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# Increasing retrievability and reusability of learning material by developing a measure of relevance based on academic teachers' conceptions

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## 1 Introduction

Web-based or web-supported teaching and learning are fast developing applications of information and communication technologies. One of the latest developments is the use of (multimedia) databases of learning material. One of the key problems concerns the retrieval of *relevant* units of learning material (ULM's). Examples of ULM's are written chapters, video segments, computer simulations, audio fragments, computer-based training packages, and so on [HiddinkHiddink1998]. This contribution reports about a research and development project that tries to enhance retrievability of ULM's by developing a measure of relevance based on a set of metadata labels that is related to the preferences of academic teachers for certain characteristics of learning material. The measure of relevance will take the form of a distance measure in a *metric space* that models the collection of ULMs present in the database. The project consists of two parts: (a) development of a distance measure that is based on the importance teachers assign to characteristics of learning material, and (b) testing the usability of the distance measure with a set of ULM's in an experimental database. The presentation focuses on the first step: the development of a distance measure.

## 2 Meta data for Units of Learning Material

Storing learning material (ULM's) in a (multimedia) database can have many advantages (see also ):

- saving production costs by reusing learning material [Tan NguyenTan Nguyen1993, RadaRada1995, Sarti Van MarckeSarti Van Marcke1995, Olimpo, Chioccariello, Tavella, TrentinOlimpo et al.1990] that is stored in a multimedia database [Persico, Sarti, ViarengoPersico et al.1992] and providing search facilities so that learning material can be easily retrieved.

- making this collection of learning materials available to a possibly very large group of teachers or instructional designers;
- a database can provide insulation between program and data, so that modifying the data (e.g. updating the curriculum) does not break the program
- providing multiple views on the same data, allowing a teacher, for example, to see all objects while a learner will only see the objects that fit his learning abilities and current knowledge level.

For searching these databases of multimedia databases in general, the field of Information Retrieval (IR) is developing methods to query a multimedia database in terms of its contents. Queries such as ``give me all pictures that contain a tree", and ``give me all audio fragments that contain a female singing voice" can be posed to the database system. In the field of Educational Technology, however, we would like to pose questions such as ``give me all ULM's that have been developed for university freshmen about constructing bridges, and I'd like to see lots of interactivity". A computer system will never be able to answer such a question if it hasn't been told what the subject of the learning material is, how much interactivity it contains, and for what target group it was developed. These characteristics have to be added manually (by human beings) to the ULM's, and this information is what we call ``meta-data": it tells us something about the ULM. Often, the meta-data also contains information about who created it, when, what are the copyrights, what technology is needed to use the ULM, and so forth. Mostly, for the descriptions for these characteristics a term is chosen from a predefined vocabulary where possible, the other characteristics are rated with free text. This allows teachers to enter words from a known vocabulary in order to retrieve learning material that fit their requirements.

Two major initiatives that use meta-data for retrieving learning objects are the IMS project[1] and the ARIADNE project[2]. These, and other, efforts to develop a metadata standard are brought together in a single group that is proposing a labeling scheme for learning objects[3]: the Learning Objects Metadata Group[4] (LOMG) of the Learning Technology Science Committee (LTSC) of the IEEE. In the research that is reported here, the proposed standard is adopted as much as possible.

# 3 The distance measure

Adding metadata to ULMs is more powerful than just provide a means to retrieve learning material with very specific characteristics. For example, if a teacher specifies a search question for ULMs with ``some" interactivity, then a ULM with ``a bit more" interactivity may also be very well suited for his or her[5] purposes; it depends on *how important the teacher thinks interactivity is*. The same is valid for the other characteristics (``metadata fields"): if the teacher thinks that the time a student needs to work with the ULM is not important, then deviations from the specified value can be tolerated.

Our research involves the development of a measure of how much a ULM deviates conceptually from the search specification. As has been made clear above, this depends on the teachers' conceptions about teaching: how important do they think interactivity is? Or the duration of the ULM? In Figure 1 we have depicted a three-dimensional space whose dimensions consist of characteristics of learning material: educational level[6], interactivity, and duration. The arrow

represents a *vector* in this space, pointing to a metadata record with value ``little" for interactivity, ``15" for duration, and ``univ 1" (first-year university) for educational level. As these values can be ordered per dimension, they can be modelled by the mathematical concept ``metric space".

