Journal of Distance Education/
Revue de l'enseignement à distance
Spring/Printemps 1991
Vol. VI, No. 1, Pp. 5–27

ARTICLES/ARTICLES

Practical Objectives at the Open university of the Netherlands

Paul Kirschner, Marthie Meester, and Evert Middelbeek

Abstract

The Open university of the Netherlands (OuN) differs from more traditional polytechnics and universities along two dimensions. One, it is an institution for *open, higher distance* education (dimension 1), which, two, offers *interdisciplinary* degree programs in the Natural Sciences (dimension 2). This necessitates a different approach to the curricula in general and to practicals in particular than that adopted by more traditional institutions. Using the forced-choice method of pair comparisons and a Likert scale inventory, a list of eight general objectives, 64 specific objectives, and 38 end-terms for undergraduate practicals in the Natural Sciences were evaluated to determine their importance to the overall aims of the degree programs. This led to prioritizing objectives and ultimately to decisions regarding their inclusion in the curricula.

Resumé

L'Université ouverte des Pays-Bas (OuN) diffère des universités et institutions polytechniques plus traditionelles selon deux dimensions. Premièrement, l'OuN est une institution d'éducation *supérieure ouverte* (dimension 1) et, secondement, elle offre des programmes de diplômes interdisciplinaires dans les sciences naturelles (dimension 2). Ceci requiert une conception différente des curricula, en général, et de la pratique adoptée par les institutions plus traditionnelles, en particulier. Utilisant la méthode de choix forcé de comparaisons binaires et un inventaire d'évaluation numérique, 64 objectifs spécifiques et 38 travaux pratiques de fin de semestre pour étudiants dans les sciences naturelles furent évalués pour déterminer leur importance dans le contexte d'une vue d'ensemble des programmes. Cet exercice a conduit au développement de priorités pour les objectifs et aux décisions de les inclure dans les curricula.

Introduction

Although undergraduate students in the natural sciences usually spend a great deal of time working on practicals, this is not the case at the Open university of the Netherlands (OuN). This is not because the OuN thinks that practicals lack educational value, but rather because it is trying to educate a different type of natural scientist in a different type of educational setting.

Before proceeding it is important to define what is meant by the term "practicals." It is a didactic method for teaching and practising those activities related to experimentation, beginning with the perception of a problem or the observation of a phenomenon through the reporting of results. The importance of practicals is made clear by Hodson's (1988) claim that *experimentation* is a subset of *laboratory bench work*, which is a subset of *practical work*, which, in turn, is a subset of university *teaching/learning methods*.

The OuN differs from most institutions of higher learning in two *important* ways. First, it is an institution for open higher *distance* education, and, therefore, its student population differs from the population attending more traditional colleges and universities. For example, almost 70% of the students taking courses in the Natural Sciences are older than 25 years of age, 55% have already received a degree from another institution (i.e., a polytechnic or university), and 70% are employed in a paying position (Joosten & Van Meurs, 1988). Second, the Faculty of Natural Sciences has adopted an interdisciplinary approach and provides Master's level degree programs in the fields of Environmental Sciences, Nutrition and Toxicology, and Planning and Management in the Natural Sciences. Most regular universities are primarily monodisciplinary in approach, training biologists, chemists, physicists, geologists, or any of the sub-specializations within and between those monodisciplines.

Given these differences it was considered important to evaluate not only the goals set for the practicals, but also the means of achieving them. Two departments at the OuN, the Faculty of Natural Sciences and the Centre for Educational Technology, collaborated on this effort, the aims of which were:

- to select suitable objectives for students enrolled in the Faculty of Natural Sciences;
- to list and explain the objectives of practical work and the premises upon which they were based, and to predict possible problems;

- to allocate educational resources (printed matter, computer-assisted learning resources, audio-visual media, tutoring, and laboratory work) for maximum effectiveness; and
- to test the benefits of the allocated media.

This article presents the results of the effort to determine, categorize, and explain the importance of different objectives and end-terms for practicals in the Natural Sciences (based on previous work by Kirschner & Meester, 1988) for the science curriculum at the OuN. This is the first of three studies on this topic. The second study (already in progress) focuses on objectives for and end-terms of practicals in the Natural Sciences at traditional universities in the Netherlands (in comparison with the OuN). A third study will focus on objectives for and end-terms of practicals in the Natural Sciences at open universities throughout the world. The results of the third study will, of course, be compared with the results obtained in the first two studies.

