Levels of integrating perspectives

For the sake of being able to measure improvement in levels of integration we quantified the levels at an interval scale from 1 to 4. Using Atlas.ti the transcripts were divided into fragments that covered one topic. This resulted in roughly 40 fragments per meeting, except in the third meeting when one supervisor talked quite long about particular topics (Table 2). Codes were attributed to fragments of *group* interaction. Each of the fragments got one code – determined by the highest level of statement or reasoning in that fragment, irrespective of which student made the statement or expressed the reasoning. Only correct reasoning was scored. Students' statements or reasoning led by the teacher were not coded. Intrareliability (consistency in coding 7.5 months later) was high (.86).

RESULTS

Meeting	M 1	M 2	M 3	M 4	M 5	Total
Level 1	29	25	11	21	17	103
Level 2	10	6	1	7	3	27
Level 3	3	9	7	7	20	46
Level 4	0	2	0	4	4	10
Total	42	42	19	39	44	186

Table 2: Numbers of integration levels codes for fragments in each meeting

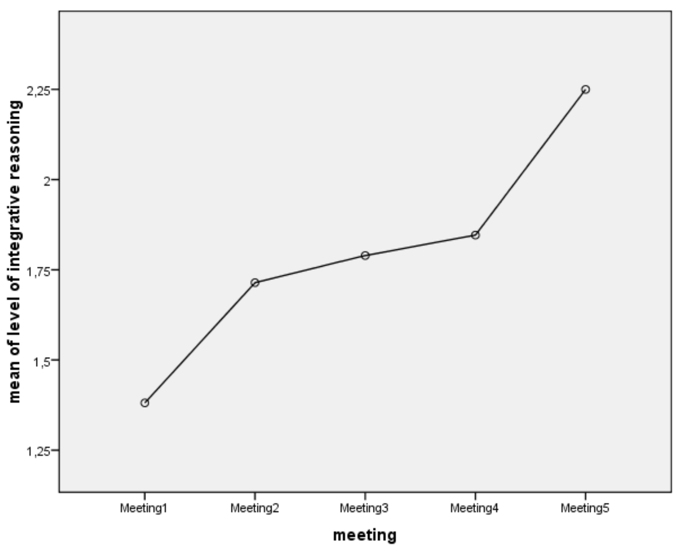

Figure 2. Mean level of integration during group interaction per meeting

Table 2 provides the number of integration level codes per meeting and level, and Figure 2 shows the average level of integrative reasoning per one-hour meeting. A one-way ANOVA with linear contrast showed that the increase in average reasoning level was statistically significant, $F(1, 181) = 16.61$, $p = .000$, $\eta^2 = .08$, which is a moderate effect size according to Cohen (1988). This suggests that our goal of improving integrative level was accomplished in the boundary-crossing approach taken. In the first meetings, the students mostly mentioned school *or* work perspectives, but in the later meetings, they more often included both perspectives when reasoning about work-related problems such as method comparison.

To give the reader a sense of the nature of improvement in integrating perspectives, we now turn to qualitative examples of each level in chronological order. When asked what is involved in method comparison, the students mentioned several statistical techniques and concepts but had little idea which to use for a method comparison. Because they did not mention correlation, which is actually at the core of method comparison, the teacher then asked:

Teacher: Correlation, do you remember what it is?

Sylvana: Yes.

Teacher: Correlation coefficient?

Ferdie: Yes, that.

Sylvana: I think with that line.

Ferdie: Yeah, that's it.

Sylvana: I think it is something like this [drawing a straight line].

This fragment from meeting 1 was coded at level 1 because students only mentioned something statistical without any reasoning.

From meeting 2 we quote Sylvana:

Sylvana: If the results [of the new method] deviate too much [from the reliable old method] (…) then you cannot use the method, because then the patients' measurements are not all right. Only a specific deviation is allowed.

This was considered reasoning (indicated by "if … then" and "because") but using only work-related, non-statistical reasons (level 2). If she had shown understanding of the deviation earlier in the transcript in terms of a slope of the regression line, variation coefficient or a standard deviation, then we would have coded it at level 4. We also see a bud of taking the perspective of a medical specialist: "then the patients' measurements are not all right".