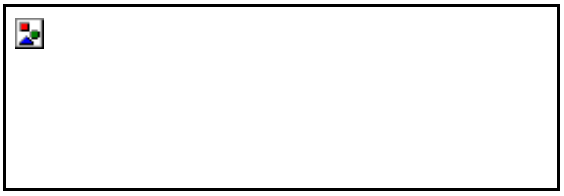

Figure 1: A multidimensional space of metrics

A teacher could specify the characteristics of the desired ULM using these values. The educational database will then search its metadata records, and examine the position of these records relative to the specified values. The distance measure, which now can be seen as a distance measure in a multidimensional space, is an indication of inhowfar the retrieved metadata records fulfill the search specification. The database system could then present, say, the 20 ULMs that best match the search specification.

As explained, this distance measure depends on how important the teachers think the characteristics are. A small deviation in an important characteristic may cause the teacher to reject the ULM. So one of the problems that need to be solved before a distance measure can be constructed, is to investigate what this relative importance is that teachers assign to characteristics of learning material. We are also interested in the precise influence that the teachers' belief has on these preferences; this will be elaborated uponin the next section.

# 4 Research questions

Our focus is the teachers' belief system, and its effect on the teachers' preferences for characteristics of learning material. Two main factors were believed to influence the relevance a teacher assigns to a particular search result: (a) the conceptions of teaching held by the teacher, and (b) the educational context of his teaching.

If, for example, a teacher is very student-oriented then he may find the amount and nature of interactivity very important. Another teacher may have a more instructivistic viewpoint, that is he designs learning material by examining the nature of the subject matter, determining learning objectives, selecting an appropriate strategy and applying this strategy onto the students. Such a teacher may find the subject matter of learning material very important, as well as its learning objectives. Theoretically, a teacher's conceptions of teaching would reflect the teacher education he (or she) has enjoyed, both theory and practice. However, in reality it seems that teachers base their belief system upon their daily experiences, both during their own training and their classes. found, reviewing a large body of research literature, that the personal beliefs of preservice teachers changed during their professional formation.

There have been several research efforts to determine aspects of teacher belief and to measure them, many utilizing different research methodologies. According to , the concept of ``teachers' conceptions" itself is too ambiguous to provide a coherent set of research results. Furthermore, conceptions are held unconsciously by the teachers, making it difficult to measure; use has to be made of time consuming methods to ilicit and assess thoughts. This, in turn, forces many investigations to limit the size of the subject population, so that the results may not be very generalizable.

analyzed academic teachers' conceptions of teaching, and synthesized a framework consisting of five dimensions, which are consistent with other research results on teacher belief [ Proser, Trigwell, TaylerProser et al.1994, Gow KemberGow Kember1993]. We chose these five dimensions because they of their dimensional nature. The dimensions as defined by are binary (i.e. consisted of only two values), but we will interpret these dimensions as a continuous scale. We assume that a teacher will seldom be on the extreme side of the dimension, and more possibly will be somewhere in between. Using a continuum allows us to locate these positions ``in between" as well. These dimensions are:[7]

**Learning Outcome**

The expected outcome of the learning process. This dimension ranges from ``students know more" to ``students know differently".

**Nature of Knowledge**

the nature of the knowledge to be learned, which ranges from knowing the subject matter, to being able to relate the subject matter to reality.

[Students' Conceptions] The degree to which the teacher takes the conceptions the students have into account.

[Bidirectionality] The degree of bidirectionality the teacher thinks is most appropriate: none (teaching is unidirectional, i.e. transmitting knowledge) or a lot (teaching is bidirectional, e.g. engaging in a conversation with the students).

[Content Control] The amount of control students have on the content of teaching.

use these dimensions as ``building blocks" for five conceptions of teaching; they coded the extremes of the dimensions as A and B, and described each conception as values of these dimensions. So, each conception they identified in their research can be seen as a combination of five values of A, B or AB; one for each dimension. The conception *learning is imparting information*, for example, is composed of the five dimensions as shown in Table 1.