The Background of This Study

Long before the OuN opened its doors or even produced its first course, a working group in the Natural Sciences made fundamental choices regarding the diploma programs to be offered in terms of both content and the means by which that content would be delivered. The group consisted almost entirely of natural scientists and educators in the natural sciences from our "traditional" universities. The workings of this group differed radically from that sketched by Hurd (1982). Hurd characterizes such groups as ad hoc or ad lib "bull" or "rap" sessions wherein conflicts of interest and personal bias permeate discussions and where the final report is a minority position that "no one [is] particularly happy with...and [where] there is little likelihood it will influence educational policy or research" (p. 284). The OuN working group in the natural sciences, lacking both an institutional history and vested interests (both of which usually give rise to conflicts), presented a final report that essentially is still intact after seven years of course development and five years of student enrollment.

This group made recommendations regarding not only content for the various diploma programs and courses, but also for the intent of programmed undergraduate practicals. It was felt that a minimum amount of practical experience is necessary when studying the natural sciences and that the practicals designed to provide this experience should emphasize the acquisition of insight into the scientific way of thinking and the consequences thereof. The working group believed that many of these objectives could be reached by making use of video, computer-assisted instruction, simulations, modelling, and so forth (Kuenen, 1983).

Once the objectives had been set, the OuN set about choosing faculty members for the Faculty of Natural Sciences. A number of publications and research experience were taken into account, but they were not the only criteria used for selection purposes. Candidates were also evaluated on the basis of their vision of natural sciences education and their experience in this area. The faculty selected represented all disciplines (physics, biology, chemistry, and geology) and included educational and media technologists. Together they set about giving body to the framework devised by the program working group. This required deciding which of two course development models would guide their work. The first is that used by the British Open University and is referred to here as the *internal variant.* In this model all course materials, from conception through production, are produced within a large department or faculty by members of a course team. The second variant, and the one currently in use at the OuN, is referred to as the *recruitment variant.* It is characterized by much smaller departments within which small core course teams are responsible for course development and production. The core course teams are composed of a chairperson who is a content area specialist, an educational technologist who is a specialist on the didactics of open higher distance education, a media technologist specializing in the use of electronic media (CAI, [interactive] video and videodisk, television, and audio), and a publisher. The chairperson recruits subject-matter specialists from other universities, industry, or government to lend expertise in the development of the course.

One of the first problems to be resolved by the Faculty of Natural Sciences was the question of how and to what extent students should make use of laboratory practicals. A typical biology program at a Dutch university requires between 700 and 800 hours of programmed practicals in the first three years of study. For chemistry and physics the number of hours spent in practicals is somewhat higher (between 800 and 1000 hours). These figures do not include the non-programmed practicals during the research and/or practical internship parts of the study.

Everyone agreed that practicals were necessary and that practicals at the OuN should differ, both in quality (goals, contents, and methods) and in quantity, from practicals at traditional universities. The problem was to define the nature of these differences. Thus were sown the seeds for this study.

Objectives for Practicals

The first step taken was to study Kirschner and Meester's (1988) comprehensive review of learning objectives and end-terms for practicals. We define objectives as that which a student may be expected to attain in an educational setting. An end-term is that which the student may be expected to reach at the end of the study for which practicals are but a means. Based on a study of more than 20 years of published curriculum research in the Natural Sciences, Kirschner and Meester identified 8 general objectives, 2 general end-terms, 59 specific objectives, and 38 specific end-terms of undergraduate practicals in the natural sciences, independent of specific scientific disciplines. Though no list is ever exhaustive, this is probably the most complete to date.

Given the short amount of time allotted to practicals in an undergraduate study in the Natural Sciences, it was neither possible nor desirable to include all objectives needed to reach all end-terms listed by Kirschner and Meester. The process of deciding which objectives to adopt was guided by: one, the decision to develop an interdisciplinary program; and two, the limits imposed by open distance education.

The available literature offered little help in making these decisions. No major consensus exists among science educators as to which objectives are most important. Kerr (1964) studied the nature and purpose of practical work in secondary school science teaching by surveying 701 science teachers. He asked the teachers to list in order of importance ten statements referring to practical work found in published reports on science teaching methods. He then produced a rank order listing of the aims of practical work as these science teachers identified them (see Table 1, columns 1 and 2). Since Kerr's work at least seven other studies have been published that report teacher ratings of very similar practical objectives (Gunning & Johnstone, 1976; Woolnough, 1976; Ogborn, 1977; Gould, 1978; Boud, Dunn, Kennedy, & Thorley, 1980; Beatty & Woolnough, 1982; Lynch & Ndyetabura, 1983). Table 1 presents the different rank orderings for six of the eight studies. The remaining two (Gunning, 1976; Ogborn, 1977) were not included because the objectives reported in those studies were not comparable to those listed by Kerr (1964).

