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ABSTRACT

This study sought to evaluate the goals and functions of practical tests for undergraduate students in the natural sciences in university distance education (DUE) programs in the Netherlands, and to compare the findings with results from similar research conducted in regard to science practicals at the Open University of the Netherlands (OuN) and traditional university-level education (UE). Fifteen faculty at DUE institutions were asked to rate the importance of 8 general learning objectives, 102 specific learning objectives among which were 64 specific learning objectives and 38 specific end-terms for undergraduate practicals in the natural sciences. The study found that most faculty at DUE institutions approached practicals in similar ways, and that the ability to solve problems, interpret experimental data, and use knowledge and skills in unfamiliar situations were considered the most important general objectives for students at DUE institutions. It also found that although the differences between OuN and DUE rankings were larger than the difference between DUE and UE rankings, the rankings by faculty at each of the three institutions were statistically unique. Sixteen appendixes provide data on the ratings of general objectives, specific objectives, and end-terms by DUE, UE, and OuN faculty. (Contains 22 references, 16 appendices and the survey instruments.) (MDM)

Learning objectives for practicals in institutes of higher distance education

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Learning objectives for practicals in institutes of higher distance education.

OTIC Research report 24

Paul Kirschner
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Evert Middelbeek
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Contents

Summary

The research described in this report is part of a research project on the *perceived importance* of learning objectives and end-terms for practicals in undergraduate higher science education. This report focuses on higher distance education. The results for institutes for university distance education (DUE) are reported and compared with the results obtained in earlier studies at the Open university of the Netherlands (OuN) and the more traditional (face-to-face) universities in the Netherlands (UE).
A focal point of this study is to determine whether, and to what extent, the perceived importance of the objectives and end-terms depends on the type of institute (traditional face-to-face education or open distance education) and/or the type of education offered (monodisciplinary versus inter/multidisciplinary).
An inventory of learning objectives and end-terms for undergraduate practicals in the natural sciences, as contained in the literature, was made at an earlier stage of this project. The resulting list, consisting of a small number of general learning objectives and end-terms (and a large number of specifications thereof), is the starting point of the instruments used in this and previous research.
The respondents in this study are members of the faculties and/or departments of distance universities offering education in the natural sciences throughout the world.

The major conclusions from the research are:
- The different institutes making up the sample population for DUE approach practicals in the Natural Sciences in a similar way. This can be seen on the coefficient of concordance (Kendall's *W*). The degree of concordance across the sample population is large. As a matter of fact it's level of significance is about the same as that of the OuN. This is rather remarkable considering the differences between the individual respondents with respect to culture, language, educational background, etcetera. The only things which they all appear to have in common is that they all are institutes for distance education and they all approach the Natural Sciences in a monodisciplinary way.
- The ability to solve problems, interpret experimental data and use knowledge and skills in unfamiliar situations are far and away the most important general objectives for the students attending these institutions to achieve. The importance of the first two is also reflected in the ratings of their component specific objectives. The operationalisations of the third general objective are, on the other hand, ranked very low.
- The ability to describe an experiment is far and away the least important general objective for the students attending these institutions to achieve. When the component specific objectives subsumed under the general objectives are used to calculate the relative importance of the general objectives, then the ability to describe an experiment jumps from last to second place.
- The specific objectives which DUE rates as *indispensable* are primarily elementary laboratory skills relating to doing practical work. Those objectives which were rated as *neutral* are, on the other hand, primarily higher academic skills relating to reasoning and problem solving.

1 The Open university of the Netherlands and other institutions for higher distance education

This report is part of a research project into the evaluation of learning objectives and end-terms for undergraduate science practicals in institutes of higher education. Two reports '*Learning objectives for practicals at the Open university of the Netherlands*' and '*Learning objectives for practicals in institutes for higher education in the Netherlands*' have preceded the present study. The former is a study of the value placed upon objectives and end-terms for practicals at the Open university of the Netherlands (OuN). The latter concerns the evaluation of (the same) objectives and end-terms by more 'traditional' institutes of higher (face-to-face) education in the Netherlands, both university education (UE) and higher vocational education (HVE).
In the present report we discuss the evaluation of these same learning objectives and end-terms by a number of institutes for university distance education (DUE) which have programmes in the Natural Sciences and compare these results with those found at the OuN and in UE.

Traditional (face-to-face) universities differ so much from distance universities (DU's) that it is quite conceivable that a number of objectives and end-terms for practicals to which they strive differ from each other. This assumption is not so much based on the fact that DU's such as the OuN have limited possibilities for organizing practicals, but rather on the special nature of DU's, and specifically their underlying philosophies (distance education instead of face-to-face education). Apart from this difference, the OuN also differs from most other universities (both distance and face-to-face) in that it offers a different type of science education programme (an inter- or multidisciplinary programme as opposed to a monodisciplinary one). These differences have led to a reconsideration of learning objectives and end-terms for science education in general and science practicals in particular within the OuN.

With regard to the *nature of the institutions*, it can be said that the OuN as well as the distance universities in other countries distinguish themselves from other types of institutes in that they put special emphasis on a number of freedoms which they offer to students. They all allow their students to study where they wish, while some (i.e. the OuN, the Center for Distance Education at the Empire State College) also allow their students to study when they want and to choose their own pace of study. As a consequence, the number of times that students should be required to come to a specific place at a specific time in a specific phase of their study, e.g. for practicals, need be kept to a minimum. This limitation should necessitate these institutions to choose those learning objectives and end-terms that are really necessary for their programmes from all the possible learning objectives for a specific domain of study. This, in turn, implies that these institutions should reconsider the role and function of practicals in the undergraduate part of their educational programmes and give priority to a certain type of learning objectives (e.g. academic or cognitive skills) at the expense of other learning objectives (e.g. motor skills).

With regard to the *type of educational programme offered*, it can be said that the OuN (as well as some fairly new disciplines within UE) offers multi- or interdisciplinary programmes. A typical example of such an educational programme is the Environmental Science programme at the OuN, which seeks an integration of the natural and the social sciences. All these programmes aim at an integration or synthesis of disciplines by putting special emphasis on evaluative or synthetic behaviour and by focusing on the syntactic structure of the various disciplines. In monodisciplinary programmes, on the other hand, the emphasis will be on analytic behaviour and on the substantive structure of a specific discipline.

Together these differences yield a 2 x 2 matrix, of which the cells can be compared with each other:

	distance education	*face-to-face university education*
monodisciplinary	most open distance universities	most UE science faculties
inter-/multi-disciplinary	OuN	new UE science faculties

The present report is the third and last in a series of reports concerning the empirical part of the research project *'Practicals in Higher Science Education'*. The first report (Meester, Kirschner, Middelbeek & Hermans, 1989; Kirschner, Meester & Middelbeek, 1990) discusses the results of a research project carried out within the staff of the product group Natural Sciences at the OuN on the perceived importance of learning objectives and end-terms for practicals at the OuN.
The second report (Meester, Kirschner, Middelbeek & Hermans, 1990) discusses the results of research into the appreciation of learning objectives for practicals in other institutions of higher education (both university and polytechnic or vocational colleges) in the Netherlands apart, as well as in comparison with the OuN. Paragraph 2.1 gives a short synopsis of the results of this research.
This final report discusses the results of research into learning objectives and end-terms for practicals in institutes of higher distance education abroad in comparison with the OuN and traditional (Dutch) universities.

2 The research

This research is aimed at the evaluation of general and specific learning objectives and end-terms for undergraduate science practicals in different institutes of university level distance education. In the analysis, the following stages can be distinguished:
- arrangement in order of importance of general learning objectives for practicals in DUE;
- evaluation of specific learning objectives for practicals by the respondents (and their relationship to the six general learning objectives);
- evaluation of end-terms for practicals by the respondents;
- comparison of the results of DUE with those of UE;
- comparison of the results of the OuN with those of DUE and UE;
- explicit formulation of the similarities and differences between the three types of education on the basis of their views on undergraduate practicals.

Before we start to describe the actual research, we will define a number of concepts used throughout this report.
The concept of *practical* is used to indicate a didactic method for learning and practising all the activities involved in the carrying out of one's profession. Within the Natural Sciences at the university level, this professional practise entails experimental work, beginning with the conception of a problem or the observation of a phenomenon to the communication of findings in the form of a report or a presentation. Hodson (1988) presents this relationship as follows:

experimental work is a subset of laboratory work. He refers to this as *laboratory bench work.* Laboratory work is a subset of practicals, which in turn is a subset of the didactics of science education. Figure 1 gives a schematic representation of this interrelationship.

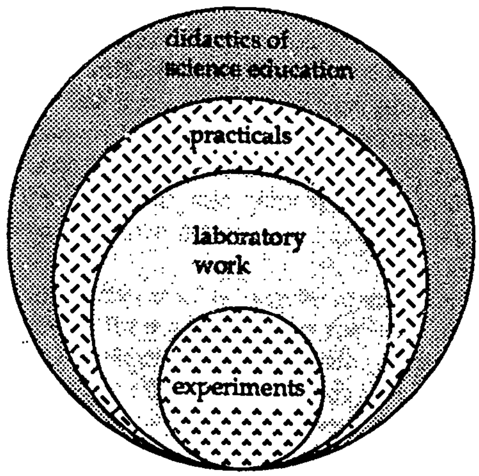

Figure 1
Interrelationship between experiments, laboratory work and practicals (Hodson, 1988)

The *undergraduate* part of an educational programme is the part of the programme that consists of short, well-defined courses that are obligatory for all students (of a certain discipline). In traditional universities in the Netherlands, the biology, chemistry and physics programmes comprise approximately 800-1000 hours of undergraduate practicals. Besides this undergraduate part of the programme, approximately 1200 hours are reserved for work experience or research training.
The *general learning objectives* have been formulated on the basis of the expected learning results; they have been fitted with a list of achievements that specify the eventual behaviour of the students (the *specific learning objectives*).
The difference between *objectives* and *end-terms* for practicals can be described as follows: for the attainment of the general and the specific objectives, the execution of practicals is a purpose in itself whereas for the achievement of the end-terms, the execution of practicals (besides many other didactic methods) is a means to an end.

2.1 *Synopsis of the results of the research within the OuN and other institutions for higher education in the Netherlands*

In this section, we discuss the most poignant results of the previous two studies. For more complete information, the reader is referred to these two reports as well as appendices 1 through 4 in which the scores for the specific objectives and end-terms for the OuN and UE are given.

General learning objectives

The members of the product group Natural Sciences of the OuN and science faculty members from Dutch universities and institutes of higher vocational education were asked to evaluate (using a paired comparison evaluation instrument) eight general learning objectives (Kirschner and Meester, 1988). The general objectives were formulated on the basis of a clustering of the specific objectives that were found in the literature and reflect the course of an ideal experiment. In the course of the research, as a result of further analysis and reclassification of the specific objectives, two general objectives were excluded so that six were left.[1] The results of these evaluations are listed in table 1.

Table 1
Ranking of importance of general learning objectives

general learning objectives[a]	*rank*[b] *OuN*	*ave score*	*rank UE*	*ave score*	*OuN-UE*
to solve problems (*A*)	4	2.83	4	2.55	0.28
to use knowledge and skills in unfamiliar situations (*B*)	1	3.58	2	2.73	0.85
to design (simple) experiments to test hypotheses (*C*)	3	3.08	1	3.09	-0.01
to use lab skills in performing (simple) experiments (*D*)	6	0.50	5	2.05	-1.55[c]
to interpret experimental data (*E*)	2	3.42	3	2.68	0.74
to clearly describe the experiment (*F*)	5	1.42	6	1.77	-0.35

[a] The letters after the objectives correspond to the letters in appendix 8.
[b] 1 = most important; 6 = least important
[c] $p < 0.001$

The difference between the most and least highly valued objective at the OuN is 3.08. A 'paired *t*-test' has demonstrated that a distinction can be made between the four most highly valued general objectives for the OuN (*B*, *E*, *C*, and *A*) which do not differ from each other statistically (t=0.68; p>0.12) and the two least valued general objectives (*F* and *D*) (t=2.2; p<0.005).
The order of priority with regard to the general objectives as expressed by the respondents from UE is, on the other hand, quite subtle. The difference here between the most and least important objective is only 1.32. Two important general objectives 'to design experiments to test hypotheses' (*C*) and 'to interpret experimental data' (*E*) score significantly higher (t=3.23; p<0.05; t=2.34; p<0.05 respectively) than the least important general objective 'to clearly describe an experiment' (*F*). The most important objective (*C*) also scores significantly higher ($t \geq 2.38$; p<0.05) than the objective 'to use laboratory skills'(*D*). Otherwise there are no significant differences.
The last column of the table gives the differences between the average scores of the OuN and UE. A positive difference means that the objective is considered more important at the OuN than in UE. A negative difference means that the opposite is the case.
These results tend to the conclusion that, with regard to the learning objectives for undergraduate practicals, the OuN places much more emphasis on learning to use knowledge in unfamiliar situations (*B*) and learning to interpret data (*E*) than UE. This is probably the result of the highly specific character of the OuN which focuses on and strives to provide 'a type of education which enables its graduates to learn to think in a problem oriented manner (End-terms, 1986). On the other hand, UE places a great deal more emphasis on learning to use laboratory skills in performing experiments (*D*) than the OuN. In other words, what the OuN graduate misses in laboratory skills is/must be more than compensated by training in problem oriented and problem solving thinking. None of the other differences was significant.

Specific learning objectives
We used a Likert-scale inventory to assess the perceived importance of 64 specific learning objectives. The frequency distribution of the specific objectives in order of decreasing importance can be found in table 2.

[1] The motivation for this decision can be found in paragraph 5.1

Table 2
Frequency distribution and percentages of 64 specific learning objectives arranged in order of decreasing importance

type of institute	*1*[a]	*2*	*3*	*4*	*5*
UE	23 (36%)	33 (52%)	8 (13%)	-	-
OuN	11 (17%)	37 (58%)	10 (16%)	6 (9%)	-

[a] 1 = indispensable ($1.00 \le x < 1.80$); 2 = important ($1.80 \le x < 2.60$); 3 = neutral ($2.60 \le x < 3.40$); 4 = not really necessary ($3.40 \le x < 4.20$); 5 = superfluous ($4.20 \le x \le 5.00$)

A striking aspect of this table is the large number of objectives classified as worthwhile (*indispensable* or *important*) by both respondent groups, especially by the group of UE respondents (88% of all the specific learning objectives), whereas the categories *not really necessary* and *superfluous* are empty for UE. This is not really surprising, given the fact that the list of specific objectives is based on literature on objectives for practicals in traditional undergraduate science education (Kirschner and Meester, 1988). The OuN, on the other hand, assesses nearly 10% of the objectives as being *not really necessary* and is less positive about twice the number of objectives as UE (16 vs. 8 objectives). This is also not surprising when one considers the programmatic and philosophical differences between the OuN and UE. Five of these objectives are common to both response groups. Nine of the remaining eleven objectives deal with using laboratory skills in performing experiments (general objective *D*). This supports the differences noted in the previous section.
This quantitative analysis was enriched with the following qualitative analysis. The OuN varies greatly from UE with regard to 21 specific objectives. These objectives provide specific information about how the OuN differs from UE. These may be objectives which the OuN considers much more important than UE ($\Delta Z \geq 1$) or objectives which OuN values as much less important than UE ($\Delta Z \leq -1$). It does not necessarily mean that UE does not value these objectives as important, but merely that the OuN values them as either *much more important* or *much less important*. A typical example of this is the objective 'to confirm facts, principles and theory from lecture/books' (see table 3).

The learning objectives of the list with negative ΔZ values all, except for one, relate to practical manual skills *during* the actual realization of an experiment. All of them, except for 'processing of experimental data' are specifications of general objective *D* 'to use laboratory skills in performing (simple) experiments'. UE values these practical laboratory skills as *indispensable* objectives, but for an OuN graduate in science they are *not really necessary* (Meester et al., 1989).
Of the 11 objectives with positive ΔZ-scores, seven are specifications of general objective *A* 'to solve problems'.

Table 3
Specific learning objectives with a large difference between the OuN and UE

specific learning objective	*ΔZ(OuN-UE)*	*general obj.*
to incorporate unexpected experimental results in a new model	2.14	E
to solve problems in a multi-solution situation	1.57	A
to derive and evaluate relationships	1.46	A
to solve difficult scientific problems	1.37	A
to confirm facts, principles and theory from lecture/books	1.35	A
to derive testable hypotheses from theories	1.34	A
to recognize and define scientific problems	1.19	B
to be flexible in modifying experiments	1.12	A
to discuss results with other scientists	1.09	F
to react adequately to unforeseen results	1.09	B
to decompose large problems into smaller problems	1.04	A
to use practical (as opposed to theoretical) lab skills	-1.86	D
to calibrate instruments	-1.74	D
to set up lab equipment quickly and correctly	-1.73	D
to collect experimental data	-1.72	D
to carry out accurate measurements	-1.70	D
to handle modern equipment	-1.66	D
to put basic laboratory techniques to use	-1.47	D
to conduct experiments safely	-1.47	D
to manipulate apparati	-1.46	D
to process experimental data	-1.02	E

[a] $\Delta Z \geq +1$ means this learning objective is considered much more important by the OuN than by UE
$\Delta Z \leq -1$ means this learning objective is considered much less important by the OuN than by UE

End-terms
The article by Kirschner & Meester (1988) mentions the following two general end-terms:
I to obtain good (scientific) attitudes
II to understand the scientific method
Each of these end-terms corresponds to a large number of specifications. Nearly all of the specifications of the end-terms were rated as important to very important by the product group Natural Sciences of the OuN. This is not surprising considering the fact that these are end-terms for an undergraduate study in the natural sciences as a whole, for which practicals are but a means to that end.
When applying the criterion that a $|\Delta Z| \geq 1$ indicates an essential difference between the institutes to be compared, the OuN differs considerably from UE with regard to six end-terms. Three of the end-terms were rated higher by the OuN than UE, namely: to be self-confident and independent, to build a framework for facts, principles and theory from lectures/books, and to survey literature relevant to a problem. Three other end-terms were rated more important by UE than by the OuN, namely: to do experiments, to work in research and development labs, and to use the laboratory as an instrument of discovery. These differences confirm the picture that UE is more concerned with mastering the actual techniques of experimenting while the OuN is more interested in the theoretical side of practicals.
One striking aspect is the difference with respect to the end-term 'to be self-confident and independent' which the OuN rates much more highly than UE. UE students, by virtue of their admission to the university are already fairly self-confident and independent. OuN students must accrue these qualities through their studies. The staff there is also well aware of this and as such places more value on such end-terms.