Table 1: An example of the decomposition of a teacher conception into five dimensions.

| Dimension | code | meaning |
|---|---|---|
| Learning Outcome | A | to know more |

| | | |
|---|---|---|
| Nature of Knowledge | A | curriculum bound |
| Students' Conceptions | A | not taken into account |
| Bidirectionality | AB | both high and low |
| Students' Content Control | A | none |

As these five dimensions are not necessarily limited to describing five conceptions of teaching, they are more powerful than the conceptions of teaching found by other researchers. Theoretically, $3^5 = 243$ different combinations (teachers' conceptions) are possible as we have 3 options for each of the dimensions. We therefor chose these dimensions as the basis for our research.

We can then pose the first research question as follows:

> **RQ 1** Does the importance teachers assign to characteristics of learning material depend on their conceptions of teaching as modeled by the five dimensions of Samuelowicz and Bain?

Not only the conceptions of teaching can be of influence, but also the educational context in which the teacher is performing. If the target group of learners do not have sufficient self-management capabilities that they can work through large assignments unattended, then they may need other pedagogical materials; he will then find the pedagogical aspects of learning material of particular interest. Or, if the teacher wants to find extra assignments for fast students. The subject matter may then be considered less important, while the difficulty of the learning material must be relatively high to make sure the fast students will not become bored. This leads to the second research question:

> **RQ 2** Does the importance teachers assign to characteristics of learning material depend on the educational context?

# 5 Method

## instrument

To measure the the teachers' conceptions and their preferences for characteristics of learning material, a questionnaire was developed. Most questions have a closed format (multiple choice, ranking of alternatives, or rating scales). The structure of the questionnaire is as follows:

- The first part contains general questions about age, years of experience in education, years of experience with computers.
- The second part is designed to measure the teachers' position relative to the five dimensions of Samuelowicz and Bain. This is done in two ways: first, six case-based questions are posed to measure the position of a teacher on a dimension *indirectly* (questions B1 to B6). Next, 24 proposition-based attitude questions are used to measure

the position of a teacher on a dimension *directly* by posing attitude questions with a 5-point Likert scale (questions B7.1 to B7.24). The results on both types of questions will be used to cross-validate the results of this part of the survey.

- The third part of the questionnaire contains six educational contexts in which a need for learning material is described. For each educational context, the teacher is asked to rank five characteristics of learning material from most important to least important.

## The dimensions

The five dimensions were redefined to be a bit more formal than the definition of Samuelowicz and Bain. We define the position of a teacher on one of these dimensions to be somewhere on a continuous scale between '0' and '10'. We chose this scale because the Dutch grades range from 1 to 10, so a grade '7' gives us immediately the impression ``moderately good''; we included '0' because we would then have a continuum of exactly 10 units. During formative evaluation of the questionnaire (see below), we found that the variable 'SC' covered too many different notions, so we split it up into three sub-variables: conceptions on the subject matter, conceptions on the teaching process, and conceptions on society and the world.

First, we will describe for all seven variables how they are defined:

**SCa**

Students' Conceptions type 'a': a variable on this dimension takes the value '0' if the teacher, when taking educational decisions, does not take into account what the students' conceptions are regarding the subject matter. A variable takes the value '10' if the teacher *does* take these conceptions fully into account.

**SCb**

Students' Conceptions type 'b': a variable on this dimension is '0' if the teacher does not take into account what the students' conceptions are regarding the educational process; the variable will take the value '10' if the teacher does take these conceptions fully into account.

**SCc**

Students' Conceptions type 'c': a variable on this dimension is '0' if the teacher does not take into account what the students' conceptions are regarding the society around them. The variable will be '10' if the teacher does take these conceptions into account.

**CC**

Content Control: a variable on this dimension is '0' if the students have no control whatsoever on the content of the courses. The variable is '10' if the students really have a lot of freedom in determining their own course content.

[NK] Nature of Knowledge: a variable on this dimension is '0' if the nature of the knowledge to be taught is very theoretical and no relation with practice are shown by the teacher. The variable is '10' if the knowledge as it is taught by the teacher has a very strong relationship with practice.

**LO**

Learning Outcome: a variable on this dimension takes the value '0' if the teacher has the opinion that the goal of learning is to know *more*, and '10' if the teacher finds that the goal is to know *differently*.

[BI] Bidirectionality: the extend to which a teacher thinks that education is a two-way process (value '10'); a teacher that thinks that education means primarily a one-way transfer of knowledge is assigned value '0' on this dimension.