Clearly, although general trends can be noted, there is a lack of consensus about which objectives are most important. The affective objective of "arousing and maintaining interest in the natural sciences" provides a typical example of this lack of agreement. Interpreting these differences is difficult. Do they reflect different schools of thought about how and why practicals should be used? Or is it the case that philosophical similarities

Table 1
A Comparison of Rankings and Objectives for Practical Work in Science in Six Studies

	Kerr (1964)	Woolnough (1976)	Gould (1978)	Boud (1980)	Beatty[b] (1982)	Lynch (1983)
To encourage accurate observation and careful recording	1	1	1	3	1	6
To elucidate the theoretical work so as to aid comprehension	2	6	8.5	8	8	4
To be an integral part of the process of finding facts by investigation and arriving at principles	3	8	8.5	4	7	3
To promote simple, common-sense, scientific methods of thought	4	3	2	1	3	1
To develop manipulative skills	5	5	6	2	5	5
To verify facts and principles already taught	6	10	10	o[a]	9	o
To make biological, chemical, and physical phenomena more real through actual experience	7	2	3	5	4	2
To give training in problem solving	8	7	4	7	6	o
To fit the requirements of practical examination regulations	9	9	7	o	10	10
To arouse and maintain interest in the subject	10[a]	4	5	9	2	8
n	701	655	214	307	238	257
school type	sixth form	high school	high school	university	elementary school	university
subject	all sciences	science	biology	science	science	science

Note:
a) An empty circle (o) means that an objective was not included in that study.
b) Beatty studied final year elementary school children.

or differences are masked by the questions lending themselves to multiple interpretations. For example, an objective such as "maintaining interest" might be ranked high by those who consider it a precondition for everything else and low by those who, while agreeing with this, considered it to be implicitly embedded in all other objectives and thus unnecessary to teach explictly.

Interestingly, Kerr's research (carried out in 1962) preceded what has come to be considered a revolution in educational thinking about the didactics of Natural Science education in the United States and Great Britain. In 1960 in the United States the Physical Sciences Study Committee (PSSC) introduced sweeping changes in the different natural sciences curricula. They attempted to present physics as not merely a body of facts but rather as a continuing process by which men [sic] seek to understand the nature of the physical world (Haber-Schaim, Cross, Dodge, & Watter, 1976). Then, in 1963, the Biological Sciences Curriculum Study (BSCS) Committee was organized to improve biological education at all levels of instruction. It grew from an expressed dissatisfaction of biology teachers with the "tools" with which they "had to work" (Grobman & Mayer, 1968). Teachers wanted to teach modern biology in an imaginative, investigative, and inquiry-oriented fashion, but the texts then available fostered the rote memorization of lists of names, facts, and dates.

In 1964, the Nuffield Foundation sponsored a project of curriculum development and reform in the Natural Sciences in Great Britain. The goal was to foster a critical approach...with an emphasis on experimentation and enquiry rather than on the mere assimilation of facts. Materials were intended to guide the students through a process of discovering biological truths, showing students why they should be curious, what kinds of questions they "should investigate," and how they should devise and carry out experiments. "Experiments are not intended to prove things [students] already know; they are to investigate whether something does or does not happen so that [the student] can form hypotheses which, themselves, can be tested by further experiments" (Nuffield, 1966).

If the changes observed since Kerr's study were attributable to a change in thinking about science curricula, then one would expect to see a persistent increase in emphasis placed on practical work as an aid to developing scientific skills and a de-emphasis of practical work as a means of encouraging the retention of theoretical or factual material. Such clear trends are not in evidence in Table 1. In fact, the results of this research showed so little concordance that we dared not draw on the conclusions it generated to determine the OuN curriculum. New research was needed.

Purposes of the Study

The research reported here assesses the importance of general and specific learning objectives for and end-terms of programmed undergraduate practicals in the diploma programs of the Faculty of Natural Sciences at the OuN. Specifically, we sought to rank the general objectives and to classify the specific objectives and end-terms on a scale ranging from indispensable through superfluous. The goal was to improve the current curricula and set up new, instructionally superior curricula.

We consciously chose not to go the "theoretical route" to achieve these ends. Experience has shown that theoretical educational research has rarely led to meaningful and (possibly more important) accepted change in the educational system. Those who must implement the changes (educators, administrators, etc.) are often too far removed from those who "think up" the changes (educational technologists, educational or curriculum theorists, etc.). For this reason we chose to assess the importance of different objectives and end-terms by taking an inventory of the personal insights on this matter.

Method

Subjects

The subjects were 12 faculty members of the Faculty of Natural Sciences at the Open university of the Netherlands, three of whom were female. All 12 had attained at least a Master's degree in their specific discipline and 9 had attained a Ph.D. The subjects came from the following disciplines: physics, biology, chemistry, earth sciences, biochemistry, toxicology, and pharmacology. All had been involved in the development of OuN study materials as a course team chairperson and/or author.