Finally, the three end-terms rated more highly by UE relate to the using and carrying out experiments and research. The OuN has to a large extent abandoned this type of activity when programming its Natural Science distance education. The end-term 'to build a framework for facts, principles and theory from lectures/books' indicates that within the OuN the emphasis is on integration of (theoretical) knowledge from various sources.

In conclusion, the results of the first two studies showed that:
- There is a definite difference between the OuN and UE. This difference is noteworthy, but explainable. Although the OuN and UE are both academic (as opposed to vocational) institutions, this similarity is not as strong as the differences between them. UE is monodisciplinary; the OuN is not. UE trains its students to *do* research; the OuN trains its students to *apply* the research of others.
- UE values the 'use of laboratory skills in performing (simple) experiments' (*D*) more highly than the OuN does. This was to be expected.
- The identity of the type of institute clearly comes to the fore. UE places little emphasis on practical skills (although much more than the OuN), but emphasizes the formulation of hypotheses or models and the design of experiments to test hypotheses (academic skills). The OuN attaches great importance to the ability to define and solve problems, to derive hypotheses from theories and to adapt models to new experimental results, and puts much less emphasis on laboratory skills (even less than UE).

3 Respondents

For this part of the research, 36 faculties, sectors or departments of distance universities offering education in (a subject area of) the Natural Sciences were written to with the request to let two instruments (see paragraph 4) be filled in by the person or persons responsible for practicals within the institute.
The institutes concerned were solicited according to the following two-step procedure:
- the boards of governors/directors of the various faculties, sectors, departments etc. were written to with the request to pass the instruments sent to them on to either a member of the educational committee or the coordinator of practicals of the group;
- in addition, the boards of governors/directors were asked to make the names and addresses of the respondents known to us by means of a reply card and a stamped self-addressed envelope, to allow us to contact him/her personally, if necessary.
Of the 36 institutes that were approached, three sent the instruments back blank for reasons of having no science program or teaching science at a lower level.
Of the remaining 33 institutes 18 respondents representing 11 different universities returned the inventories which leaves us with a response of 33%. Of these 18 respondents, three are left out of consideration in this study because they didn't meet our condition of being concerned with *practicals* in *science education* at an institute of *higher distance education*. The list of universities participating in this study can be found in appendix 5.
The remaining 15 respondents (10 institutes) represent the science disciplines chemistry (5), biology (4), physics (3), geology and earth sciences (2). Most of the respondents have a long record of service in higher distance education: ten of them have been working at these institutes for more than 10 years.
We decided to take as a starting point in this report the number of respondents instead of responding universities because of the fact that the participants belonging to the same institute appeared to respond for different disciplines within these institutes.

4 Research method

4.1 *Instruments*

Two instruments (inventories) were developed to determine the perceived importance of the learning objectives and end-terms. The first instrument consists of a paired comparison of eight general learning objectives (see appendix 6). These eight general objectives, derived from the article by Kirschner & Meester (1988), are based on the successive steps that a scientist ideally takes when carrying out an experiment.
These are:

- to formulate hypotheses
- to solve problems
- to use knowledge and skills in unfamiliar situations
- to design (simple) experiments to test hypotheses
- to use laboratory skills in performing (simple) experiments
- to interpret experimental data
- to clearly describe the experiment
- to remember the central idea of an experiment over a significantly long period of time.

In the instrument, each of the eight objectives is paired with each of the other seven, yielding a total of 28 pairs of objectives. Each of these pairs is presented on a separate page of a questionnaire book with a request to the respondents to indicate which of the two objectives, they consider most important.

An example of a page:

'After completing their study in the natural sciences, students should be able to:

0 use knowledge and skills in unfamiliar situations
0 interpret experimental data'

The pairs were arranged in such a way that each objective appeared an equal number of times as the first and as the second objective. The objectives were distributed as equally as possible over the inventory, although it turned out to be impossible to prevent the same objective from appearing in two successive pairs. The respondents were requested to start by going through the inventory once before filling it in and, once started, not to leaf forward or backward so that they would not be influenced by previously made choices.
We deliberately opted for a comparison in pairs instead of introducing ranking of priority 1 - 8, as has been done in several other studies (Kerr, 1963; Woolnough, 1967; Gould, 1978; Boud, 1980; Beatty, 1982). In our view, it is very difficult to rank the eight learning objectives as such, because the differences in importance are usually fairly small. A paired comparison forces the respondent to weigh the objectives in each pair against each other, and to choose between them.

The second instrument comprises, in random order, the specific learning objectives and end-terms taken from the same article by Kirschner & Meester. The respondents were asked to indicate the importance of each objective on a five-point Likert scale (see appendix 7).

The five scale units range from indispensable to superfluous and have been given the following meaning:

indispensable:	This learning objective is essential and must be included in the program; much emphasis should be placed on this objective
important:	This objective should be included but not necessarily emphasised
neutral:	I don't have an opinion as to this objective; by a vote on such an objective I would abstain
not really necessary:	This objective is of minimal importance; if there is a lack of time or opportunity then this objective need not be included
superfluous:	This objective should not be included in the curriculum; no time need be reserved for this objective

The respondents were again asked to start by reading through all the items once before filling them in and, once started, not to leaf forward or backward or to change answers already given.

An undergraduate study in the natural sciences should prepare students to:

- handle modern equipment

indispensable	*important*	*neutral*	*not really necessary*	*superfluous*

- understand the scope and limiting conditions of the experimental techniques used

indispensable	*important*	*neutral*	*not really necessary*	*superfluous*

- analyse experimental data in order to draw conclusions from them

indispensable	*important*	*neutral*	*not really necessary*	*superfluous*

Initially, the 97 specific objectives and end-terms of the second instrument were formulated in the same way as in the article of Kirschner & Meester (in random order). On closer consideration - after a draft version of this instrument had been presented to a number of scientists, teaching methodologists and educational experts - several items were found to be vague or open to more than one interpretation. After reformulation, the list of specific learning objectives and end-terms was submitted to a number of educational experts and natural scientists for evaluation. As a result of this, five items were excluded, six items were split up into two items, two items were split up into three items and many items were reformulated in order to render them as unequivocal as possible. Some items also changed places: a few specific objectives became end-terms and vice versa. The final list consists of 102 items, among which 64 specific learning objectives and 38 specific end-terms. This list was sent to the institutes, as described in paragraph 3.

4.2 *Validity and reliability*

A test or scale is valid (or invalid) for the scientific or practical purpose of its users and not valid (or invalid) in a vacuum. The inventories developed here are *neither* meant for prediction *nor* for the testing of hypothesized relations or theoretical constructs. *Criterion-related validity* and *construct validity* respectively are therefore not of consequence here. What is of consequence is the representativeness of sampling adequacy of the content of a measuring instrument. *Content validity* is guided by the question: "Is the substance or content of this measure representative of the content or the universe of content of the property being measured" (Kerlinger, 1973). Seeing as how the inventories are based upon, to our knowledge, the most complete set of objectives collected to date (Kirschner & Meester, 1988), the answer to this question is an unequivocal yes. Two measures of reliability have been calculated for the list of objectives and end-terms and its subscales: Cronbach's α and Guttman's split-half coefficient. Cronbach's α is a reliability measure for internal consistency which gives a unique estimate of the reliability for a single usage. It is based on the ratio between item variances and the variance of the whole. The split-half method, on the other hand, treats one list as if it were two comparable lists (instruments), each of them half the size of the original list. The reliability of the questionnaire expressed in Cronbach's α is 0.95; the Guttman split-half coefficient is 0.91. When this questionnaire is subdivided into specific learning objectives and end-terms Cronbach's α is 0.93 and 0.85 and the split-half coefficient is 0.89 and 0.88 respectively. The reliability of the instrument and its subscales is high. In other words, the measurements made with the instrument is relatively free of chance.

In order to determine the extent to which the individual orders of priority correspond to each other, the concordance coefficient (Kendall's W) has been calculated (Siegel, 1956; Hays, 1981). This coefficient is a measure of the relation among *several* rankings of N objects or individuals (learning objectives) and m subjects (the respondents). It expresses thus the degree of association among variables and can vary between the value 0, representing no agreement, and 1 (representing perfect agreement). From a high value of W one may deduce that the respondents have arranged the items on the basis of the same criterion. This does not necessarily mean, however, that the order of priority is 'correct', as each respondent may have used an 'incorrect' criterion for his/her arrangement.

The concordance coefficient, W, is defined as:

$$W = \frac{S}{S_{max}} = \frac{12S}{m^2(N^3 - N)}$$

in which:

m = number of respondents

N = number of general learning objectives

S = total number of actual differences in the order of priority of objectives between the respondents

S_{max} = highest possible number of differences in the order of priority objectives between the respondents

Table 4 shows the values of W, as well as the calculated values of X^2 and the corresponding significance levels.

Table 4
Concordance coefficient per respondent group

Institute	*m*	*N*[a]	*W*	X^2	*sign.*
DUE	15	6	0.37	27.52	< 0.001
UE	22	6	0.08	8.94	n.s.[b]
OuN	12	6	0.46	27.48	< 0.001

[a] The reason that *N* is 6 and not 8 was mentioned in paragraph 2.1 and is discussed again in paragraph 5.1
[b] n.s. = not significant

From this we may conclude that the DUE respondents are highly consistent in their view on the use of practicals in the undergraduate part of educational programmes. In fact, they are (statistically) as consistent as the members of the faculty of Natural Sciences at the OuN, for which a highly significant degree of concordance was found. For the OuN, such a high value is not surprising, considering the fact the respondents concerned all belong to the same institute and are working together as a close-knit group to give shape to innovative education at the OuN. For DUE, different institutes spread throughout the world, it is surprising.

5 Results

In this chapter we will first discuss the results of the ranking of the general objectives. Subsequently the results of the evaluation of the specific learning objectives will be discussed and finally the end-terms.

5.1 *General learning objectives*

Before starting with the systematic discussion of the results, attention should be paid to the following. On the basis of the results of earlier research into learning objectives for practicals at the OuN (Meester et al, 1989), it was decided to discard two of the eight original general objectives. After analysis and rearrangement of the 64 specific learning objectives, it was found that the two general objectives 'to formulate hypotheses' and 'to remember the central idea of an experiment over a significantly long period of time' only corresponded to two and one specifications respectively. These specifications could be and were brought under other general objectives. The two specific objectives concerning the formulation of hypotheses were brought (as component skills) under the general objective 'to solve problems'; the specification of the other general objective under 'to clearly describe experiments'. Although these two original general objectives may be interesting for further analysis from an intellectual viewpoint, they are uninteresting from a practical point of view. General objectives which cannot be operationalized into one or more specific objectives cannot really be considered to be *general* and are not of any great importance to education. These two general objectives were therefore left out of the discussion and the analysis of the results. As each of the 28 pairs is independent of the other pairs, this decision does not have any consequences for the processing of the results.
The six remaining general learning objectives are:

A to solve problems
B to use knowledge and skills in unfamiliar situations
C to design (simple) experiments to test hypotheses
D to use laboratory skills in performing (simple) experiments
E to interpret experimental data
F to clearly describe the experiment

These six general learning objectives can be found in appendix 8, together with the corresponding specific learning objectives.

In order to gain insight into the evaluation by the respondents of the six general learning objectives, we tallied the number of times that a certain general objective was given preference over another objective, for the entire research population. According to Thurstone (Swanborn, 1982) this is the first step towards the analysis of the response on a comparison in pairs. It allows one to get a first impression of the order of priority. Figure 2 shows the results.

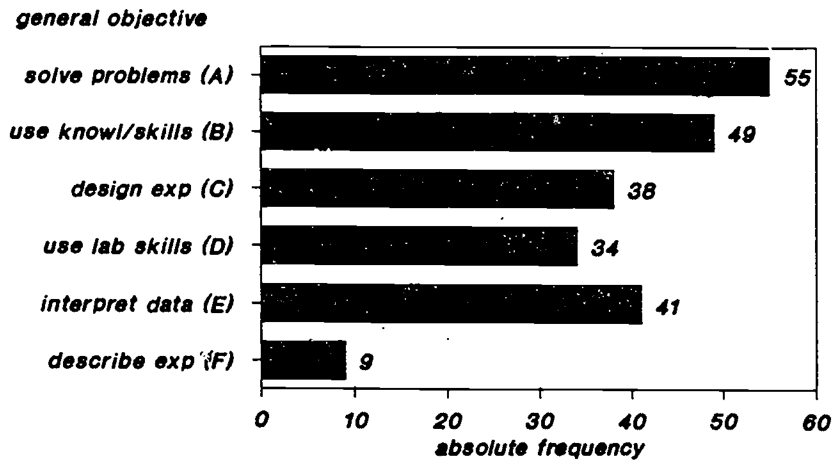

Figure 2
Frequency distribution (max = 75) of the general learning objectives for DUE

The average scores of the objectives can be obtained by dividing the absolute frequency of each objective by the number of respondents. The highest possible score is five, the lowest possible score zero. In table 5 the general objectives are arranged in order of a decreasing average score, i.e. of decreasing perceived importance.

Table 5
Ranking of general learning objectives in order of decreasing importance.

rank	*ave. score*	*general learning objective*
1	3.60	to solve problems (*A*)
2	3.27	to use knowledge and skills in unfamiliar situations (*B*)
3	2.73	to interpret experimental data (*E*)
4	2.53	to design (simple) experiments to test hypotheses (*C*)
5	2.27	to use laboratory skills in performing (simple) experiments (*D*)
6	0.60	to clearly describe the experiment (*F*)

The order of priority with regard to the general objectives as expressed by the respondents from DUE institutes is quite outspoken (table 5). The difference between the most and least important objective is 3.00.
The most highly rated general objective 'to solve problems' (*A*) scored significantly higher than the three least important general objectives *C*, *D*, and *F* (t=2.17, $p<0.05$; t=2.23, $p<0.05$; t=8.53, $p<0.001$ respectively). All the other objectives (*B*, *E*, *C*, and *D*) score significantly higher than the least important general objective 'to clearly describe the experiment' (*F*) (t=5.62, $p<0.001$; t=6.96, $p<0.001$; t=5.85, $p<0.001$; t=3.03, $p<0.01$ respectively).

5.2 *Specific learning objectives*

The second instrument, a Likert scale inventory on the specific learning objectives and the end-terms, was divided into its component parts for analysis and discussion purposes. Appendix 9 gives a survey of the results of the specific learning objectives sublist arranged in order of decreasing importance for DUE institutes. Besides the average value (x) and standard deviation (*s.d.*), a normalized score (Z) has been given for each objective. This score makes it easier to compare the results of DUE, OuN and UE with each other. This Z-score is based on the averages of the 64 specific objectives and indicates how many standard deviations the score for an objective is removed from the total average score ($Z = 0$). Table 6 gives the distribution of the specific objectives over the different categories of importance. The results of the OuN and UE have been included here as well (Meester et al, 1990).

Table 6
Frequency distribution of 64 specific learning objectives arranged in order of decreasing importance

type of institute	*number of respondents*	*1a*	*2*	*3*	*4*	*5*
DUE	15	13 (20%)	37 (58%)	14 (22%)	-	-
UE	22	23 (36%)	33 (52%)	8 (13%)	-	-
OuN	12	11 (17%)	37 (58%)	10 (16%)	6 (9%)	-

[a] 1 = indispensable ($1.00 \le x < 1.80$); 2 = important ($1.80 \le x < 2.60$); 3 = neutral ($2.60 \le x < 3.40$); 4 = not really necessary ($3.40 \le x < 4.20$); 5 = superfluous ($4.20 \le x \le 5.00$).

A striking aspect of this table is the large number of objectives classified as *important* by all the respondent groups. Furthermore the categories *not really necessary* and *superfluous* are empty for DUE and UE. This is not really surprising, given the fact that the list of specific objectives is based on literature on objectives for practicals in traditional undergraduate science education (Kirschner and Meester, 1988). When we look at the 13 specific objectives belonging to the category indispensable ($1.00 \le x < 1.80$) we see that four of the objectives are relevant to the actual understanding of the purpose of the experiment and to activities prior to the execution of the experiment, four of the objectives deal with the actual execution of the experiment and the remaining five objectives relate to the processing of experimental data and a description of the experiment after the execution of the experiment. In table 7 the successive stages have been indicated with the headings 'prior to the experiment', 'during the experiment' and 'after the experiment'.