## Characteristics of learning material

We selected five educational characteristics from the set of IEEE metadata fields. The criteria for these characteristics were that they should be easy to understand by the teachers, and that they should be (probably) important to the teacher during the search process. The following were selected:

[subject] of the ULM;

[pedagogical function], such as exercise, theory, test, example;

[educational level], such as primary/secondary education, freshmen and graduate student;

[duration] of the ULM, which is the time a typical learner needs to work through it;

[amount of interactivity] of the ULM.

The questionnaire explained these five in some detail.

Six educational contexts were then described, such as: *suppose that some of your students are very fast learners, and that you would like to support them with additional materials.* For each context, the subjects were asked to give a ranking of the five characteristics, with rank '5' being the most important and rank '1' being the least.

## formative testing

The questionnaire has been tested and improved in two rounds with the help of samples of academic teachers (four in the first round, and four in the second), whose comments were used to enhance the quality of the questions. The first evaluation round was intended to resolve ambiguities, misunderstandings, and spelling errors. The position of the teachers in the second round on the dimensions were estimated by the researchers before the questionnaire was given to them, and these positions were compared to the position indicated by the questionnaire results. Discrepancies were then discussed with the teachers in order to find what caused them. This procedure also helped us to get a feeling of the validity of the questionnaire results.

During the evaluation rounds, it became clear that the dimension ``Student's Conceptions'' was not properly defined. About half of the teachers interpreted it as prerequisite knowledge, and there was no doubt that they said they would take prerequisite knowledge into account when making educational decisions. So we refined this concept into three parts: (a) students' conceptions about the subject matter, (b) students' conceptions about the educational processes at

their institution, and (c) students' conceptions about themselves and their relations to the world.

The teachers that were involved during formative testing of the questionnaire are excluded from the actual data collection.

Each question of the second part intended to measure the position of a teacher on one of the dimensions of Samuelowicz and Bain. This was done by assigning a score from 0 to 10 to each answer of each question, where the number indicated the position of the teacher on that dimension. As assigning these numbers is a subjective process, it was done by two researchers independently, and after that the results were compared. If the difference was more than three, then the researchers tried to find out if they had a different interpretation of the question or the answers. If so, then either one (or both) researchers adjusted their scores. If the difference was less than three, then nothing was changed. The final score for an answer then was calculated as the average of the score each researcher had given them. This way, the subjectivity of the score assignments was reduced.

Table 2 illustrates which questions of the questionnaire were used to measure which variables.

Table 2: The variables and the questions that measure them.

| Variable | Questions | Number |
|---|---|---|
| SCa | B1c, B7.4, B7.13, B7.19 | 4 |
| SCb | B1c, B7.14, B7.20 | 3 |
| SCc | B1c, B7.8, B7.21 | 3 |
| CC | B2, B3, B7.7, B7.16 | 4 |
| NK | B4, B6, B7.3, B7.9, B7.15 | 5 |
| BI | B7.5, B7.6, B7.10, B7.11, B7.12, B7.18 | 6 |
| LO | B5, B7.1, B7.2, B7.17, B7.22, B7.23, B7.24 | 7 |

# 6 Subjects

A sample of 196 teachers of the University of Twente has been selected. The subjects were chosen randomly from the University's course guide, and were evenly distributed among all faculties (both technical and non-technical). All subjects were contacted by phone to ask whether they were willing to participate in the research. A paper copy of the questionnaire has been sent to those who agreed. Several teachers asked whether they could fill in the questionnaire through the World-Wide Web. This option has been made available; the paper copy of the questionnaire that is sent to each participant mentions this possibility but leaves the choice to the subject.

# 7 Results

## 7.1 Respondents

Of the 196 selected teachers, only 86 could be reached by phone (44%) within about three tries. Of these 86 teachers, 71 (83%) were willing to participate in the research. These 71 teachers were sent a paper copy, of which 53 were returned (75%). Only three were returned via the World-Wide Web, the others were returned by mail.

Table 3 illustrates the distribution of the respondents across faculties, which is fairly equal (we didn't perform an analysis of per-faculty means because of the large number of variables involved and the small number of respondents per faculty).