In the third meeting one of the supervisors said they were satisfied with correlation coefficients of .9 for particular chemical substances. The supervisors and teacher stimulated the students to find out what the norm at their own labs was. In the fourth meeting Petra reported:

Petra: But there are things that are different in my lab. (…) They [the supervisors] said that a correlation of .9 was enough, but at my lab, they say .099, uhm, .99.

Here she mentioned both work-related (norm in my lab) and statistical elements (correlation coefficient), but we coded this as a statement rather than an example of reasoning (level 3) because she just reported facts without an explanation. In the identification and reflection processes we again see perspective taking: identifying how school and various labs may be different (yet legitimately co-existing). In a similar vein, students discovered that the outlier tests learned at school (Dixon's, Grubb's) are hardly ever used in labs.

To illustrate students' reasoning at the fourth level we first need to discuss one of the dilemmas introduced by one supervisor in the third meeting. The dilemma mentioned in the first section arose in the fifth meeting when the students discussing Ferdie's data (represented with some adjustments in Figure 1), because machine B systematically measured lower than machine A. This gave rise to interaction at level 4 because a school perspective (correction factor, learned during mathematics lessons) was connected to work (clinical) perspective (either for using a correction factor or changing the reference value – the cut-off point for medical decisions).

Sylvana: If you assume that this one [machine A] is reliable and this one [machine B] lower, then you can/

Petra: build in a correction factor.

Ferdie: That would be possible but the point is that these are totally different measurements.

Sylvana: But then you take reference values as your starting point.

Ferdie: I think you cannot just build that [correction factor] in.

Sylvana: Otherwise you would have to adjust that one [pointing to the reference value].

DISCUSSION

We asked how well students in our boundary-crossing approach learned to integrate school and work perspectives. The quantitative analysis suggests that the students' integration levels improved significantly and with medium effect size. The qualitative illustrations give a sense of how the students' reasoning increasingly involved school and work perspectives. In the last meetings they showed a rather sophisticated understanding of work-related dilemmas that involved statistics.

We suggest that boundary-crossing approaches are helpful in helping vocational students or students integrate knowledge from different sources such as statistics and the laboratory in their reasoning. However, this teaching experiment only considered three students in a setting in which all three worked on a similar work project (method comparison). More teaching experiments with larger groups in different vocational areas and with the regular teachers are desirable. Moreover, it is our experience (cf. diSessa & Cobb, 2004) that the quality of students' learning cannot be cleanly attributed to one characteristic of an approach (in this case a boundary-crossing approach). The quality of teaching, the suitability of the teaching materials, and participation by the students are all influential as well.

Yet we think our approach is promising. The regular teacher was very positive about the approach. After the third meeting she exclaimed: “This is a feast. This is what it should be like.” The students also appreciated the approach and claimed they had learned a lot. One interesting effect of inviting the workplace supervisors was that they started negotiating with the teachers about what was possible and desirable in the curriculum. They asked about the curriculum, the books used, and mentioned some wishes for a regional meeting in which school and work could be attuned. In other words, unplanned boundary crossing between supervisors and teachers was the result of the invitation to the third meeting. This last point underlines the importance of widening the focus on transfer to boundary crossing processes at the level of broader practices.

We think that research in the vocational area could be relevant to general education as well, because context-based, project-based and other authentic approaches are explored in general education. Insight into how mathematics and statistics are used at work and how vocational students can be prepared for this practical usage should be a useful resource for general education as well.

As Lave (1988) wrote: “It seems impossible to analyse education – in schooling, craft apprenticeship, or any other form – without considering its relations with the world for which it ostensibly prepares people.” This underlines the importance of studying relations between knowledge taught in education on the one hand and knowledge used in daily life or workplace settings on the other. Though she writes “it seems impossible” not to consider such relations, research at the boundary between school and work is still rare (e.g., Bakker et al., in press; Hahn, 2012).

One explanation for the lack of research on the transitions between school and work might be that vocational education is not a wide-spread educational system in many countries. Researchers are often unfamiliar with it and research in this area often requires hybrid expertise. Yet we encourage future research in this area because research in vocational education can help us understand how to bridge the gap between on the one hand abstract and general mathematics and statistics typically taught at schools and on the other situated workplace mathematics as typically found in workplaces.

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