Table 7
The 13 indispensable learning objectives of the DUE distributed in accordance with three consecutive stages

specific learning objective[a]	*x*	*s.d.*
prior to the experiment		
to understand what is to be measured in an experiment	1.40	0.83
to understand the purpose of an experiment	1.53	0.74
to make order-of-magnitude calculations and estimates	1.60	0.63
to recognize hazards so as to take safety precautions	1.73	0.70
during the experiment		
to conduct experiments safely	1.57	0.65
to observe phenomena in a quantitative way	1.60	0.51
to use practical (as opposed to theoretical) lab skills	1.67	0.62
to collect experimental data	1.73	0.80
after the experiment		
to analyze experimental data to draw conclusions	1.33	0.49
to interpret reliability and meaning of results	1.40	0.51
to apply principles instead of rote formulae	1.60	0.51
to communicate experimental findings in written form	1.67	0.82
to evaluate experimental outcome with respect to a hypothesis	1.67	0.90

[a] The complete text of the objectives can be found in appendix 8

In conclusion we can say that these indispensable learning objectives belong to the very basic skills of doing practical work. Next, we will look at the other end of the list of specific objectives (appendix 9). In the *neutral* category are 14 objectives, which all score relatively high in this category (almost all have $x < 3.0$, see table 8).

Table 8
The 14 neutral learning objectives of the DUE

specific learning objective	*x*	*s.d.*	*general objective*
to calibrate instruments	3.07	1.28	D
to solve difficult scientific problems	3.07	1.10	A
to incorporate unexpected experimental results in a new model	3.00	1.13	E
to construct models based on experimental findings	2.93	0.96	B
to develop measurement techniques	2.87	1.19	C
to confirm already known facts and laws	2.87	1.13	E
to construct models which fit experimental findings	2.87	1.13	B
to set up lab equipment quickly and correctly	2.80	1.08	D
to handle modern equipment	2.80	1.08	D
to confirm facts, principles and theory from lectures/books	2.73	1.22	E
to keep a day-to-day lab diary	2.73	1.22	D
to suggest follow-up investigations	2.73	1.03	F
to estimate outcome of experimental measurements within given precision	2.67	1.18	E
to translate.a conceptional definition into set of measurement procedures	2.60	0.83	C

Four of them are specifications of general objective *D* and obviously do not manifest themselves as really important goals for distance education. Two specific objectives are relating to confirming already known facts, laws and theory. Verification of the already known will not be a really important goal of modern practicals, a result we also found at the OuN and UE. The remaining eight objectives in the category neutral probably aim too high for undergraduate practicals. They all have to do with higher academic skills.

5.3 *End-terms*

Appendix 10 gives a survey of the 38 specific end-terms in order of (decreasing) importance as scored by DUE. Here too, the average value (x), the standard deviation (*s.d.*) and the normalized score (Z) are given.
Table 9 gives the distribution of the end-terms over the different categories of importance. The results of OuN and UE have again been included here (Meester et al, 1990).

Table 9
Frequency distribution of 38 end-terms arranged in order of decreasing importance

type of institute	*number of respondents*	*1*[a]	*2*	*3*	*4*	*5*
DUE	15	4 (10%)	19 (50%)	14 (37%)	1 (3%)	-
UE	22	3 (8%)	23 (60%)	12 (32%)	-	-
OuN	12	6 (18%)	18 (47%)	13 (34%)	1 (3%)	-

[a] 1 = indispensable ($1.00 \le x < 1.80$); 2 = important ($1.80 \le x < 2.60$); 3 = neutral ($2.60 \le x < 3.40$); 4 = not really necessary ($3.40 \le x < 4.20$); 5 = superfluous ($4.20 \le x \le 5.00$)

The different institutes evaluate the majority of the end-terms as *indispensable* or *important*, a relatively large part is rated *neutral*. None of the end-terms is considered *superfluous*.

In DUE, four of the 38 end-terms are assessed as *indispensable* (see table 10). All four relate to higher academic skills, i.e. to attitudes concerning the way scientific problems should be approached.

Table 10
End-terms considered *indispensable* by DUE

specific end-term	*x*
to approach observed phenomena from a scientific point of view	1.53
to have a critical attitude to experimental results	1.53
to solve problems in a critical, academic way	1.71
to approach a problem with an open mind	1.73

Close examination of the end-terms rated neutral (14) and not really necessary (1) reveals that these end-terms can be grouped around a more or less common denominator: end-terms with a rather 'romantic' or 'idealistic' view on undergraduate practicals (i.e. experience kinship with the scientist), end-terms concerning working attitude and working conditions (i.e. tackle a problem with the help of others), and end-terms related to certain academic skills (i.e. determine limits under which a theory applies).

6 Discussion

As with the results, the discussion will first focus on the general objectives, then the specific objectives and finally the end-terms.

6.1 *General learning objectives*

From the background data received, we can conclude that those DUE institutes which responded in our study can be characterised as monodisciplinary in nature. In this respect they do not differ very much from the traditional Dutch universities which responded to an earlier study. Being similar in this respect, we will first compare DUE to UE. After doing this we will compare the OuN with both DUE and UE.

6.1.1 *General learning objectives: DUE compared with UE*

DUE and UE ranked the general objectives in a very similar manner (see table 11). Four of the six objectives were ranked in an identical way by both groups (*B*, *D*, *E*, and *F*; ranks 2, 5, 3, and 6 respectively). Only two objectives differ, namely *A* and *C*. Objective *A*, 'to solve problems', ranked fourth in UE, is far and away the most important objective in DUE. Objective *C*, 'to design (simple) experiments to test hypotheses', ranked as most important in UE is ranked fourth in DUE. As a matter of fact, objective *C* was ranked significantly lower in DUE than *A* (t=2.17, p<0.05).

Although the ranking is very similar, the differences between the scores are more pronounced in DUE than in UE. This can be seen in the number of significant differences between the scores from the paired comparison within DUE (7) and those within UE (3). The most pronounced difference was the scoring of the general objective *F*, 'to clearly describe the experiment'. Although this objective received the lowest score in both educational types, DUE scored more than a full point lower than UE. Clearly, though this general objective is not a priority in either type of institution, the importance in DUE is almost nil.

On the basis of these data, it appears that there are no really noteworthy differences between DUE and UE.

Table 11
Ranking of importance of general learning objectives

general learning objectives	*rank[a] OuN*	*ave score*	*rank DUE*	*ave score*	*rank UE*	*ave score*
to solve problems (*A*)	4	2.83	1	3.60	4	2.55
to use knowledge and skills in unfamiliar situations (*B*)	1	3.58	2	3.27	2	2.73
to design (simple) experiments to test hypotheses (*C*)	3	3.08	4	2.53	1	3.09
to use lab skills in performing (simple) experiments (*D*)	6	0.50	5	2.27	5	2.05
to interpret experimental data (*E*)	2	3.42	3	3.27	3	2.68
to clearly describe the experiment (*F*)	5	1.42	6	0.60	6	1.77

[a] 1 = most important; 6 = least important

6.1.2 *General learning objectives: OuN compared to DUE and UE*

In addition to comparing DUE with UE, we can also compare the OuN with both of the aforementioned. In this way we can see whether or not the OuN is unique in that it is a distance university (DUE and OuN should be more similar to each other than either is to UE) or whether it is unique in the fact that it offers an interdisciplinary science programme (in which case DUE and UE should be more similar to each other than either is to the OuN) or both.

Kendall's rank correlation coefficient (τ)[2] is a good measure of the correlation between two ordinal measures. This correlation coefficient is based on the number of pairs of ranks that are ordered in the same direction in two different sample groups and varies from 0 by complete disagreement to +1 by complete agreement. It is thus, in effect, an enumerator of the extent of *disagreement* in the rankings in the two groups (Glass and Stanley, 1970; Siegel, 1956). In our case, those measures are the ranks given by each of the types of institutes to the general objectives. This leads to three comparisons, namely DUE-UE, OuN-DUE, and OuN-UE. None of the comparisons proved to be significant ($\tau = 0.33, 0.47$, and 0.60 respectively, $p>0.05$). From this we can conclude that none of the institutes is significantly similar to any of the other two; thus the three types are statistically *different*. A possible explanation for this is that the factors which differentiate distance education from face-to-face education and monodisciplinary education from multi- or interdisciplinary education play a role in this uniqueness.
A confounding variable which we did not take into account when we set up this research may be the cultural (dis)similarities between the respondent groups. By this we mean the educational climate, culture and history of the different respondent groups. Although the OuN and UE differ along the two dimensions discussed thus far, they do have a certain similarity that cannot be discounted. All of the individual respondents come from a West European (Dutch) scientific and academic culture. Although they work in strikingly different educational institutes, they have similar, if not for all intents and purposes identical, educational histories. They all attended one or more of the 9 traditional Dutch universities with Natural Science curricula, attended the same types of secondary schools, and had to meet very similar requirements to achieve the positions which they fulfil. If we look at the values for τ, we see that although none of the values is significant, they increase from DUE-UE (where the nature of the institution and the cultural factors are dissimilar) through OuN-DUE (where the nature of the institution is similar but the cultural factors are dissimilar) to OuN-UE (where the nature of the institution differs, but the cultural factors are similar). Table 11 shows the average scores for each of the general objectives for each of the institutional types.

The similarity gradient in Kendall's τ discussed in the preceding paragraph can also be seen in a comparison of the average scores for each of the groups of respondents for the general objectives. UE and DUE differ significantly with respect to their scoring of objectives *A* and *F* ($\Delta x=1.05$, $t=2.12$, $p<0.05$ and $\Delta x=1.17$, $t=3.30$, $p<0.005$ respectively). The ability to solve problems (*A*) is more highly valued by DUE in relative terms (rank 1 versus rank 4), but also in absolute terms. The same is true for being able to describe an experiment (*F*).
The OuN and DUE differ significantly with respect to their scoring of objectives *D* and *F* ($\Delta x=1.77$, $t=3.59$, $p<0.005$ and $\Delta x=0.82$, $t=2.31$, $p<0.05$ respectively). DUE values the use of lab skills to perform (simple) experiments (*D*) more highly than the OuN, not only relatively (rank 4 versus rank 6), but also in absolute terms. The opposite is the case for being able to describe an experiment (*F*). Here it is the OuN which places more value on this objective. This is well in line with the general philosophy of the OuN where the end-terms for the Natural Sciences stress written and oral communication while tempering the necessity for working in a laboratory. This difference with other distance universities may thus be the result of the Dutch Open university's strong resolve to interdisciplinary programming on the one hand and its steadfast belief in the freedom for students to study where and when they wish.
The results obtained with respect to objective *F* need to be discussed further. The low score, for all institutes, of general objective *F* 'to clearly describe the experiment' is quite surprising, because the publication of research results in scientific magazines and the presentation of results at congresses and conferences is quiet common in scientific circles. This result is even more surprising if one considers the high score of the specific objectives which are part of this general

[2] Other possible measures are Spearman's rank correlation coefficient which is based upon the absolute differences in the rankings by two groups and Kendall's coefficient of concordance which was described in section 4.2. We calculated all three, and they all yielded the same conclusions. We chose to present (τ) here.

objective and in particular those specifications relating to written communicative skills (see paragraph 5.2). This discrepancy may be the result of the use of the verb 'to describe'. According to the various taxonomies of objectives (Bloom et al., 1956; Gronlund, 1970; Klopfer, 1971) 'to describe' can be interpreted in two ways. According to Bloom the verb first of all fits in the lowest category of objectives within the cognitive domain namely the category of knowledge objectives. Characteristic verbs are: to reproduce, to remember, to recognize, to describe, to enumerate, etc. The emphasis is on remembering or spontaneously recognizing subject matter, facts, definitions, connections and methods.
Apart from this interpretation as a 'low' cognitive objective, it is also possible to interpret the verb as a relatively 'high' cognitive objective. In this respect the word to describe is used in the sense of synthesizing. Synthesis is the ability to put parts together to form a new whole. This may involve the production of a unique communication (theme or speech), a plan of operations (research proposal), or a set of abstract relations (scheme for classifying information)' (Bloom, 1956). Here, emphasis is put on creative behaviour; the creation of new patterns or structures. According to Gronlund (1970) objectives such as the ability to develop a proper line of reasoning, the ability to give a good lecture or the ability to summarize the essentials of an experiment belong to the category synthesis. Apparently the respondents, like the respondents of the OuN, have interpreted the general objective in the sense of low cognitive, especially in comparison with the other general objectives. By contrast, the specific objectives relating to communicative skills are interpreted as higher, more creative and therefore both UE institutes and DUE institutes count them among the *indispensable* objectives.

In a comparison of average scores for the OuN and UE, the only significant difference in average score is on objective *D* ($\Delta x=1.55, t=3.80, p<0.001$). Though the relative difference between the groups with respect to the use of laboratory skills is small (rank 5 for UE and rank 6 for OuN), the absolute difference is very large. Again we see here the OuN's dedication to approach the Natural Sciences in a way that is different from more traditional, monodisciplinary, universities. The OuN focuses on and strives to provide "a type of education which enables its graduates to learn to think in a problem-oriented manner" (End-terms, 1986). In other words, what the OuN graduate misses in laboratory skills is/must be more than compensated by training in problem oriented and problem solving thinking.

Finally, the lack of significant differences between the groups can be seen in the comparison of the absolute differences between the different response groups (see table 12). Metaphorically speaking, the OuN and UE are in essence children of the same parents (almost twins if you wish), who spent their formative years in similar environments and have only recently been split up and placed in vastly different environments. Both nature and nurture are thus similar. Is it strange then that although differing greatly on certain items, their overall behaviour is very similar?

Table 12
The difference in the averages (Δx) for the general learning objectives when comparing the various institutes. Values with a $\Delta > 1$ or ≤ 1 are printed in bold letters.

general objective	*OuN-DUE*	*OuN-UE*	*DUE-UE*
to solve problems (*A*)	-0.77	0.28	1.05
to use knowledge and skills in unfamiliar situations (*B*)	0.31	0.85	0.54
to design experiments to test hypotheses (*C*)	0.55	-0.01	-0.56
to use laboratory skills in performing experiments (*D*)	-1.77	-1.55	0.2
to interpret experimental data (*E*)	0.15	0.74	0.59
to clearly describe the experiment (*F*)	0.82	-0.35	-1.17
sum of the absolute differences: $\Sigma\|\Delta x\|$	*4.37*	*3.78*	*4.13*

6.2 *Specific learning objectives*

Drawing conclusions from the results of the specific learning objectives requires special care. There is a certain degree of subjectivity with regard to the interpretation of each specific objective. This study can only indicate a tendency in objectives which are considered more or less important as well as indicate the corresponding general objectives. It is almost impossible to achieve a one-to-one correspondence, because certain specific learning objectives might occasionally be considered to belong to different general objectives. The distinction between specific learning objectives and end-terms is also not always unequivocal. We consider 'to solve difficult scientific problems' for instance to be an objective because we interpret it as the ability to solve problems, partly prior to an experiment. However this could also be considered as an end-term of a study of the Natural Sciences. Despite the above mentioned interpretation problems we are of the opinion that it is safe to analyze the results of the specific objectives and to draw conclusions from this analysis.

6.2.1 *Specific learning objectives versus general learning objectives*

The subsumption of each of the specific objectives to one of the six general objectives was presented in a previous article. This classification is, of course, open to discussion. It is, thus, interesting to use the results of this research to check as to whether or not there is any empirical basis for the classification.

One way to do this is by calculating Cronbach's α, a measure of reliability, for each of the general objectives. Cronbach's α is a measure of homogeneity between the variance of the separate objectives and the variance of the scale (each general objective) as a whole (see paragraph 4.2). Table 13 shows the value of α for each of the general objectives. In calculating the scores, we used the responses from the OuN, UE, and HVE together to achieve a maximum sample size. This table gives a strong indication that the specifications of the general learning objectives as defined in Kirschner & Meester (1988) and revised in Meester et al (1990) are fairly homogenous and that the classification is very well plausible. Only the objective 'to solve problems' (*A*) has a rather low α (0.58).

Table 13
Cronbach's α for the specifications of the general learning objectives

general learning objective	number of specifications	Cronbach's α
A -to solve problems	10	0.58
B -to use knowledge and skills in unfamiliar situations	6	0.77
C -to design experiments to test hypotheses	8	0.78
D -to use laboratory skills in performing experiments	17	0.91
E -to interpret experimental data	16	0.75
F -to clearly describe the experiment	7	0.73

In order to determine whether a relationship exists between perceived importance of the general objectives and the ratings of the constituent specific objectives we calculated an average *Z*-score for each group of specifications, where *Z* is the normalized score for a objective. We arrived at this score by summing up the *Z*-scores for all of the specific objectives belonging to a general objective and dividing this by the number of specifications.The average *Z*-scores for the different group(ing)s of respondents are given in table 14.

Table 14
Average *Z*-scores for the specifications per general learning objective and the differences between them for the different response groups

general objective	*OuN*[a]	*DUE*[a]	*UE*[a]	*OuN-DUE*[b]	*OuN-UE*[b]	*DUE-UE*[b]
to solve problems (*A*)	+0.39	+0.02	-0.15	+0.37	+0.54	+0.17
to use knowledge and skills in unfamiliar situations (*B*)	+0.42	-0.40	-0.43	+0.82	+0.85	+0.03
to design experiments to test hypotheses (*C*)	-0.21	-0.11	-0.18	-0.11	-0.03	+0.07
to use laboratory skills in performing experiments (*D*)	-0.85	-0.05	+0.07	-0.80	-0.92	-0.12
to interpret experimental data (*E*)	+0.43	+0.24	+0.12	+0.19	+0.31	+0.12
to clearly describe the experiment (*F*)	+0.40	+0.09	+0.36	+0.31	+0.04	-0.27

[a] A positive score indicates above average evaluation of the objective; a negative score indicates below average evaluation.
[b] A positive difference indicates a greater importance attached to the objective by the first institute; a negative difference indicates the opposite.