Table 3: Distribution of respondents across the faculties

| Faculty | Number | Percentage |
|---|---|---|
| Mechanical Engineering | 3 | 75 |
| Electrical Engineering | 6 | 86 |
| Chemical Technology | 3 | 75 |
| Applied Physics | 5 | 100 |
| Mathematical Sciences | 5 | 63 |
| Philosophy and Social Sciences | 2 | 67 |
| Applied Communication Sciences | 3 | 75 |
| Public Administration adn Public Policy | 7 | 100 |
| Industrial Technology & Management | 4 | 57 |
| Civil Technology & Management | 1 | 50 |
| Educational Technology | 5 | 45 |
| Computer Science | 5 | 83 |
| Business Information Technology | 2 | 67 |
| unknown | 2 | |

Of two questionnaires the faculty could not be traced: a unique number was written on the self-addressed envelope that accompanied the copy; this number corresponded to a translation table, however the respondents returned the copy in a different envelope.

## 7.2 standardizing

The values obtained from scoring the answers have different statistical characteristics, even values of questions that measure the same dimension. These differences, specifically the mean and the standard deviation, are caused by the fact that the questions are different in nature. In order to still be able to calculate averages of answers for a particular dimension, the values have been standardized to have a mean of 0 and a standard deviation of 1. We asume the values have a natural distribution, so that all values are N(0,1) distributed. This allows us to calculate means within dimensions, which will be used in further statistical analysis.

## 7.3 cross validation

In the second part of the questionnaire, case-based questions and attitude questions were used. We will now verify if the case-based questions can cross-validate the attitude questions. Table 7.3 presents the correlations between the averages (if there were more than one) of the case-based questions and the attitude questions. Pearson's correlation coefficient was used as the values are numerical. The bold printed correlation coefficients are significant at the 0.01 level. For variable 'BI' no correlation could be calculated because the only case-based question that was present for this variable was removed during the formative evaluation because it was confounding.

Table 4: Pearson's correlation between case-based questions and attitude questions.

| Variable | Correlation | N |
|---|---|---|
| SCa | 0.28 | 28 |
| SCb | -0.09 | 27 |
| SCc | -0.12 | 24 |
| CC | **0.54** | 50 |
| NK | 0.12 | 51 |
| LO | **0.37** | 49 |

Note that for the SC variables we have only 24 to 28 observations, because we formulated one question for all three variables that was designed to inquire which of the SC conceptions (a, b or c) were important to the teacher when making educational decisions, and to measure how important this type was to the teacher. Many teachers chose one type of conception, which means that this question produced no data for the other types of conceptions.

As Table 7.3 shows, not all case-based questions and the attitude questions correlate significantly. This can be explained by the fact that the case-based questions elicit a certain behavior in a hypothetical situation, while the attitude questions require the subject to be the

judge of their own attitude. As states, these conceptions are often held unconsciously, and appear to be highly contextualized. The discrepancies we found between the behavioral questions and the attitude questions support this view.

As both types of questions do not validate each other, the question that now arises is: which of these two types of questions is the most valid? We cannot know this without further analysis. As we have more answers on the attitude questions, these seem to be more reliable so we will use these answers in the remaining of our data analysis.

## 7.4 Reliability

In order to determine the reliability of the data obtained, the results of the attitude questions (in the second part of the survey) were tested for conformance using Cronbach's α.

The conformance indications turned out to be quite low for some questions; some were even less than 0.10 . In order to improve the conformance, questions that were confounding were removed from the data set. The decision which question to remove was based on the item-total correlation, so items that correlate least with the total score, were removed. Only questions whose removal would provide a reasonable improvement of the reliability (α increased more than 0.10) were actually removed.

The variables and their Cronbach α coefficient are shown in Table 5. Per variable, the number of questions and the conformance index α is given on the left side of the table. The right side of the table shows, if applicable, what question was removed, and the α after removal. As five questionnaires were not complete, the data of 48 subjects could be extracted.

Table 5: Conformance of the answers, 48 subjects

| Variabele | nr. of questions | α | removed question | α' |
|---|---|---|---|---|
| SCa | 3 | 0.13 | B7. 13 | 0.47 |
| SCb | 2 | 0.09 | | 0.09 |
| SCc | 2 | 0.10 | | 0.10 |
| CC | 2 | 0.48 | | 0.48 |
| NK | 3 | 0.42 | B7.3 | 0.70 |
| LO | 7 | 0.45 | | 0.45 |
| BI | 5 | 0.43 | B7.5 | 0.52 |

As can be observed, SCb and SCc do not have a good conformance. We will therefor no longer consider these variables in the analysis of the results.