It is evident that the largest differences between the OuN on the one hand and DUE and UE on the other are for the general objectives *B*, *D* and (to a lesser degree) *A*. As stated earlier, the OuN finds the use and development of laboratory skills (*D*) much less important than does DUE and UE (difference is negative), but deems objectives dealing with the use of knowledge and skills in unfamiliar situations (*B*) and solving problems (*A*) as being more important than the other institutions (difference is positive). Not strange when one takes into account the objectives of the Natural Science programme of the OuN. The differences between DUE and UE are only very modest. We can prioritize the general objectives based upon the scores in table 13 and compare this to the rankings obtained by the paired comparison. This has been done in table 15.

Table 15
Rough sequence of general learning objectives[a] determined on the basis of average *Z*-scores for the specific learning objectives and the paired comparison.

type of institute	*order based on*	*1*	*2*	*3*	*4*	*5*	*6*
OuN	Z-score	0.43	0.42	0.40	0.39	-0.21	-0.85
	spec. objectives	E	B	F	A	C	D
	paired comparison	B	E	C	A	F	D
	average score	3.58	3.42	3.08	2.83	1.42	0.50
DUE	Z-score	0.24	0.09	0.02	-0.05	-0.11	-0.40
	spec. objectives	E	F	A	D	C	B
	paired comparison	A	B	E	C	D	F
	average score	3.60	3.27	2.73	2.53	2.27	0.60
UE	Z-score	0.36	0.12	0.07	-0.15	-0.18	-0.43
	spec. objectives	F	E	D	A	C	B
	paired comparison	C	B	E	A	D	F
	average score	3.09	2.73	2.68	2.55	2.05	1.77

[a] 1 = most important; 6 = least important

The table shows a fairly large degree of similarity between the two ways of ranking the general objectives for the OuN. It is primarily objective *F* 'to clearly describe the experiment' and *C* 'to design experiments to test (simple) hypotheses', which yield the greatest discrepancies. For objective *F* we have already discussed the role which interpretation of the verb 'to describe' may have played in the paired comparison in earlier reports and articles (Kirschner et al, 1991; Meester et al, 1990). This objective scored lower on the paired comparison than on the average *Z*-score for all three groups. If we give *F* a higher priority more in agreement with the order based on average *Z*-scores, then the order of *A* and *C* will only be reversed for the two rankings.The two ways of ranking for DUE (and UE) are very different. A remark can be made about the difference in ranking for objective *B* 'to use knowledge and skills in unfamiliar situations' in DUE and UE. While this objective ranks rather high based upon the paired comparison, it receives the lowest rank based upon the specifications. This may be due to the fact that unfamiliar situations (generally speaking and thus in the ranking of the general objectives) should occur in UE and DUE. In practice, though, these situations occur sparsely in undergraduate practicals (specifically speaking). This is probably reflected in the scoring of the specific objectives.
The ranking based on the average *Z*-scores for DUE and UE are very comparable; for the ranking based on the paired comparison general objectives *A* and *C* have changed the positions 1 and 4. This is strangely in the light of the practically same position in the ranking of average *Z*-scores.

6.2.2 *Specific learning objectives: DUE compared UE*

To compare the various institutes we make use of *Z*-scores. Appendix 11 gives the differences between DUE and UE in order of the decreasing absolute differences in *Z*-scores ($|\Delta Z|$). In order to assess the *Z*-scores we have to determine which difference in *Z*-scores is sufficiently large to characterise a difference in the identity of the institute and at the same time which disparity in *Z*-scores is small enough to ensure that the evaluation of a specific objective is virtually the same for both institutes. For the upper limit we have chosen for a disparity of one standard deviation; for the lower limit for a disparity of half a standard deviation. According to these criteria DUE differs from UE in only eight specific objectives. For these objectives either DUE puts a great deal of emphasis on them and UE does not or vice versa. In table 16 these objectives are shown in order of their decreasing ΔZ scores.

Table 16
Specific learning objectives in which DUE differs greatly from UE

specific learning objective	*ΔZ (DUE - UE)*	*general objective*
to derive and evaluate relationships	1.25	A
to confirm facts. principles and theory from lectures /books	1.24	E
to design relevant observation techniques	1.22	C
to confirm already known facts and laws	1.13	E
to apply principles instead of rote formulae	1.12	E
to estimate outcome of experimental measurements within given precision	-1.21	E
to suggest follow-up investigations	-1.05	F
to handle modern equipment	-1.01	D

Two of the objectives which DUE considers to be much more important than UE refer to the confirmation of established facts, laws and theories. However, also DUE places them in the category neutral (see section 5.2), so these objectives are not really important.

A more striking result is that DUE and UE do not markedly differ with respect to 37 objectives (see appendix 11 and table 17). It would also be possible to draw this conclusion by comparing the indispensable objectives for DUE and UE respectively as they have been classified according to the three stages of the execution of an experiment: 'prior to the experiment', 'during the experiment' and 'after the experiment' (for DUE see table 8 and for UE see Meester et al., 1990). The learning objectives in the stages 'prior to experiment' and 'during the experiment' appeared to coincide almost completely, except for three additional objectives for UE dealing with the properly planning of an experiment, the understanding of measurement of different phenomena and the carrying out of accurate measurements. For UE the objectives categorized in 'after the experiment' contain five of the six objectives of DUE (except to apply principles instead of rote formulae) and an additional eight objectives, which deal with presenting the results of a experiment (3), evaluating experimental results (3), processing experimental data (1) and applying statistics (1). If we look up these specific objectives in the list of mean values for DUE (appendix 8) they all appear to have a mean value of ≤ 2.0. So there is only a modest difference between the evaluation of DUE and UE respondents. In conclusion we can say that the differences between DUE and UE with regard to the appreciation of specific objectives for undergraduate practicals are very small.

6.2.3 *Specific learning objectives: OuN compared to DUE and UE*

In addition to comparing DUE with UE, we can also compare the OuN with both DUE and UE and indicate the various discrepancies. In appendix 12 and 13 the differences between OuN and DUE and between OuN and UE are given in order of decreasing absolute difference in *Z*-scores ($|\Delta Z|$). Again we will draw a line at $|\Delta Z| = 1$ and $|\Delta Z| = 0.5$. With the help of these limits the specific learning objectives can be classified in three groups as seen in table 17 where the number of objectives per institute combination is given.

Table 17
The number of specific learning objectives classified according to the size of $|\Delta Z|$ in a comparison of DUE and UE, OuN and DUE and OuN and UE

comparison of	$\|\Delta Z\| \geq 1$	$0.5 < \|\Delta Z\| < 1$	$\|\Delta Z\| \leq 0.5$	
DUE and UE	8	19	37	(appendix 10)
OuN and DUE	25	16	23	(appendix 11)
OuN and UE	21	20	23	(appendix 12)

Some results in this table are noteworthy to indicate:

- The number of specific learning objectives on which DUE and UE vary a great deal is not very large (8); the number of objectives they practically agree on is considerably larger (37) (see also section 6.2.2).
- The number of learning objectives showing dissimilarities between the OuN and DUE or UE is almost equal (although the type of objective concerned may vary a great deal) and this particular number (25 and 21 respectively) is approximately three times as high as the number of differences between DUE and UE.
- The number of learning objectives on which the OuN and DUE on the one hand and the OuN and UE on the other hand hold the same view is the same (namely 23).

From the above mentioned outcomes one might conclude that as far as practicals are concerned the OuN differs much more from DUE and UE than DUE and UE differ from one another! This conclusion is more or less in accordance with the specific character of the Natural Sciences at the Open university of the Netherlands. The type of science education offered by the OuN is more inter- or multidisciplinary than education in the DUE and UE institutes, which are all monodisciplinary. This requires a different attitude with regard to monodisciplinary practicals. We can look at the specific learning objectives with considerable differences in Z-scores in another way. We have seen (table 17) that the OuN varies to a large extent from DUE with regard to 25 specific objectives. We can check how many of those objectives also occur in the list of 21 objectives the OuN differs strongly from UE. This proves to be the case with 13 of them. These 13 objectives could be considered as the objectives which provide specific information about the OuN; objectives which clearly distinguish the OuN from DUE and UE. These may be objectives which the OuN considers much more important than DUE and UE ($\Delta Z \geq 1$) or objectives which OuN values as much less important than DUE or UE ($\Delta Z \leq -1$). It does not necessarily mean that DUE or UE does not value these objectives as important, but merely that the OuN values them as either much more important or much less important (see table 18).

Table 18
Specific learning objectives with a large difference between the OuN and both DUE and UE

specific learning objective	*ΔZ (Ou-DUE)*	*ΔZ (Ou-UE)*	*general objective*
to incorporate unexpected experimental results in new model	2.39	2.14	E
to solve difficult scientific problems	1.37	1.37	A
to solve problems in a multi-solution situation	1.24	1.57	A
to decompose larger problems into smaller problems	1.20	1.04	A
to derive testable hypotheses from theories	1.20	1.34	A
to be flexible in modifying experiments	1.08	1.12	D
to react adequately to unforseen results	1.08	1.09	B
to use practical (as opposed to theoretical) lab skills	-2.08	-1.86	D
to collect experimental data	-1.80	-1.72	D
to put basic laboratory techniques to use	-1.61	-1.47	D
to manipulate apparati	-1.55	-1.46	D
to carry out accurate measurements	-1.24	-1.70	D
to conduct experiments safely	-1.23	-1.47	D

The learning objectives in the list with negative ΔZ values all relate to experimental laboratory skills during the actual realization of the experiment. All of them are specifications of general objective *D* 'to use laboratory skills in performing (simple) experiments'. Table 8 shows that DUE values three of these practical laboratory skills as indispensable objectives and UE four of them, but for an OuN graduate in science they are not really necessary (Meester et al, 1989).
Four of the learning objectives with a $\Delta Z \geq +1$ are specifications of general objective *A* 'to solve problems'. The faculty of Natural Sciences at the OuN shows a clear preference for the achievement of the problem-solving skill. Since the amount of time and money that can be spent on practicals is not limitless, the preference for this higher academic skill must be gone at the cost to lower level manual skills dealing with the use of laboratory skills. The other three specific objectives with $\Delta Z \geq +1$ are related in some way with reacting to unforseen or unexpected experimental results. This flexibility, which in its ultimate form can be seen as the ability to incorporate serendipity into the scientific process (the classic example being the discovery of penicillin by Fleming), can be seen as a benchmark academic skill in al sciences. The ability to change one's view in light of new empirical evidence and not get caught up in existing scientific dogmas is the essence of the *true scientist*. Paul Dehart Hurd (1969) expressed this in the following way: "Since the natural sciences are distinguished by a continual flow of new knowledge, by refinements of existing knowledge, accompanied by new theories and knowledge, the teaching of science must reflect the same dynamic characteristics" (p. 9).

6.3 *End-terms*

In this paragraph we compare the results of end-term evaluations for institutions of higher distance education (OuN and DUE) and university education in the Netherlands (UE).

A division of the specific end-terms into three groups based on the $|\Delta Z|$ score (see appendices 14, 15 and 16) generates the following picture when comparing OuN, UE and DUE (table 19).

Table 19
The number of specific end-terms classified according to the size of $|\Delta Z|$ in a comparison of the OuN, UE and DUE

comparison of	$\|\Delta Z\| \geq 1$	$0.5 < \|\Delta Z\| < 1$	$\|\Delta Z\| \leq 0.5$	
DUE and UE	4	14	20	(appendix 14)
OuN and DUE	10	13	15	(appendix 15)
OuN and UE	6	11	21	(appendix 16)

The number of end-terms showing a considerable difference in appreciation ($|\Delta Z| \geq 1$) is approximately twice as high in the comparison of OuN and DUE as it is in the other comparisons, while the number of end-terms classified similarly ($|\Delta Z| \leq 0.5$) is less. This result suggests that the OuN differs more from DUE than it does from UE. In fact, the results presented in table 17 for the specific learning objectives indicate a similar conclusion (see section 6.2.3). In the next sections we will look at the nature of the differences between the institutions.

6.3.1 *End-terms: DUE compared to UE*

When applying, as we did in paragraph 6.2, the criterion that a $|\Delta Z| \geq 1$ indicates an essential difference between the institutes to be compared, DUE differs considerably from UE with regard to only four end-terms (table 20).

Table 20
End-terms showing considerable differences between DUE and UE

specific end-term	$\Delta Z(DUE\text{-}UE)^a$
to build a framework for facts, principles and theory from lectures/books	+2.20
to discover limitations of a theory/model	-1.78
to work in research and development labs	-1.65
to work in groups to solve scientific problems	-1.01

[a] $\Delta Z \geq +1$ = this end-term is considered much more important by DUE than by UE
$\Delta Z \leq -1$ = this end-term is considered much less important by DUE than by UE

Two of the end-terms which DUE considers to be much less important than UE refer to working conditions ('work in research and development labs'/'work in groups to solve scientific problems') which are hard to fulfil within distance education.
Within DUE much emphasis is put on integration of (theoretical) knowledge ('build a framework for facts, principles and theory from lectures/books') which was also found within OuN (see table 22). This was also the case with respect to the specific objectives which pertain to the confirmation of facts, principles and theories. Clearly DUE sees the practical as a vehicle for the conveyance/confirmation of theoretical knowledge.

6.3.2 *End-terms: OuN compared to DUE and UE*

Tables 21 and 22 give a survey of the essential differences in end-term evaluations between OuN and DUE and OuN and UE respectively.

Table 21
End-terms showing considerable differences between OuN and DUE

specific end-term	*ΔZ (OuN - DUE)*[a]
to discover limitations of a theory/model	+1.43
to work independently of others	+1.28
to formulate a problem that can be researched	+1.16
to work in groups to solve scientific problems	+1.13
to survey literature relevant to some problem	+1.02
to do experiments	-1.85
to use mental skills inherent to professionals	-1.27
to illustrate facts, principles and theory of lectures/books	-1.14
to use motor skills inherent to professionals	-1.01
to use the lab as an instrument for discovery	-1.01

[a] $\Delta Z \geq +1$ = this end-term is considered much more important by OuN than by DUE;
$\Delta Z \leq -1$ = this end-term is considered much less important by OuN than by DUE

Table 22
End-terms showing considerable differences between OuN and UE

specific end-term	*ΔZ (OuN - UE)*[a]
to be self-confident and independent	+1.52
to build a framework for facts, principles and theory from lectures/book	+1.49
to survey literature relevant to some problem	+1.12
to do experiments	-2.19
to work in research and development labs	-1.53
to use the lab as an instrument for discovery	-1.31

[a] $\Delta Z \geq +1$ = this end-term is considered much more important by OuN than by UE
$\Delta Z \leq -1$ = this end-term is considered much less important by OuN than by UE

From comparison of tables 19, 20 and 21 the following conclusions may be drawn:

- Three end-terms showing differences between OuN and DUE also turn up in the comparison between OuN and UE (tables 20 and 21). Two of those relate to the execution of experiments ('do experiments' and 'use the lab as an instrument for discovery'). Such end-terms are not prominent within the OuN-programme for distance education in the Natural Sciences. The end-term 'to survey literature relevant to some problem' is more important to OuN than it is to DUE and UE. However, it should be noticed that this end-term is also rated important within the latter institutes.
- The end-term 'to build a framework for facts, principles and theory from lectures/books' is more important to DUE and OuN than it is to UE (tables 19 and 21).
- Although there is considerable difference in the appreciation of the end-term 'to formulate a problem that can be researched' between OuN and DUE ($\Delta Z = +1.16$), this end-term was evaluated as important in DUE. For the end-term 'to use motors kills inherent to professionals' a ΔZ (OuN - DUE) of - 1.01 was found. Since this end-term was rated neutral within DUE, this end-term is not very important to both institutes (table 20).

- The end-term 'to work in groups to solve scientific problems' is valued higher within OuN and UE than within DUE (tables 19 and 20).

7 Conclusions

In light of the results presented in this report we can make a number of conclusions with respect to learning objectives and end-terms for undergraduate practicals, and for the differences and similarities between the OuN, UE, and DUE.

With respect to DUE we can conclude that:

- The different institutes making up the sample population for DUE approach practicals in the Natural Sciences in a similar way. This can be seen on the coefficient of concordance (Kendall's *W*). The degree of concordance across the sample population is large. As a matter of fact it's level of significance is about the same as that of the OuN. This is rather remarkable considering the differences between the individual respondents with respect to culture, language, educational background, etcetera. The only two things which they all appear to have in common is that they all are institutes for distance education and they all approach the Natural Sciences in a monodisciplinary way.
- The ability to solve problems, interpret experimental data, and use knowledge and skills in unfamiliar situations are far and away the most important general objectives for the students attending these institutions to achieve. The importance of the first two are also reflected in the ratings of their component specific objectives. The operationalisations of the third general objective are, on the other hand, ranked very low.
- The ability to describe an experiment is far and away the least important general objective for the students attending these institutions to achieve. When the component specific objectives subsumed under the general objectives are used to calculate the relative importance of the general objectives, then the ability to describe an experiment jumps from last to second place.
- The specific objectives which DUE rates as *indispensable* are primarily elementary laboratory skills relating to an experiment. Those objectives which were rated as *neutral* are, on the other hand, primarily higher academic skills relating to reasoning and problem solving.
- None of the 64 specific objectives is considered *not really necessary* or *superfluous*.

- Four of the 38 end-terms are valued as *indispensable*. They relate to attitudes concerning the way scientific problems should be approached.