Due to the straight-forward nature of the questions in the third part of the questionnaire, in which we asked the respondents to rank five characteristics of learning material in order of importance for a certain educational context, we did not design reliability and validity checks for this part into the questionnaire.

## 7.5 Correlations

### 7.5.1 Correlations between dimensions

In Table 6, the correlations between the dimensions are given. For these correlations, we used the standardized data from which were eliminated the confounding answers as described in Section 7.4. Pearson's correlation coefficient was used, as the data is numerical.

Table 6: Correlations between the dimensions of teaching conceptions.

| | SCa | CC | NK | LO |
|---|---|---|---|---|
| CC | 0.23 | | | |
| NK | **0.38** | 0.17 | | |
| LO | 0.12 | 0.13 | 0.27 | |
| BI | 0.18 | **0.32** | **0.39** | 0.19 |

We will discuss the correlations that are significant at the 0.05 level (printed in bold face in Table 6).

The degree of conceptions of students about the subject matter that the teacher takes into account (SCa) correlates with the nature of the knowledge that is taught; a teacher that takes the students' conceptions about the subject matter into account, is likely to find the relations of the subject matter with the reality important. On the other hand, a teacher that doesn't take the conceptions of the students into account, is likely to just teach the theory and not expand on the practical aspects much.

Then, there is a correspondence between the amount of content control a teacher gives to his students (CC) and the bidirectionality of his teaching. The data shows that a teacher that allows a lot of control over the content to his students, is also likely to talk a lot with them.

Finally, there is a correspondence between the nature of the knowledge that is taught, and the amount of bidirectionality. A teacher that find the practical side of the theory important, is likely to view teaching as a bidirectional process.

## 7.6 Mean differences between contexts

In order to answer RQ2, we should test if the ranks in the contexts have significantly different means. Therefor, we performed paired samples t-tests for each characteristic; for example, for

characteristic ``duration'' we performed paired t-tests for the means in context 1 and 2, context 1 and 3, and so forth. Per characteristic, this yields 15 t-tests. We will use $\alpha < 0.01$ to be sure that the chances of accepting the null hypothesis while it is not true is relatively small (0.01 ×15 ×6 = 0.90, so there's a 90% chance that we accept one mean difference as being significantly not equal to zero, while it is). We will summarize the results of these tests in Table 7.6.

Table 7: Characteristics that have a significant mean difference between two contexts.

| characteristic | contexts | t | df | sig |
|---|---|---|---|---|
| level | 1 - 4 | -2.6 | 44 | 0.01 |
| level | 2 - 4 | -3.2 | 45 | 0.003 |
| level | 2 - 3 | -3.5 | 44 | 0.01 |
| level | 4 - 6 | 3.0 | 44 | 0.004 |
| function | 1 - 3 | 3.5 | 44 | 0.001 |
| function | 1 - 4 | 4.1 | 44 | 0.000 |
| function | 4 - 6 | -3.1 | 44 | 0.004 |
| duration | 2 - 3 | 2.8 | 44 | 0.007 |

The table shows eight significantly differing means, of which we can expect about one to be due to statistical errors. It should be noted that only three characteristics have differing means, the means of ``interactivity'' and ``subject'' are equal across all contexts.

## 7.7 Correlations between dimensions and preferences

For each of the six contexts, correlations were calculated between the rank for each characteristics and the teachers' score on the five dimensions. This would yield six tables with each 15 scores, so we will not include these tables in this article; they are available on request from the author, however.

As a rank variable is involved, we will use Spearman's $\rho$ as correlation coefficient. Table 8 displays the correlations that have been found.

Table 8: Correlations between characteristics of learning material and dimensions of teaching conceptions.

| Context | dimension | characteristic | Spearman's $\rho$ | N | sign. |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| 3 | BI | duration | -0.39 | 45 | 0.01 |
| 4 | SCa | function | -0.37 | 46 | 0.01 |
| 5 | CC | duration | -0.37 | 46 | 0.01 |
| 5 | BI | duration | -0.39 | 46 | 0.01 |
| 6 | CC | duration | -0.47 | 45 | 0.01 |
| 6 | BI | duration | -0.59 | 45 | 0.00 |

Note that for each context, 15 t-tests were performed. As $\alpha < 0.01$, there is a 1% chance per t-test that the correlation is the result of statistical variance instead of a true relation. As there are six contexts, we should expect 0.01 ×15 ×6 = 0.9 relations to be due to statistical errors.