In analyzing the reactions of the respondents for the general learning objectives, the specific learning objectives and the end-terms we note the following differences between the three groups:

- The difference between the OuN and DUE is larger than the difference between the DUE and UE. This is probably the result of the monodisciplinarity of the programmes in DUE and UE as opposed to the OuN which strives towards an interdisciplinary programme. Apparently, the type of programme weighs more heavily on the way in which the faculty members think than the nature of the institution.
- Each of the three types of institution is statistically unique from the other two. Seeing as how each of the groups represents one of the cells in the matrix presented in section 1, this was to be expected.
- A strange artefact showing up in the results is the gradient of similarity with respect to the rating of the general objectives made visible through the calculation of Kendall's τ. One would expect OuN and DUE, which differ on one of the two dimensions (both are institutions for distance education; the type of programme offered is different) or DUE and UE, which also differ on one dimension (the nature of the institution is different; both offer monodisciplinary programmes) to be more similar than OuN and UE, which differ on both dimensions. The results show that DUE-UE are least similar, followed by DUE-OuN, with OuN-UE being most

similar. Apparently there is another factor (possibly a cultural one) which is stronger than both of the dimensions which causes this anomaly.

- There is a large degree of similarity between UE and DUE with respect to the specific objectives. The specific role which we thought that the *nature of the institution* would play in the evaluation of the objectives by the respondents did not crystallise here.
- The OuN differed from UE and DUE with respect to the specific objectives. This points in the direction of the expected role that the *type of programme* offered would play in the evaluation of the objectives by the respondents.
- The OuN distinguishes itself from UE and DUE primarily in the much lower evaluation of "real" practical skills (laboratory performance skills - specifications of general objective *D*) and a higher evaluation of problem solving skills.

Bibliography

Beatty, J.W., and Woolnough, B.E. (1982). Practical work in 11-13 science; The context, type and aims of current practice. *British Educational Research Journal*, 8, 23-30.

Bloom, B.S., Engelhart, M.D., Furst, E.J., Hill, W.H. and Krathwohl, D.R. (1956). *Taxonomy of educational objectives: The classification of end-terms. Handbook I: Cognitive domain*. New York: David McKay Company, Inc.

Boud, D.J., Dunn, J., Kennedy, T. and Thorley, R. (1980). The aims of science laboratory courses: A survey of students, graduates and practising scientists. *European Journal of Science Education*, 2, 415-428.

Eindtermen: algemene en voor de diplomalijn milieukunde [End-terms: general and specific for the diploma programme Environmental Sciences] (1986). Produktgroep Natuurwetenschappen aan de Open Universiteit, Heerlen.

Glass, G.V. & Stanley, J.C. (1970). *Statistical methods in education and psychology*. Englewood Cliffs: Prentice-Hall, Inc.

Gould, C.D. (1978). Practical work in sixth-form biology. *Journal of Biological Education*, 12, 33-38.

Gronlund, N.E. (1970). *Stating behavioral objectives for classroom instruction*. New York: The Macmillan Company.

Hays, W.L. (1981). *Statistics (3rd ed.)*. New York: CBS College Publishing.

Hodson, D. (1988). Experiments in science and science teaching. *Educational Philosophy and Theory*, 20, 53-66.

Hurd, P.D. (1969). *New directions in teaching secondary school science*. Chicago: Rand McNally & Company.

Kerlinger (1973). *Foundations of behavioral research*. London etc., Holt, Rinehart & Winston.

Kerr, J.F. (1963). *Practical work in school science*. Leicester: Leicester University Press.

Kirschner, P.A. (1988). *Practicals and the acquisition of academic skills*. Paper presented at the annual meeting of the National Association for Research on Science Teaching, March xx-yy, 1988, San Francisco, California.

Kirschner, P.A., Meester, M.A.M. (1988). The laboratory in higher science education: problems, premises and objectives. *Higher Education*, 17, 81-88.

Kirschner, P.A., Meester, M.A.M., & Middelbeek, E. (1991 in press). Practical objectives at the Open university of the Netherlands. *Journal of Distance Learning*, in press.

Klopfer, L.E. (1971). Evaluation of learning in science. In Bloom, C.S., Hastings, J.T. and Madaus, G.F. (Eds.). *Handbook on formative and summative evaluation of student learning*. New York: McGraw-Hill, Inc.

Meester, M.A.M., Kirschner, P.A., Middelbeek, E.J. en Hermans, H. (1989). *Practicumleerdoelen aan de Open universiteit: Een beschrijvend onderzoek.* [Practical objectives at the Open university: A descriptive study] Educational Technology Innovation Centre Research rapport 13, Ou-Heerlen.

Meester, M.A.M., Kirschner, P.A., Middelbeek, E.J. en Hermans, H. (1990). *Practicumleerdoelen aan de instellingen voor hoger onderwijs (wo en hbo) in Nederland: Een beschrijvend onderzoek.* [Practical objectives at institutes for higher education (universities and higher vocational education) in the Netherlands: A descriptive study] Educational Technology Innovation Centre Research rapport 21, Ou-Heerlen.

Siegel, S. (1956). *Nonparametric statistics for the behavioral sciences*. New York: McGraw-Hill, Inc.

Swanborn, P.G. (1982). *Schaaltechnieken* [Scale techniques]. Meppel: Boom.

White, R.T. (1988). *Learning Science*. Oxford: Blockwell Ltd.

Woolnough, B.E. (1976). Practical work in sixth-form physics. *Physics Education*, 392-397.

Appendices

Appendix 1 Order of priority of specific learning objectives from research within the OuN
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Appendix 1 Order of priority of specific learning objectives from research within the OuN

The first column gives the item number for the specific learning objective from the inventory (appendix 7). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
9	E	Interpret reliability and meaning of results	1.25	1.64	0.45
16	E	Assess relevance of exp. data with regard to hypothesis	1.50	1.24	0.52
34	E	Apply elementary notions of statistics	1.50	1.24	0.67
23	A	Derive testable hypotheses from theories	1.67	0.98	0.49
71	F	Describe central aspects of an experiment	1.67	0.98	0.49
97	E	Relate exp. outcomes to a particular theory	1.67	0.98	0.49
102	E	Evaluate diff. expected & actual results	1.67	0.98	0.49
21	A	Decompose large to smaller problems	1.67	0.98	0.65
91	A	Understand what is to be measured in an exp.	1.67	0.98	0.65
1	E	Make order-of-magnitude calculations and estimates	1.75	0.85	0.75
84	A	Understand the purpose of an experiment	1.75	0.85	0.87
64	C	Recogn. hazards so as to take safety precautions	1.83	0.73	0.39
47	E	Evaluate exp. outcome with respect to a hypothesis	1.83	C.73	0.58
75	B	Apply known principles to new situations	1.83	0.73	0.58
67	E	Analyze exp. data to draw conclusions	1.83	0.73	0.58
94	8	React adequately to unforeseen results	1.83	0.73	0.72
5	D	Observe phenomena in a qualitative way	1.83	0.73	0.83
17	F	Present essentials of an exp. in written form	1.83	0.73	0.94
22	C	Design subsequent exp. involving phenomena	1.92	0.58	0.79
43	E	Incorporate unexpected exp. results in new model	1.92	0.58	0.79
25	F	Communicate exp. findings in written form	1.92	0.58	0.90
44	D	Be flexible in modifying exp.	1.92	0.58	0.90
54	A	Derive & evaluate relationships	1.92	0.58	0.90
41	B	Recognize & define scientific problems	2.00	0.46	0.43
26	E	Use obtained data to make estimates in new situations	2.00	0.46	0.60
33	A	Use exp. data to solve specific problems	2.00	0.46	0.60
63	A	Solve problems in a multi-solution situation	2.00	0.46	0.60
77	C	Properly plan an experiment	2.00	0.46	0.60
31	C	Design an exp. to verify a theory/hypothesis	2.00	0.46	0.74
10	E	Estimate outcome of exp. meas. within given precision	2.00	0.46	0.95
35	B	Apply current knowledge in solving new problems	2.00	0.46	1.13
56	E	Evaluate contribution direct to derived errors	2.08	0.33	0.51
55	F	Summarize an exp. based on results	2.08	0.33	0.67
86	C	Understand scope & limits of exp. techniques used	2.08	0.33	1.00
42	F	Communicate exp. findings in oral form	2.08	0.33	1.08
68	D	Handle waste safely	2.17	0.19	0.94
45	B	Construct models based on exp. findings	2.17	0.19	1.03
61	D	Observe phenomena in a quantitative way	2.17	0.19	1.03
72	F	Suggest follow-up investigations	2.25	0.07	0.75
62	D	Conduct experiments safely	2.25	0.07	0.87
19	E	Apply principles instead of rote formulae	2.33	-0.06	0.78
53	D	Keep a day-to-day lab diary	2.33	-0.06	1.23
38	B	Construct models which fit exp. evidence	2.33	-0.06	1.50
98	A	Understand measurement of diff. phenomena	2.42	-0.20	1.08
83	F	Discuss results with other scientists	2.42	-0.20	1.24
52	E	Process experimental data	2.50	-0.33	1.09
95	C	Design relevant observation techniques	2.50	-0.33	1.09
101	D	Understand lab instructions	2.58	-0.45	1.24
29	A	Solve difficult scientific problems	2.67	-0.59	1.07
46	A	Identify variables & determine emp. relations	2.67	-0.59	1.07
28	D	Carry out accurate measurements	2.75	-0.72	1.1
80	D	Collect experimental data	2.83	-0.85	1.11
4	D	Use practical (as opposed to theoretical) lab skills	2.92	-0.99	1.08
100	E	Confirm facts, princ. & theory from lect./books	3.00	-1.11	1.04
12	D	Put basic lab. techniques to use	3.08	-1.24	1.31
88	C	Translate conc. def. into set of meas. procedures	3.08	-1.24	1.44
24	D	Follow instructions	3.17	-1.38	1.27
92	D	Know & apply altern. meas. techniques	3.25	-1.51	1.22
65	E	Confirm already known facts and laws	3.42	-1.77	0.90
18	D	Manipulate apparati	3.50	-1.90	1.24
85	D	Handle modern equipment	3.58	-2.03	1.08
89	D	Set up lab equipment quickly & correctly	3.67	-2.17	1.07
32	C	Develop measurement techniques	4.00	-2.69	1.13
20	D	Calibrate instruments	4.17	-2.95	0.72

Appendix 2 Order of priority of end-terms from research within the OuN

The first column gives the item number for the specific end-term from the inventory (appendix 7). The roman numerals in column two correspond with the general end-terms.

		End-term	x	Z	s.d.
03	II	Solve problems in a critical, academic way	1.17	2.16	0.39
08	II	Approach observed phenomena from a scient. point of view	1.33	1.88	0.49
14	I	Make decisions in proper course of action of prob-solving	1.50	1.59	0.52
79	I	Have a critical attitude to exp. results	1.50	1.59	0.52
90	I	Survey literature relevant to some problem	1.50	1.59	0.90
74	I	Interpret data in literature	1.75	1.15	1.14
49	I	Formulate a problem that can be researched	1.83	1.01	0.72
66	I	Approach a problem with an open mind	1.92	0.86	0.79
15	I	Form attitudes related to value & uses of exp. science	2.00	0.72	0.43
06	II	Deeply understand the discipline studied	2.00	0.72	1.04
37	I	Discover limitations of a theory/model	2.00	0.72	1.21
39	I	Act independently & take initiative	2.08	0.58	0.79
57	I	Apply one's insights, discoveries & conclusions	2.25	0.29	0.75
48	I	Plan ahead	2.33	0.15	0.49
27	II	Be interested in the subject area	2.33	0.15	1.15
11	I	Work in groups to solve scient. problems	2.42	-0.01	0.79
81	II	Appreciate relationship between nature & science	2.42	-0.01	1.00
76	II	Design new exp. in their own fields	2.42	-0.01	1.16
50	II	Experience challenge of exp. method	2.50	-0.15	0.90
58	I	Be self-confident and independent	2.50	-0.15	1.00
67	I	Take active part in the process of science	2.50	-0.15	1.09
70	I	Work independently of others	2.58	-0.29	1.00
78	II	Experience spirit & essence of scient. inquiry	2.58	-0.29	1.00
59	II	Build framework for facts, princ & theory from lect/books	2.58	-0.29	1.24
02	II	Use the lab as an instrument for discovery	2.67	-0.44	0.89
51	I	Appreciate the usual & unusual	2.67	-0.44	0.98
30	II	Determine limits under which a theory applies	2.67	-0.44	1.37
40	I	Concretize theoretical notions	2.75	-0.58	1.06
69	II	Do experiments	2.83	-0.72	0.94
13	II	Illustrate facts, princ. & theory of lectures/books	2.83	-0.72	1.03
99	I	Use mental skills inherent to professionals	2.83	-0.72	1.03
36	II	Intuitively understand scientific phenomena	2.92	-0.88	0.90
82	I	Tackle a problem without help of others	2.92	-0.88	1.08
93	II	Experience kinship with the scientist	3.25	-1.45	0.97
60	II	Experience past and present scientists' joy	3.25	-1.45	1.06
07	I	Use motor skills inherent to professionals	3.33	-1.59	0.98
73	II	Experience joys & sorrows of experimenting	3.33	-1.59	0.98
96	II	Work in research & development labs	3.50	-1.88	1.17

Appendix 3 Order of priority of specific learning objectives from research within UE

The first column gives the item number for the specific learning objective from the inventory (appendix 7). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
62	D	Conduct experiments safely	1.32	1.54	0.48
84	A	Understand the purpose of an experiment	1.32	1.54	0.48
9	E	Interpret reliability and meaning of results	1.36	1.46	0.49
17	F	Present essentials of an exp. in written form	1.36	1.46	0.49
91	A	Understand what is to be measured in an exp.	1.36	1.46	0.58
25	F	Communicate exp. findings in written form	1.41	1.35	0.50
77	C	Properly plan an experiment	1.50	1.17	0.51
16	E	Assess relevance of exp. data with regard to hypothesis	1.50	1.17	0.67
64	C	Recogn. hazards so as to take safety precautions	1.50	1.17	0.80
87	E	Analyze exp. data to draw conclusions	1.55	1.06	0.51
47	E	Evaluate exp. outcome with respect to a hypothesis	1.59	0.98	0.50
28	D	Carry out accurate measurements	1.59	0.98	0.59
56	E	Evaluate contribution direct to derived errors	1.62	0.92	0.74
61	D	Observe phenomena in a quantitative way	1.64	0.87	0.49
4	D	Use practical (as opposed to theoretical) lab skills	1.64	0.87	0.66
80	D	Collect experimental data	1.64	0.87	0.66
102	E	Evaluate diff. expected & actual results	1.68	0.79	0.57
52	E	Process experimental data	1.73	0.69	0.55
71	F	Describe central aspects of an experiment	1.73	0.69	0.55
98	A	Understand measurement of diff. phenomena	1.73	0.69	0.63
34	E	Apply elementary notions of statistics	1.73	0.69	0.77
55	F	Summarize an exp. based on results	1.76	0.62	0.70
1	E	Make order-of-magnitude calculations and estimates	1.77	0.60	0.61
101	D	Understand lab instructions	1.82	0.50	0.91
68	D	Handle waste safely	1.82	0.50	1.05
86	C	Understand scope & limits of exp. techniques used	1.95	0.23	0.58
33	A	Use exp. data to solve specific problems	1.95	0.23	0.74
31	C	Design an exp. to verify a theory/hypothesis	1.95	0.23	0.84
12	D	Put basic lab. techniques to use	1.95	0.23	0.95
97	E	Relate exp. outcomes to a particular theory	2.00	0.12	0.53
5	D	Observe phenomena in a qualitative way	2.00	0.12	0.62
10	E	Estimate outcome of exp. meas. within given precision	2.00	0.12	0.62
19	E	Apply principles instead of rote formulae	2.00	0.12	0.62
35	B	Apply current knowledge in solving new problems	2.05	0.02	0.95
21	A	Decompose large to smaller problems	2.09	-0.06	0.75
22	C	Design subsequent exp. involving phenomena	2.09	-0.06	0.75
75	B	Apply known principles to new situations	2.09	-0.06	0.75
26	E	Use obtained data to make estimates in new situations	2.14	-0.17	0.77
72	F	Suggest follow-up investigations	2.14	-0.17	0.77
42	F	Communicate exp. findings in oral form	2.14	-0.17	0.94
85	D	Handle modern equipment	2.23	-0.36	0.87
94	B	React adequately to unforeseen results	2.23	-0.36	0.87
23	A	Derive testable hypotheses from theories	2.23	-0.36	1.02
89	D	Set up lab equipment quickly & correctly	2.27	-0.44	0.70
18	D	Manipulate apparati	2.27	-0.44	0.98
53	D	Keep a day-to-day lab diary	2.27	-0.44	1.20
44	D	Be flexible in modifying exp.	2.32	-0.54	1.09
45	B	Construct models based on exp. findings	2.41	-0.73	0.96
38	B	Construct models which fit exp. evidence	2.41	-0.73	1.05
41	B	Recognize & define scientific problems	2.41	-0.73	1.14
54	A	Derive & evaluate relationships	2.48	-0.88	0.75
88	C	Translate conc. def. into set of meas. procedures	2.50	-0.92	0.80
92	D	Know & apply altern. meas. techniques	2.50	-0.92	0.80
46	A	Identify variables & determine emp. relations	2.55	-1.02	0.96
24	D	Follow instructions	2.55	-1.02	1.06
63	A	Solve problems in a multi-solution situation	2.59	-1.11	1.05
20	D	Calibrate instruments	2.64	-1.21	1.05
95	C	Design relevant observation techniques	2.68	-1.29	0.99
83	F	Discuss results with other scientists	2.68	-1.29	1.13
43	E	Incorporate unexpected exp. results in new model	2.81	-1.56	1.08
32	C	Develop measurement techniques	3.00	-1.96	0.98
29	A	Solve difficult scientific problems	3.00	-1.96	1.38
100	E	Confirm facts, princ. & theory from lect./books	3.24	-2.46	1.09
65	E	Confirm already known facts and laws	3.33	-2.65	0.91

Appendix 4 Order of priority of specific end-terms from research within UE

The first column gives the item number for the specific end-term from the inventory (appendix 7). The roman numerals in column two correspond with the general end-terms.

		End-term	x	Z	s.d.
79	I	Have a critical attitude to exp. results	1.45	2.09	0.51
3	II	Solve problems in a critical, academic way	1.64	1.67	0.58
69	II	Do experiments	1.73	1.47	1.08
14	I	Make decisions in proper course of action of prob-solving	1.86	1.18	0.71
15	I	Form attitudes related to value & uses of exp. science	1.86	1.18	0.89
37	I	Discover limitations of a theory/model	1.91	1.07	0.68
6	II	Deeply understand the discipline studied	1.91	1.07	0.75
8	II	Approach observed phenomena from a scient. point of view	1.95	0.98	0.72
2	II	Use the lab as an instrument for discovery	2.00	0.87	0.76
48	I	Plan ahead	2.05	0.76	0.72
49	I	Formulate a problem that can be researched	2.09	0.67	1.23
74	I	Interpret data in literature	2.14	0.56	0.71
66	I	Approach a problem with an open mind	2.14	0.56	1.08
27	II	Be interested in the subject area	2.18	0.47	1.10
90	I	Survey literature relevant to some problem	2.18	0.47	1.18
39	I	Act independently & take initiative	2.27	0.27	0.55
57	I	Apply one's insights, discoveries & conclusions	2.27	0.27	0.70
76	II	Design new exp. in their own fields	2.36	0.07	0.85
78	II	Experience spirit & essence of scient. inquiry	2.36	0.07	0.95
30	II	Determine limits under which a theory applies	2.36	0.07	1.14
99	I	Use mental skills inherent to professionals	2.45	-0.13	1.06
11	I	Work in groups to solve scient. problems	2.45	-0.13	1.18
81	II	Appreciate relationship between nature & science	2.50	-0.24	1.06
13	II	Illustrate facts, princ. & theory of lectures/books	2.52	-0.29	1.03
96	II	Work in research & development labs	2.55	-0.35	1.30
50	II	Experience challenge of exp. method	2.59	-0.44	1.05
40	I	Concretize theoretical notions	2.62	-0.51	0.80
67	I	Take active part in the process of science	2.64	-0.55	1.09
60	II	Experience past and present scientists' joy	2.73	-0.75	1.24
7	I	Use motor skills inherent to professionals	2.81	-0.93	1.08
70	I	Work independently of others	2.86	-1.04	0.94
51	I	Appreciate the usual & unusual	2.91	-1.16	1.19
73	II	Experience joys & sorrows of experimenting	2.91	-1.16	1.44
82	I	Tackle a problem without help of others	3.05	-1.47	0.95
36	II	Intuitively understand scientific phenomena	3.05	-1.47	1.18
58	I	Be self-confident and independent	3.14	-1.67	1.17
93	II	Experience kinship with the scientist	3.18	-1.76	1.10
59	II	Build framework for facts, princ & theory from lect/books	3.19	-1.78	1.08

Appendix 5 List of participating institutes of higher distance education

Athabasca University, Canada

Télé-Université (TELUQ), Université de Quebec, Canada

Centre for Off-campus Studies, Universiti Sains Malaysia (Science University of Malaysia). Malaysia

University of Queensland, Australia

Empire State College, New York, USA

British Open University, Milton Keynes, GB

Sukhothai Thammathirat Open University (STOU), Thailand

Open University Sri Lanka, Sri Lanka

Everyman's University, Tel Aviv, Israel

University of Wisconsin Superior, Wisconsin, USA

Appendix 6 A paired comparison of general objectives, LDSI-2

LDSI-2

Name:...............

A practical is defined as those activities relating to experimentation beginning with the conception of a question or the observation of a phenomenon through the reporting of the results in written or oral form. Examples of experimentation are: demonstrations, 'wet' labs, pen and paper experiments, simulations, etc.

This booklet contains 28 pairs of general learning objectives for practicals. Please choose the objective by each pair which you consider the most important of the two. You can do this by placing a cross (x) in the circle preceding the relevant objective. Please do not look back to or change previous choices! Thank You.

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 use knowledge and skills in unfamiliar situations
0 interpret experimental data

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 remember the central idea of an experiment over a significantly long period of time
0 design (simple) experiments to test hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 formulate hypotheses
0 solve problems

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 design (simple) experiments to test hypotheses
0 use knowledge and skills in unfamiliar situations

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 interpret experimental data
0 design (simple) experiments to test hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 remember the central idea of an experiment over a significantly long period of time

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 remember the central idea of an experiment over a significantly long period of time
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 solve problems

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 remember the central idea of an experiment over a significantly long period of time
0 formulate hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 interpret experimental data
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 solve problems
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 formulate hypotheses
0 interpret experimental data

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 formulate hypotheses
0 design (simple) experiments to test hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 use knowledge and skills in unfamiliar situations

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 interpret experimental data

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 design (simple) experiments to test hypotheses
0 clearly describe an experiment

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 formulate hypotheses
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 interpret experimental data
0 remember the central idea of an experiment over a significantly long period of time

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 remember the central idea of an experiment over a significantly long period of time
0 solve problems

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 solve problems
0 interpret experimental data

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 solve problems
0 design (simple) experiments to test hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 use knowledge and skills in unfamiliar situations
0 remember the central idea of an experiment over a significantly long period of time

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 use knowledge and skills in unfamiliar situations
0 formulate hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 use laboratory skills in performing (simple) experiments
0 use knowledge and skills in unfamiliar situations

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 solve problems
0 use knowledge and skills in unfamiliar situations

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 formulate hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 design (simple) experiments to test hypotheses
0 use laboratory skills in performing (simple) experiments

Een inventarisatie van specifieke leerdoelen

In het artikel "*The laboratory in higher science education: Problems, premises and objectives*" (Kirschner & Meester, Higher Education, 1988) wordt een uitgebreide inventarisatie gepresenteerd van globale en specifieke leerdoelen (circa 100), zoals die in de literatuur voor natuurwetenschappelijke *practica* worden vermeld.

Deze vragenlijst is het tweede instrument dat wij gebruiken om te onderzoeken welke leerdoelen voor practica binnen de verschillende opleidingen voor hoger natuurwetenschappelijk onderwijs worden nagestreefd. Het eerste instrument (LDSI-2 "*Een paarsgewijze vergelijking van globale leerdoelen*") beoogt te komen tot een rangschikking naar prioriteit van *globale* leerdoelen. In dit vragenformulier vindt u de *specifieke* practicumdoelen uit bovengenoemd artikel in enigszins aangepaste vorm en in willekeurige volgorde terug. Het is de bedoeling met dit vragenformulier te achterhalen welk belang er, in het kader van de door u verzorgde opleiding(en), aan ieder leerdoel afzonderlijk wordt gehecht. We verzoeken u het vragenformulier in te vullen na het lezen van onderstaande toelichting.

Toelichting
Alle leerdoelen zijn in deze vragenlijst zodanig geformuleerd dat ze aansluiten op een gemeenschappelijke stam die U bovenaan ieder blad kunt terugvinden en die luidt: "*An undergraduate study in the natural sciences should prepare students to:*". Met "undergraduate study" doelen we hier op het cursorisch deel van de studie, te weten het gemeenschappelijk (verplichte) deel dat voorbereidt op de afstudeerfase.
We vragen u voor ieder leerdoel afzonderlijk op een vijfpuntsschaal aan te geven welk belang u eraan toekent. Aangezien het nodig is dat iedere respondent dezelfde betekenis hecht aan de verschillende schaalwaarden, is hieronder een korte omschrijving van de in de schaal opgenomen kernwoorden gegeven.

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

onontbeerlijk — dit leerdoel is essentieel en moet in de opleiding beslist aan bod komen; we besteden er in ruime mate aandacht aan

belangrijk — dit leerdoel is belangrijk; we besteden er in de opleiding aandacht aan

neutraal — over dit leerdoel heb ik geen mening; ik sluit me aan bij de overheersende opvatting erover.

niet echt nodig — dit leerdoel is niet erg belangrijk; is er te weinig tijd/te weinig gelegenheid dan komt het te vervallen

vervalt — dit leerdoel hoeft niet nagestreefd te worden; in de opleiding ruimen we er *geen* tijd voor in

Alvorens tot invulling van het vragenformulier over te gaan, verzoeken we u de lijst met leerdoelen eerst een keer geheel door te lezen. Wilt u vervolgens het belang van ieder leerdoel aangeven zonder daarin eerder gegeven antwoorden te betrekken, met andere woorden zonder terug te bladeren om eerder gegeven antwoorden te raadplegen of te veranderen.
U kunt uw mening kenbaar maken door desbetreffende categorie aan te kruisen. A.u.b. één antwoord per vraag.

An undergraduate study in the natural sciences should prepare students to:

1- make order-of-magnitude calculations and estimates

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

2 - use the laboratory as an instrument for discovery

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

3 - solve problems in an critical, academic way

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

4 - use practical (as opposed to theoretical) laboratory skills

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

5 - observe phenomena in a qualitative way

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

6 - deeply understand the discipline studied (as opposed to being able to simply 'work-by-the-book')

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

7 - use motor skills inherent to professionals in the natural sciences

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

8 - approach observed phenomena from a scientific point of view

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

9 - interpret the reliability and meaning of results gained through experimentation (either their own or those of others)

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

10 - estimate the outcome of experimental measurements within a given precision prior to actual experimentation

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

11 - work in groups to solve scientific problems

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

12 - put basic laboratory techniques (such as titration, microscopy or physical measurement) to use

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

13 - illustrate facts, principles and theories discussed in lectures or books

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

14 - make decisions as to the proper course of action in solving problems

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

15 - form attitudes relating to the value and uses of experimental science (physics, biology and chemistry)

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

16 - assess the relevance of experimental data with regard to a hypothesis being studied

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

17 - present the essentials of an experiment in written form

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

18 - manipulate apparati

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

19 - apply principles rather than rote use of computational formulae in the theoretical analysis of the lab experiment

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

20 - calibrate instruments

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

21 - decompose large problems into a number of smaller problems

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

22 - design subsequent experiments involving the phenomena being studied

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

23 - derive testable hypotheses from theories

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

24 - follow instructions

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

25 - communicate experimental findings in written form

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

26 - use data already obtained to make estimates regarding not yet tested situations

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

27 - be interested in the subject area being studied.

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

28 - carry out accurate measurements

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

29 - solve difficult scientific problems

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

30 - determine the limits under which a theory applies

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

31 - design an experiment to test a theory or hypothesis

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

32 - develop measurement techniques

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

33 - use experimental data to solve specific problems

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

34 - apply elementary notions of statistics (e.g. random errors, systematic errors, mean values, uncertainty and confidence limits) in evaluating experimental data

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

35 - apply what is already known to solve new problems

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

36 - intuitively understand scientific phenomena

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

37 - discover the limitations of a theory or model

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

38 - construct models which fit experimental evidence

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

39 - act independently and take initiative

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

40 - concretize (illustrate) theoretical notions

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

41 - recognize and define scientific problems

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

42 - communicate experimental findings in oral form

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

ndergraduate study in the natural sciences should prepare students to:

43 - incorporate unexpected experimental results in a new model

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

44 - be flexible with respect to modifying experiments in light of results obtained in prior experimentation

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

45 - construct models based on experimental findings

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

46 - identify the variables that adequately describe some system's state and empirically determine the way they are related

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

47 - evaluate the outcome of an experiment with regard to the hypothesis being tested

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

48 - plan ahead

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

49 - formulate a problem so that it can be researched

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

50 - experience the intellectual challenge of using the experimental method

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

51 - appreciate the usual as well as the unusual within the natural sciences

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

52 - process experimental data

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

53 - keep a day-to-day laboratory diary in such a way that a third person can repeat the experiments

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

54 - derive and evaluate relationships between observed scientific phenomena

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

55 - summarize the important aspects of an experiment based on collected data

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

56 - evaluate how errors in direct measurements may contribute to errors in a derived measure

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

57 - apply one's own insights, discoveries and conclusions in explaining observed phenomena

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

58 - be self-confident and independent

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

59 - build a framework for facts, principles and theories encountered in lectures and books

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

60 - experience the joy experienced by scientists past and present

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

61 - observe phenomena in a quantitative way

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

62 - conduct experiments safely

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

63 - solve problems in which there is more than one usable solution strategy

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

64 - recognize hazards so as to take appropriate safety precautions

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

65 - confirm already known facts and laws

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

66 - approach a problem with an open mind

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

... undergraduate study in the natural sciences should prepare students to:

67 - actively take part in the process of science

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

68 - handle waste safely from an environmental point of view

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

69 - do experiments

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

70 - work independently of others

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

71 - describe the central aspects of an experiment (i.e. its goals, underlying theory and basic methods)

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

72 - suggest follow-up investigations once the results of a scientific investigation are known

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

73 - experience the joys and sorrows of experimenting

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

74 - interpret data in the literature

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

75 - apply known principles to new situations

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

76 - design new experiments in their own field of research

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

77 - properly plan an experiment

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

78 - experience the spirit of scientific inquiry and the essence of scientific thinking

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

79 - have a critical attitude towards experimentally gained results

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

80 - collect experimental data

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

81 - appreciate the relationship between nature and science

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

82 - tackle a problem without the help of others

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

83 - discuss results of scientific investigations with other scientists

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

84 - understand the purpose of an experiment

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

85 - handle modern equipment

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

86 - understand the scope and limiting conditions of the experimental techniques used

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

87 - analyse experimental data in order to draw conclusions from them

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

88 - translate a conceptual definition of a quantity into a set of measurement procedures

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

89 - set up laboratory equipment quickly and correctly

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

90 - survey the literature relevant to some problem at hand

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

91 - understand what is to be measured during an experiment

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

92 - apply alternative measuring techniques for improving reliability and precision of data gained

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

93 - experience a kinship with the scientist

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

94 - react adequately when confronted with unforeseen results

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

95 - design observation techniques relevant to the task at hand

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

96 - work in research and developments laboratories

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

An undergraduate study in the natural sciences should prepare students to:

97 - relate the outcomes of an experiment to a particular theory

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

98 - understand how different phenomena are measured during an experiment

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

99 - use mental skills inherent to professionals in the natural sciences

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

100 - confirm facts, principles and theories discussed in lectures or books

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

101 - understand laboratory instructions

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

102 - evaluate why expected (theoretical) results differ from actual experimental findings

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

Appendix 8 List of general objectives and end-terms with the corresponding specific learning objectives and end-terms.

This classification is based upon the classification of specific learning objectives and end-terms by Meester and Kirschner (1988). The number of general learning objectives has been reduced from eight to six. Several specific learning objectives have been reformulated; four specific learning objectives have become end-terms, and four end-terms have become specific learning objectives.
N.B.: the numbers preceding the specific learning objectives and end-terms correspond with the item number from the inventory (appendix 7).