The data shows that in three of the six contexts, teachers that find bidirectional education important are likely to care less about the duration of computer-based learning material. In two of the six contexts, teachers that allow students much control over the content of the course are also more likely to care less about the duration of the material. In one of the contexts, teachers that care about what the students think of the subject matter, were likely to find the pedagogical function of the material less important.

# 8 Discussion

## 8.1 Measurability

The variable ``Students' conceptions'' is, even after our improvements, not very well defined and is relatively hard to measure. The variables SCb and SCc are the only two that have a *negative* correlation (although not significant) between the case-based questions and the attitude questions. SCa has a correlation coefficient 0.28 with a reliability of 0.14, which makes it resonable to believe that the variable is valid. Another observation that supports the view that SCb and SCc have not been well defined, are the conformance indexes: 0.09 respectively 0.10 for SCb and SCc, and 0.47 for SCa. Also, in earlier research had problems discerning the Students' Conceptions dimension as well as the Learning Outcome dimension. In our research, however, this dimension is both moderately valid (cross validation correlation 0.37) and reliable (Cronbach's $\alpha$ is 0.45).

Another variable that has a low cross-validation, is NK with 0.04 correlation between case-based and attitude questions (see Table 7.3). As the attitude questions of variable NK have the highest conformance (0.70) of all (Table 5), we believe that the bad quality of the case-based questions for NK are the cause of the bad correlation, and we think that the variable NK as measured by the attitude questions *is* valid in spite of the bad cross-validation results.

The other variables are reasonably well measured, and seem to provide sufficient validity and reliability.

### 8.2 Conceptions of teaching

It should be noted that all observations support the difference between constructivistic and instructivistic teaching. Globally, we see on the one hand teachers that do not take into account what the students think and know about the subject matter; these teachers determine by their own what should be in the courses without consulting the students. In general they view teaching as a unidirectional process, in which the subject matter is transferred to the students (see Table 6).

On the other hand, we see teachers that do listen to their students, and that adapt the content of their courses to what the students already think about it; they even allow the students to choose subjects themselves (see Table 6).

Our observations present empirical evidence, albeit relatively weak, for these two very different conceptions on teaching, which are consistent with the notions of instructivism and constructivism.

### 8.3 Characteristics of learning material

The data shows that there are significant differences in mean ranks between contexts, so we have to conclude that the contexts are of influence on the teachers' preferences for characteristics of learning material. Two characteristics, however, are not sensitive to the contexts: ``subject'' and ``interaction''. Apparently, teachers have a fixed preference for these characteristics, which isn't subject to context changes. This can be explained by the proposition that constructivists find interaction very important throughout all phases of the educational process, while instructivists consider the precise subject matter as being crucial when making educational decisions (see for example ).

Also, there are small to medium interactions between dimensions of teachers' conceptions of teaching and their preference for characteristics of learning material; most notably, the ``duration'' characteristic is sensitive to the dimensions ``bidirectionality'' and ``content control''. This is also in concordance with constructivistic theory: constructivistic teachers consider bidirectionality and control of content very important, and generally consider the time the learning process takes as just a necessity.

## 9 Distance Measure

The results show that the teachers' preference for characteristics of learning material depends on the educational context and on the teachers' conceptions of teaching. However, if we consider the interaction between the five dimensions and the five characteristics of learning material, we see that of a total of 15 possible interactions, we have only found 3. There are also many more educational contexts than the ones we examined; and we do not know their effect on the teachers' preferences for characteristics. So, although we now know that the teachers' preferences are related to the educational context and the teachers' belief system, we do not have sufficient data to construct a distance measure that predicts the teachers' preferences.

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## Footnotes:

[1] http://www.imsproject.org

[2] http://ariadne.unil.ch

[3] We differentiate between ULMs and learning objects in general because there are many different definitions of these concepts.

[4] http://ltsc.ieee.org/wg12

[5] Where we write 'he' or 'his', we also mean 'her' and 'hers'.

[6] Mavo, havo, and vwo are three dutch secondary school types.

[7] We have renamed the dimensions in order to make it easier to define a continuous scale; refer to the original paper for the original definitions.

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