Specific learning objectives

A. *To solve problems*

21 decompose large problems into a number of smaller problems
23 derive testable hypotheses from theories
63 solve problems in which there is more than one usable solution strategy
54 derive and evaluate relationships between observed scientific phenomena
33 use experimental data to solve specific problems
29 solve difficult scientific problems
84 understand the purpose of an experiment
91 understand what is to be measured during an experiment
98 understand how different phenomena are measured during an experiment
46 identify the variables that adequately describe some system's state and empirically determine the way they are related

B. *To use knowledge and skills in unfamiliar situations*

35 apply what is already known to solve new problems
75 apply known principles to new situations
41 recognize and define scientific problems
45 construct models based on experimental findings
38 construct models which fit experimental evidence
94 react adequately when confronted with unforeseen results

C. *To design (simple) experiments to test hypotheses*

31 design an experiment to test a theory or hypothesis
77 properly plan an experiment
95 design observation techniques relevant to the task at hand
32 develop measurement techniques
22 design subsequent experiments involving the phenomena being studied
64 recognize hazards so as to take appropriate safety precautions
86 understand the scope and limiting conditions of the experimental techniques used
88 translate a conceptual definition of a quantity into a set of measurement procedures

D. To use laboratory skills in performing (simple) experiments

24 follow instructions
101 understand laboratory instructions
4 use practical (as opposed to theoretical) laboratory skills
89 set up laboratory equipment quickly and correctly
18 manipulate apparati
62 conduct experiments safely
92 apply alternative measuring techniques for improving reliability and precision of data gained
12 put basic laboratory techniques (such as titration, microscopy or physical measurement) to use
85 handle modern equipment
20 calibrate instruments
28 carry out accurate measurements
5 observe phenomena in a qualitative way
61 observe phenomena in a quantitative way
44 be flexible with respect to modifying experiments in light of results obtained in prior experimentation
68 handle waste safely from an environmental point of view
80 collect experimental data
53 keep a day-to-day laboratory diary in such a way that a third person can repeat the experiments

E. To interpret experimental data

52 process experimental data
87 analyse experimental data in order to draw conclusions from them
19 apply principles rather than rote use of computational formulae in the theoretical analysis of the lab experiment
34 apply elementary notions of statistics (e.g. random errors, systematic errors, mean values, uncertainty and confidence limits) in evaluating experimental data
56 evaluate how errors in direct measurements may contribute to errors in a derived measure
16 assess the relevance of experimental data with regard to a hypothesis being studied
10 estimate the outcome of experimental measurements within a given precision prior to actual experimentation
47 evaluate the outcome of an experiment with regard to the hypothesis being tested
1 make order-of-magnitude calculations and estimates
43 incorporate unexpected experimental results in a new model
102 evaluate why expected (theoretical) results differ from actual experimental findings
26 use data already obtained to make estimates regarding not yet tested situations
9 interpret the reliability and meaning of results gained through experimentation (either their own or those of others)
97 relate the outcomes of an experiment to a particular theory
100 confirm facts, principles and theories discussed in lectures or books
65 confirm already known facts and laws

F. To clearly describe the experiment

17 present the essentials of an experiment in written form
55 summarize the important aspects of an experiment based on collected data
71 describe the central aspects of an experiment (i.e. its goals, underlying theory and basic methods)
25 communicate experimental findings in written form
42 communicate experimental findings in oral form
72 suggest follow-up investigations once the results of a scientific investigation are known
83 discuss results of scientific investigations with other scientists

End-terms

I. To obtain good scientific attitudes

49 formulate a problem so that it can be researched
90 survey the literature relevant to some problem at hand
14 make decisions as to the proper course of action in solving problems
79 have a critical attitude towards experimentally gained results
58 be self-confident and independent
39 act independently and take initiative
82 tackle a problem without the help of others
48 plan ahead
40 concretize (illustrate) theoretical notions
15 form attitudes relating to the value and uses of experimental science (physics, biology and chemistry)
57 apply one's own insights, discoveries and conclusions in explaining observed phenomena
37 discover the limitations of a theory or model
66 approach a problem with an open mind
11 work in groups to solve scientific problems
70 work independently of others
67 actively take part in the process of science
99 use mental skills inherent to professionals in the natural sciences
74 interpret data in the literature
7 use motor skills inherent to professionals in the natural sciences
51 appreciate the usual as well as the unusual within the natural sciences

II. To understand the scientific method

81 appreciate the relationship between nature and science
36 intuitively understand scientific phenomena
30 determine the limits under which a theory applies
69 do experiments
13 illustrate facts, principles and theories discussed in lectures or books
59 build a framework for facts, principles and theories encountered in lectures and books
2 use the laboratory as an instrument for discovery
96 work in research and developments laboratories
8 approach observed phenomena from a scientific point of view
50 experience the intellectual challenge of using the experimental method
73 experience the joys and sorrows of experimenting
93 experience a kinship with the scientist
60 experience the joy experienced by scientists past and present
6 deeply understand the discipline studied (as opposed to being able to simply work by the book)
78 experience the spirit of scientific inquiry and the essence of scientific thinking
27 be interested in the subject area being studied.
76 design new experiments in their own field of research
3 solve problems in a critical, academic way

Appendix 9 x, Z and s.d. of specific learning objectives for DUE institutes

The first column gives the item number for the specific learning objective from the inventory (appendix 7). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
87	E	Analyze exp. data to draw conclusions	1.33	1.82	0.49
9	E	Interpret reliability and meaning of results	1.4	1.67	0.51
91	A	Understand what is to be measured in an exp.	1.4	1.67	0.83
84	A	Understand the purpose of an experiment	1.53	1.39	0.74
62	D	Conduct experiments safely	1.57	1.30	0.65
19	E	Apply principles instead of rote formulae	1.6	1.24	0.51
61	D	Observe phenomena in a quantitative way	1.6	1.24	0.51
1	E	Make order-of-magnitude calculations and estimates	1.6	1.24	0.63
4	D	Use practical (as opposed to theoretical) lab skills	1.67	1.09	0.62
25	F	Communicate exp. findings in written form	1.67	1.09	0.82
47	E	Evaluate exp. outcome with respect to a hypothesis	1.67	1.09	0.90
64	C	Recogn. hazards so as to take safety precautions	1.73	0.95	0.70
80	D	Collect experimental data	1.73	0.95	0.80
86	C	Understand scope & limits of exp. techniques used	1.8	0.80	0.68
98	A	Understand measurement of diff. phenomena	1.8	0.80	0.68
17	F	Present essentials of an exp. in written form	1.8	0.80	0.86
101	D	Understand lab instructions	1.8	0.80	1.08
16	E	Assess relevance of exp. data with regard to hypothesis	1.87	0.65	0.92
52	E	Process experimental data	1.87	0.65	0.92
77	C	Properly plan an experiment	1.87	0.65	0.92
35	8	Apply current knowledge in solving new problems	1.93	0.52	0.80
68	D	Handle waste safely	1.93	0.52	0.80
56	E	Evaluate contribution direct to derived errors	1.93	0.52	0.92
75	B	Apply known principles to new situations	1.93	0.52	1.03
71	F	Describe central aspects of an experiment	1.93	0.52	1.10
55	F	Summarize an exp. based on results	1.93	0.52	1.16
102	E	Evaluate diff. expected & actual results	1.93	0.52	1.16
28	D	Carry out accurate measurements	1.93	0.52	1.22
12	D	Put basic lab. techniques to use	2.00	0.37	0.38
5	D	Observe phenomena in a qualitative way	2.00	0.37	0.76
54	A	Derive & evaluate relationships	2.00	0.37	0.76
34	E	Apply elementary notions of statistics	2.00	0.37	1.00
97	E	Relate exp. outcomes to a particular theory	2.13	0.09	0.74
41	B	Recognize & define scientific problems	2.13	0.09	1.06
95	C	Design relevant observation techniques	2.20	-0.07	1.08
21	A	Decompose large to smaller problems	2.27	-0.22	0.70
23	A	Derive testable hypotheses from theories	2.27	-0.22	0.96
33	A	Use exp. data to solve specific problems	2.33	-0.35	0.62
18	D	Manipulate apparati	2.33	-0.35	0.72
94	B	React adequately to unforeseen results	2.33	-0.35	0.72
26	E	Use obtained data to make estimates in new situations	2.33	-0.35	0.98
83	F	Discuss results with other scientists	2.36	-0.41	1.08
31	C	Design an exp. to verify a theory/hypothesis	2.40	-0.50	1.06
46	A	Identify variables & determine emp. relations	2.40	-0.50	1.12
44	D	Be flexible in modifying exp.	2.40	-0.50	1.40
24	D	Follow instructions	2.40	-0.50	1.45
42	F	Communicate exp. findings in oral form	2.47	-0.65	0.92
92	D	Know & apply altern. meas. techniques	2.53	-0.78	0.64
63	A	Solve problems in a multi-solution situation	2.53	-0.78	0.83
22	C	Design subsequent exp. involving phenomena	2.50	-0.78	0.99
88	C	Translate conc. def. into set of meas. procedures	2.60	-0.94	0.83
10	E	Estimate outcome of exp. meas. within given precision	2.67	-1.09	1.18
72	F	Suggest follow-up investigations	2.73	-1.22	1.03
53	D	Keep a day-to-day lab diary	2.73	-1.22	1.22
100	E	Confirm facts, princ. & theory from lect./books	2.73	-1.22	1.22
85	D	Handle modern equipment	2.80	-1.37	1.08
89	D	Set up lab equipment quickly & correctly	2.80	-1.37	1.08
38	8	Construct models which fit exp. evidence	2.87	-1.52	1.13
65	E	Confirm already known facts and laws	2.87	-1.52	1.13
32	C	Develop measurement techniques	2.87	-1.52	1.19
45	8	Construct models based on exp. findings	2.93	-1.65	0.96
43	E	Incorporate unexpected exp. results in new model	3.00	-1.81	1.13
29	A	Solve difficult scientific problems	3.07	-1.96	1.10
20	D	Calibrate instruments	3.07	-1.96	1.28

Appendix 10 x, *Z* and *s.d.* of specific end-terms for DUE institutes

The first column gives the item number for the specific end-term from the inventory (appendix 7). The roman numerals in column two correspond with the general end-terms.

		End-term	x	Z	s.d.
8	II	Approach observed phenomena from a scient. point of view	1.53	1.86	0.52
79	I	Have a critical attitude to exp. results	1.53	1.86	0.52
3	II	Solve problems in a critical, academic way	1.71	1.48	0.47
66	I	Approach a problem with an open mind	1.73	1.43	0.88
14	I	Make decisions in proper course of action of prob-solving	1.80	1.28	0.68
6	II	Deeply understand the discipline studied	1.87	1.13	0.74
69	II	Do experiments	1.87	1.13	0.92
15	I	Form attitudes related to value & uses of exp. science	2.00	0.85	0.65
90	I	Survey literature relevant to some problem	2.13	0.57	0.92
48	I	Plan ahead	2.13	0.57	0.99
78	II	Experience spirit & essence of scient. inquiry	2.13	0.57	1.06
2	II	Use the lab as an instrument for discovery	2.13	0.57	1.13
99	I	Use mental skills inherent to professionals	2.14	0.55	1.29
74	I	Interpret data in literature	2.20	0.42	0.86
13	II	Illustrate facts, princ. & theory of lectures/books	2.20	0.42	0.94
59	II	Build framework for facts, princ & theory from lect/books	2.20	0.42	1.01
40	I	Concretize theoretical notions	2.29	0.23	0.73
81	II	Appreciate relationship between nature & science	2.33	0.15	0.82
27	II	Be interested in the subject area	2.33	0.15	1.11
39	I	Act independently & take initiative	2.47	-0.15	1.13
49	I	Formulate a problem that can be researched	2.47	-0.15	1.13
50	II	Experience challenge of exp. method	2.47	-0.15	1.19
67	I	Take active part in the process of science	2.57	-0.37	1.09
57	I	Apply one's insights, discoveries & conclusions	2.6	-0.43	0.91
51	I	Appreciate the usual & unusual	2.67	-0.58	0.90
82	I	Tackle a problem without help of others	2.67	-0.58	1.05
7	I	Use motor skills inherent to professionals	2.67	-0.58	1.18
76	II	Design new exp. in their own fields	2.67	-0.58	1.29
60	II	Experience past and present scientists' joy	2.71	-0.67	1.44
37	I	Discover limitations of a theory/model	2.73	-0.71	1.10
73	II	Experience joys & sorrows of experimenting	2.73	-0.71	1.16
30	II	Determine limits under which a theory applies	2.80	-0.86	1.26
58	I	Be self-confident and independent	2.80	-0.86	1.26
11	I	Work in groups to solve scient. problems	2.93	-1.14	1.16
36	II	Intuitively understand scientific phenomena	2.93	-1.14	1.21
70	I	Work independently of others	3.13	-1.57	1.06
96	II	Work in research & development labs	3.33	-2.00	1.18
93	II	Experience kinship with the scientist	3.53	-2.43	0.99

Appendix 11 Order of magnitude of differences in normalized learning objective scores between DUE and UE

The first column gives the item number for the specific learning objective from the inventory (appendix 7). The letters in the second column correspond with the general learning objectives.

		Objective	DUE	UE	AZ
54	A	Derive & evaluate relationships	0.37	-0.88	1.25
100	E	Confirm facts, princ. & theory from lect./books	-1.22	-2.46	1.24
95	C	Design relevant observation techniques	-0.07	-1.29	1.22
10	E	Estimate outcome of exp. meas. within given precision	-1.09	0.12	1.21
65	E	Confirm already known facts and laws	-1.52	-2.65	1.13
19	E	Apply principles instead of rote formulae	1.24	0.12	1.12
72	F	Suggest follow-up investigations	-1.22	-0.17	1.05
85	D	Handle modern equipment	-1.37	-0.36	1.01
89	D	Set up lab equipment quickly & correctly	-0.44	-1.37	0.93
45	B	Construct models based on exp. findings	-0.73	-1.65	0.92
83	F	Discuss results with other scientists	-1.29	-0.41	0.88
41	B	Recognize & define scientific problems	0.09	-0.73	0.82
38	B	Construct models which fit exp. evidence	-1.52	-0.73	0.79
53	D	Keep a day-to-day lab diary	-1.22	-0.44	0.78
87	E	Analyze exp. data to draw conclusions	1.82	1.06	0.76
20	D	Calibrate instruments	-1.96	-1.21	0.75
31	C	Design an exp. to verify a theory/hypothesis	-0.50	0.23	0.73
22	C	Design subsequent exp. involving phenomena	-0.78	-0.06	0.72
17	F	Present essentials of an exp. in written form	0.80	1.46	0.66
1	E	Make order-of-magnitude calculations and estimates	1.24	0.60	0.64
33	A	Use exp. data to solve specific problems	-0.35	0.23	0.58
75	B	Apply known principles to new situations	0.52	-0.06	0.58
86	C	Understand scope & limits of exp. techniques used	0.80	0.23	0.57
24	D	Follow instructions	-0.50	-1.02	0.52
46	A	Identify variables & determine emp. relations	-0.50	-1.02	0.52
16	E	Assess relevance of exp. data with regard to hypothesis	0.65	1.17	0.52
77	C	Properly plan an experiment	0.65	1.17	0.52
35	B	Apply current knowledge in solving new problems	0.52	0.02	0.50
42	F	Communicate exp. findings in oral form	-0.65	-0.17	0.48
28	D	Carry out accurate measurements	0.52	0.98	0.46
32	C	Develop measurement techniques	-1.52	-1.96	0.44
56	E	Evaluate contribution direct to derived errors	0.52	0.92	0.40
61	D	Observe phenomena in a quantitative way	1.24	0.87	0.37
63	A	Solve problems in a multi-solution situation	-0.78	-1.11	0.33
34	E	Apply elementary notions of statistics	0.37	0.69	0.32
101	D	Understand lab instructions	0.80	0.50	0.30
102	E	Evaluate diff. expected & actual results	0.52	0.79	0.27
25	F	Communicate exp. findings in written form	1.09	1.35	0.26
5	D	Observe phenomena in a qualitative way	0.37	0.12	0.25
43	E	Incorporate unexpected exp. results in new model	-1.81	-1.56	0.25
62	D	Conduct experiments safely	1.30	1.54	0.24
4	D	Use practical (as opposed to theoretical) lab skills	1.09	0.87	0.22
64	C	Recogn. hazards so as to take safety precautions	0.95	1.17	0.22
9	E	Interpret reliability and meaning of results	1.67	1.46	0.21
91	A	Understand what is to be measured in an exp.	1.46	1.67	0.21
26	E	Use obtained data to make estimates in new situations	-0.35	-0.17	0.18
71	F	Describe central aspects of an experiment	0.52	0.69	0.17
21	A	Decompose large to smaller problems	-0.22	-0.06	0.16
84	A	Understand the purpose of an experiment	1.39	1.54	0.15
92	D	Know & apply altern. meas. techniques	-0.78	-0.92	0.14
12	D	Put basic lab. techniques to use	0.37	0.23	0.14
23	A	Derive testable hypotheses from theories	-0.22	-0.36	0.14
47	E	Evaluate exp. outcome with respect to a hypothesis	1.09	0.98	0.11
98	A	Understand measurement of diff. phenomena	0.80	0.69	0.11
55	F	Summarize an exp. based on results	0.52	0.62	0.10
18	D	Manipulate apparati	-0.35	-0.44	0.09
80	D	Collect experimental data	0.95	0.87	0.08
44	D	Be flexible in modifying exp.	-0.50	-0.54	0.04
52	E	Process experimental data	0.65	0.69	0.04
97	E	Relate exp. outcomes to a particular theory	0.09	0.12	0.03
68	D	Handle waste safely	0.52	0.50	0.02
88	C	Translate conc. def. into set of meas. procedures	-0.94	-0.92	0.02
94	B	React adequately to unforeseen results	-0.35	-0.36	0.01
29	A	Solve difficult scientific problems	-1.96	-1.96	0.00

n.b.: AZ is an absolute scoi.

Appendix 12 Order of magnitude of differences in normalized learning objective scores between OuN and DUE

The first column gives the item number for the specific learning objective from the inventory (appendix 7). The letters in the second column correspond with the general learning objectives.

		Objective	OuN	DUE	ΔZ
43	E	Incorporate unexpected exp. results in new model	0.58	-1.81	2.39
4	D	Use practical (as opposed to theoretical) lab skills	-0.99	1.09	2.08
45	B	Construct models based on exp. findings	0.19	-1.65	1.84
80	D	Collect experimental data	-0.85	0.95	1.80
12	D	Put basic lab. techniques to use	-1.24	0.37	1.61
10	E	Estimate outcome of exp. meas. within given precision	0.46	-1.09	1.55
18	D	Manipulate apparati	-1.90	-0.35	1.55
38	B	Construct models which fit exp. evidence	-0.06	-1.52	1.46
29	A	Solve difficult scientific problems	-0.59	-1.96	1.37
22	C	Design subsequent exp. involving phenomena	0.58	-0.78	1.36
19	E	Apply principles instead of rote formulae	-0.06	1.24	1.30
72	F	Suggest follow-up investigations	0.07	-1.22	1.29
101	D	Understand lab instructions	-0.45	0.80	1.25
28	D	Carry out accurate measurements	-0.72	0.52	1.24
63	A	Solve problems in a multi-solution situation	0.46	-0.78	1.24
62	D	Conduct experiments safely	0.07	1.30	1.23
21	A	Decompose large to smaller problems	0.98	-0.22	1.20
23	A	Derive testable hypotheses from theories	0.98	-0.22	1.20
32	C	Develop measurement techniques	-2.69	-1.52	1.17
53	D	Keep a day-to-day lab diary	-0.06	-1.22	1.16
87	E	Analyze exp. data to draw conclusions	0.73	1.82	1.09
44	D	Be flexible in modifying exp.	0.58	-0.05	1.08
94	B	React adequately to unforeseen	0.73	-0.35	1.08
61	D	Observe phenomena in a quantitative way	0.19	1.24	1.05
98	A	Understand measurement of diff. phenomena	-0.20	0.80	1.00
20	D	Calibrate instruments	-2.95	-1.96	0.99
42	F	Communicate exp. findings in oral form	0.33	-0.65	0.98
52	E	Process experimental data	0.33	0.65	0.98
31	C	Design an exp. to verify a hypothesis/theory	0.46	-0.50	0.96
97	E	Relate exp. outcomes to a particular theory	0.98	0.09	0.89
24	D	Follow instructions	-1.38	-0.50	0.88
34	E	Apply elementary notions of statistics	1.24	0.37	0.87
26	E	Use obtained data to make estimates in new situations	0.46	-0.35	0.81
33	A	Use exp. data to solve specific problems	0.46	-0.35	0.81
89	D	Set up lab equipment quickly & correctly	-2.17	-1.37	0.80
92	D	Know & apply altern. meas. techniques	-1.51	-0.78	0.73
91	A	Understand what is to be measured in an exp.	0.98	1.67	0.69
85	D	Handle modern equipment	-2.02	-1.37	0.65
16	E	Assess relevance of exp. data with regard to hypothesis	1.24	0.65	0.59
84	A	Understand the purpose of an experiment	0.85	1.39	0.54
25	F	Communicate exp. findings in written form	0.58	1.09	0.51
86	C	Understand scope & limits of exp. techniques used	0.33	0.80	0.47
71	F	Describe central aspects of an experiment	0.98	0.52	0.46
102	E	Evaluate diff. expected & actual results	0.98	0.52	0.46
1	E	Make order-of-magnitude calculations and estimates	0.85	1.24	0.39
41	B	Recognize & define scientific problems	0.46	0.09	0.37
47	E	Evaluate exp. outcome with respect to a hypothesis	0.73	1.09	0.36
5	D	Observe phenomena in a qualitative way	0.73	0.37	0.36
68	D	Handle waste safely	0.19	0.52	0.33
88	C	Translate conc. def. into set of meas. procedures	-1.24	-0.94	0.30
95	C	Design relevant observation techniques	-0.33	-0.07	0.26
65	E	Confirm already known facts and laws	-1.77	-1.52	0.25
64	C	Recogn. hazards so as to take safety precautions	0.73	0.95	0.22
83	F	Discuss results with other scientists	-0.20	-0.41	0.21
54	A	Derive & evaluate relationships	0.58	0.37	0.21
75	B	Apply known principles to new situations	0.73	0.52	0.21
55	F	Summarize an exp. based on results	0.33	0.52	0.19
56	E	Evaluate contribution direct to derived errors	0.33	0.52	0.19
77	C	Properly plan an experiment	0.46	0.65	0.19
100	E	Confirm facts, princ. & theory from lect./books	-1.11	-1.22	0.11
46	A	Identify variables & determine emp. relations	-0.59	-0.50	0.09
17	F	Present essentials of an exp. in written form	0.73	0.80	0.07
35	B	Apply current knowledge in solving new problems	0.46	0.52	0.06
9	E	Interpret reliability and meaning of results	1.64	1.67	0.03

n.b.: ΔZ is an absolute score

Appendix 13 Order of magnitude of differences in normalized learning objective scores between OuN and UE

The first column gives the item number for the specific learning objective from the inventory (appendix 7). The letters in the second column correspond with the general learning objectives.

		Objective	OuN	UE	ΔZ
43	E	Incorporate unexpected exp. results in new model	0.58	-1.56	2.14
4	D	Use practical (as opposed to theoretical) lab skills	-0.99	0.87	1.86
20	D	Calibrate instruments	-2.95	-1.21	1.74
89	D	Set up lab equipment quickly & correctly	-2.17	-0.44	1.73
80	D	Collect experimental data	-0.85	0.87	1.72
28	D	Carry out accurate measurements	-0.72	0.98	1.70
85	D	Handle modern equipment	-2.02	-0.36	1.66
63	A	Solve problems in a multi-solution situation	0.46	-1.11	1.57
12	D	Put basic lab. techniques to use	-1.24	0.23	1.47
62	D	Conduct experiments safely	0.07	1.54	1.47
18	D	Manipulate apparati	-1.90	-0.44	1.46
54	A	Derive & evaluate relationships	0.58	-0.88	1.46
29	A	Solve difficult scientific problems	-0.59	-1.96	1.37
100	E	Confirm facts, princ. & theory from lect./books	-1.11	-2.46	1.35
23	A	Derive testable hypotheses from theories	0.98	-0.36	1.34
41	B	Recognize & define scientific problems	0.46	-0.73	1.19
44	D	Be flexible in modifying exp.	0.58	-0.54	1.12
83	F	Discuss results with other scientists	-0.20	-1.29	1.09
94	B	React adequately to unforeseen results	0.73	-0.36	1.09
21	A	Decompose large to smaller problems	0.98	-0.06	1.04
52	E	Process experimental data	-0.33	0.69	1.02
95	C	Design relevant observation techniques	-0.33	-1.29	0.96
101	D	Understand lab instructions	-0.45	0.50	0.95
45	B	Construct models based on exp. findings	0.19	-0.73	0.92
98	A	Understand measurement of diff. phenomena	-0.20	0.69	0.89
65	E	Confirm already known facts and laws	-1.77	-2.65	0.88
97	E	Relate exp. outcomes to a particular theory	0.98	0.12	0.86
75	B	Apply known principles to new situations	0.73	-0.06	0.79
25	F	Communicate exp. findings in written form	0.58	1.35	0.77
17	F	Present essentials of an exp. in written form	0.73	1.46	0.73
32	C	Develop measurement techniques	-2.69	-1.96	0.73
77	C	Properly plan an experiment	0.46	1.17	0.71
84	A	Understand the purpose of an experiment	0.85	1.54	0.69
61	D	Observe phenomena in a quantitative way	0.19	0.87	0.68
38	B	Construct models which fit exp. evidence	-0.06	-0.73	0.67
22	C	Design subsequent exp. involving phenomena	0.58	-0.06	0.64
26	E	Use obtained data to make estimates in new situations	0.46	-0.17	0.63
5	D	Observe phenomena in a qualitative way	0.73	0.12	0.61
56	E	Evaluate contribution direct to derived errors	0.33	0.92	0.59
92	D	Know & apply altern. meas. techniques	-1.51	-0.92	0.59
34	E	Apply elementary notions of statistics	1.24	0.69	0.55
42	F	Communicate exp. findings in oral form	0.33	-0.17	0.50
91	A	Understand what is to be measured in an exp.	0.98	1.46	0.48
35	B	Apply current knowledge in solving new problems	0.46	0.02	0.44
64	C	Recogn. hazards so as to take safety precautions	0.73	1.17	0.44
46	A	Identify variables & determine emp. relations	-0.59	-1.02	0.43
53	D	Keep a day-to-day lab diary	-0.06	-0.44	0.38
24	D	Follow instructions	-1.38	-1.02	0.36
10	E	Estimate outcome of exp. meas. within given precision	0.46	0.12	0.34
87	E	Analyze exp. data to draw conclusions	0.73	1.06	0.33
88	C	Translate conc. def. into set of meas. procedures	-1.24	-0.92	0.32
68	D	Handle waste safely	0.19	0.50	0.31
55	F	Summarize an exp. based on results	0.33	0.62	0.29
71	F	Describe central aspects of an experiment	0.98	0.69	0.29
1	E	Make order-of-magnitude calculations and estimates	0.85	0.60	0.25
47	E	Evaluate exp. outcome with respect to a hypothesis	0.73	0.98	0.25
72	F	Suggest follow-up investigations	0.07	-0.17	0.24
31	C	Design an exp. to verify a theory/hypothesis	0.46	0.23	0.23
33	A	Use exp. data to solve specific problems	0.46	0.23	0.23
102	E	Evaluate diff. expected & actual results	0.98	0.79	0.19
9	E	Interpret reliability and meaning of results	1.64	1.46	0.18
19	E	Apply principles instead of rote formulae	-0.06	0.12	0.18
86	C	Understand scope & limits of exp. techniques used	0.33	0.23	0.10
16	E	Assess relevance of exp. data with regard to hypothesis	1.24	1.17	0.07

n.b.: ΔZ is an absolute score

Appendix 14 Order of magnitude of differences in normalized end-term scores between DUE and UE

The first column gives the item number for the specific end-term from the inventory (appendix 7). The roman numerals in column two correspond with the general end-terms.

		End-term	DUE	UE	ΔZ
59	II	Build framework for facts, princ & theory from lect/books	0.42	-1.78	2.20
37	I	Discover limitations of a theory/model	-0.71	1.07	1.78
96	II	Work in research & development labs	-2.00	-0.35	1.65
11	I	Work in groups to solve scient. problems	-1.14	-0.13	1.01
30	II	Determine limits under which a theory applies	-0.86	0.07	0.93
82	I	Tackle a problem without help of others	-0.58	-1.47	0.89
8	II	Approach observed phenomena from a scient. point of view	1.86	0.98	0.88
66	I	Approach a problem with an open mind	1.43	0.56	0.87
49	I	Formulate a problem that can be researched	-0.15	0.67	0.82
58	I	Be self-confident and independent	-0.86	-1.67	0.81
40	I	Concretize theoretical notions	0.23	-0.51	0.74
13	II	Illustrate facts, princ. & theory of lectures/books	0.42	-0.29	0.71
57	I	Apply one's insights, discoveries & conclusions	-0.43	0.27	0.70
99	I	Use mental skills inherent to professionals	0.55	-0.13	0.68
93	II	Experience kinship with the scientist	-2.43	-1.76	0.67
76	II	Design new exp. in their own fields	-0.58	0.07	0.65
51	I	Appreciate the usual & unusual	-0.58	-1.16	0.58
70	I	Work independently of others	-1.57	-1.04	0.53
78	II	Experience spirit & essence of scient. inquiry	0.57	0.07	0.50
73	II	Experience joys & sorrows of experimenting	-0.71	-1.16	0.45
39	I	Act independently & take initiative	-0.15	0.27	0.42
81	II	Appreciate relationship between nature & science	0.15	-0.24	0.39
7	I	Use motor skills inherent to professionals	-0.58	-0.93	0.35
69	II	Do experiments	1.13	1.47	0.34
15	I	Form attitudes related to value & uses of exp. science	0.85	1.18	0.33
36	II	Intuitively understand scientific phenomena	-1.14	-1.47	0.33
27	II	Be interested in the subject area	0.15	0.47	0.32
2	II	Use the lab as an instrument for discovery	0.57	0.87	0.30
50	II	Experience challenge of exp. method	-0.15	-0.44	0.29
79	I	Have a critical attitude to exp. results	1.86	2.09	0.23
3	II	Solve problems in a critical, academic way	1.48	1.67	0.19
48	I	Plan ahead	0.57	0.76	0.19
67	I	Take active part in the process of science	-0.37	-0.55	0.18
74	I	Interpret data in literature	0.42	0.56	0.14
14	I	Make decisions in proper course of action of prob-solving	1.28	1.18	0.10
90	I	Survey literature relevant to some problem	0.57	0.47	0.10
60	II	Experience past and present scientists' joy	-0.67	-0.75	0.08
6	II	Deeply understand the discipline studied	1.13	1.07	0.06

n.b.: ΔZ is an absolute score

Appendix 15 Order of magnitude of differences in normalized end-term scores between OuN and DUE

The first column gives the item number for the specific end-term from the inventory (appendix 7). The roman numerals in column two correspond with the general end-terms.

		Endterm	OuN	DUE	ΔZ
69	II	Do experiments	-0.72	1.13	1.85
37	I	Discover limitations of a theory/model	0.72	-0.71	1.43
70	I	Work independently of others	-0.29	-1.57	1.28
99	I	Use mental skills inherent to professionals	-0.72	0.55	1.27
49	I	Formulate a problem that can be researched	1.01	-0.15	1.16
13	II	Illustrate facts, princ. & theory of lectures/books	-0.72	0.42	1.14
11	I	Work in groups to solve scient. problems	-0.01	-1.14	1.13
90	I	Survey literature relevant to some problem	1.59	0.57	1.02
7	I	Use motor skills inherent to professionals	-1.59	-0.58	1.01
2	II	Use the lab as an instrument for discovery	-0.44	0.57	1.01
93	II	Experience kinship with the scientist	-1.45	-2.43	0.98
73	II	Experience joys & sorrows of experimenting	-1.59	-0.71	0.88
78	II	Experience spirit & essence of scient. inquiry	-0.29	0.57	0.86
40	I	Concretize theoretical notions	-0.58	0.23	0.81
60	II	Experience past and present scientists' joy	-1.45	-0.67	0.78
74	I	Interpret data in literature	1.15	0.42	0.73
39	I	Act independently & take initiative	0.58	-0.15	0.73
57	I	Apply one's insights, discoveries & conclusions	0.28	-0.43	0.71
59	II	Build framework for facts, princ & theory from lect/books	-0.29	0.42	0.71
58	I	Be self-confident and independent	-0.15	-0.86	0.71
3	II	Solve problems in a critical, academic way	2.16	1.48	0.68
66	I	Approach a problem with an open mind	0.86	1.43	0.57
76	II	Design new exp. in their own fields	-0.01	-0.58	0.57
48	I	Plan ahead	0.15	0.57	0.42
30	II	Determine limits under which a theory applies	-0.44	-0.86	0.42
6	II	Deeply understand the discipline studied	0.72	1.13	0.41
14	I	Make decisions in proper course of action of prob-solving	1.59	1.28	0.31
82	I	Tackle a problem without help of others	-0.88	-0.58	0.30
79	I	Have a critical attitude to exp. results	1.59	1.86	0.27
36	II	Intuitively understand scientific phenomena	-0.88	-1.14	0.26
67	I	Take active part in the process of science	-0.15	-0.37	0.22
81	II	Appreciate relationship between nature & science	-0.01	0.15	0.16
51	I	Appreciate the usual & unusual	-0.44	-0.58	0.14
15	I	Form attitudes related to value & uses of exp. science	0.72	0.85	0.13
96	II	Work in research & development labs	-1.88	-2.00	0.12
8	II	Approach observed phenomena from a scient. point of view	1.88	1.86	0.02
27	II	Be interested in the subject area	0.15	0.15	0.00
50	II	Experience challenge of exp. method	-0.15	-0.15	0.00

n.b.: ΔZ is an absolute score

Appendix 16 Order of magnitude of differences in normalized end-term scores between OuN and UE

The first column gives the item number for the specific end-term from the inventory (appendix 7). The roman numerals in column two correspond with the general end-terms.

		End-term	OuN	UE	ΔZ
69	II	Do experiments	-0.72	1.47	2.19
96	II	Work in research & development labs	-1.88	-0.35	1.53
58	I	Be self-confident and independent	-0.15	-1.67	1.52
59	II	Build framework for facts, princ & theory from lect/books	-0.29	-1.78	1.49
2	II	Use the lab as an instrument for discovery	-0.44	0.87	1.31
90	I	Survey literature relevant to some problem	1.59	0.47	1.12
8	II	Approach observed phenomena from a scient. point of view	1.88	0.98	0.90
70	I	Work independently of others	-0.29	-1.04	0.75
51	I	Appreciate the usual & unusual	-0.44	-1.16	0.72
60	II	Experience past and present scientists' joy	-1.45	-0.75	0.70
7	I	Use motor skills inherent to professionals	-1.59	-0.93	0.66
48	I	Plan ahead	0.15	0.76	0.61
74	I	Interpret data in literature	1.15	0.56	0.59
36	II	Intuitively understand scientific phenomena	-0.88	-1.47	0.59
82	I	Tackle a problem without help of others	-0.88	-1.47	0.59
99	I	Use mental skills inherent to professionals	-0.72	-0.13	0.59
30	II	Determine limits under which a theory applies	-0.44	0.07	0.51
79	I	Have a critical attitude to exp. results	1.59	2.09	0.50
3	II	Solve problems in a critical, academic way	2.16	1.67	0.49
15	I	Form attitudes related to value & uses of exp. science	0.72	1.18	0.46
13	II	Illustrate facts, princ. & theory of lectures/books	-0.72	-0.29	0.43
73	II	Experience joys & sorrows of experimenting	-1.59	-1.16	0.43
14	I	Make decisions in proper course of action of prob-solving	1.59	1.18	0.41
67	I	Take active part in the process of science	-0.15	-0.55	0.40
78	II	Experience spirit & essence of scient. inquiry	-0.29	0.07	0.36
6	II	Deeply understand the discipline studied	0.72	1.07	0.35
37	I	Discover limitations of a theory/model	0.72	1.07	0.35
49	I	Formulate a problem that can be researched	1.01	0.67	0.34
27	II	Be interested in the subject area	0.15	0.47	0.32
39	I	Act independently & take initiative	0.58	0.27	0.31
93	II	Experience kinship with the scientist	-1.45	-1.76	0.31
66	I	Approach a problem with an open mind	0.86	0.56	0.30
50	II	Experience challenge of exp. method	-0.15	-0.44	0.29
81	II	Appreciate relationship between nature & science	-0.01	-0.24	0.23
11	I	Work in groups to solve scient. problems	-0.01	-0.13	0.12
76	II	Design new exp. in their own fields	-0.01	0.07	0.08
40	I	Concretize theoretical notions	-0.58	-0.51	0.07
57	I	Apply one's insights, discoveries & conclusions	0.28	0.27	0.01

n.b.: ΔZ is an absolute score

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