Instruments and Design

Two instruments were developed (both in English) to measure the degree of importance of objectives and end-terms for practicals in undergraduate natural sciences.

The first instrument was a pair comparison inventory of the eight general objectives contained in Kirschner & Meester (see Table 2). These objectives, along with the order in which they are presented in the table, are based upon the successive steps that a scientist may follow in performing an experiment or doing research.

Table 2
General Objectives Used in the Pair Comparison
(from Kirschner & Meester, 1988)

a	To formulate hypotheses
b	To solve problems
c	To use knowledge and skills in unfamiliar situations
d	To design (simple) experiments to test hypotheses
e	To use laboratory skills in performing (simple) experiments
f	To interpret experimental data
g	To describe the experiment clearly
h	To remember the central idea of an experiment over a significantly long period of time

Pair comparison is a forced-choice method in which the subject is required to choose between alternatives and is used primarily for the purpose of determining scale values. It is particularly useful when it is anticipated that some items may rest close to each other on the dimension to be scaled, causing other methods of rank ordering to yield arbitrary results. In this procedure paired items are presented to the subject with instructions to choose one member of each pair on the basis of a stated criterion (Kerlinger, 1973). In this study the criterion was the desirability of incorporating a particular objective into the undergraduate curriculum. Each of the objectives was paired with each of the other seven objectives, making a total of 28 pairs.

The sequence of pairs was arranged so that each objective was equally present as first member of the pair as it was as second member. It was not possible to arrange that one objective not be given in two consecutive pairs, but the objectives were, for the most part, as far apart as possible (Guilford, 1954). The pairs were presented in a small booklet, one pair per page.

In an attempt to compensate for question-order artefacts, subjects were instructed first to read or skim through the whole booklet to become familiar with all 28 pairs of objectives and only then to begin making choices within each pair of objectives. Respondents were requested not to refer back to or change earlier decisions.

The second instrument was a Likert-scale objectives inventory containing 102 items that were analogs of the 97 specific objectives and end-terms presented in Kirschner and Meester (1988). The 97 objectives and end-terms were screened by a number of educational technologists and educators in the Natural Sciences with respect to ambiguity, clarity, and multi-interpretability. Based on this screening, five of the items were dropped, many were rewritten to make them less ambiguous, and eight were split into multiple objectives. The final inventory consisted of 102 items that were rearranged in random fashion. The subjects were asked to assess the importance of each objective or end-term for practicals in a Natural Science curriculum at the OuN on a five-point scale. The five ratings and their corresponding definitions were:

indispensable	This 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 emphasized.
neutral	I don't have an opinion as to this objective; in a vote on such an objective I would abstain.
not really necessary	This objective is of minimal importance; if there is 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 subjects again were instructed to skim the whole inventory before rating each objective's importance without referring to or changing earlier responses.

Validity and Reliability

The inventories discussed here were meant *neither* to predict *nor* to test hypothesized relations or theoretical constructs. Criterion-related validity and construct validity are, therefore, not of consequence here. What is of consequence is the representativeness of the content assessed. Content validation 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, p. 458). As the inventories are based upon the most complete set of objectives collected to date (Kirschner & Meester, 1988), the answer to this question is an unequivocal yes.

Reliability of the total inventory of 102 items (Cronbach's alpha) was .95. The Guttman split-half coefficient was .93. Since the inventory was composed of both objectives and end-terms, it was decided to split the inventory into two subscales and calculate the reliability of each of the subscales separately. The objectives subscale had a reliability (Cronbach's alpha) of .93. The end-term subscale had a reliability (Cronbach's alpha) of .86.

Results

General Objectives

To estimate the extent to which faculty members agreed among themselves about the value of different objectives the Kendall coefficient of concordance (W) was used (Kendall, 1955). This is a measure of the relation among *several* rankings of N objects or individuals. It is especially useful in studies of interjudge reliability and has applications in studies of clusters of variables (Siegel, 1956). The coefficient, W, is defined as the following ratio:

$$W = \frac{S}{S_{max}} = \frac{12S}{m2\ (n3-n)}$$

where
m = the number of faculty members
n = the number of objectives
S_{max} = the sum of the squares of the differences between observed and expected rank totals
S = the sum of the squares of the actual deviations in the rank totals

Kendall's W expresses the degree of association among variables and can vary from zero, representing no agreement, to 1.0, representing perfect agreement.

The coefficient of concordance was .46, which is significant at better than the 1% level of probability ($W = 0.4632$, $X^2 = 38.91$, $p < .001$). This means that the subjects showed a large degree of agreement on the ranking of the objectives and that the judges (subjects) were applying essentially the same standard in ranking the N objectives under study. Finally, the number of circular triads (a measure of inconsistency in the answer patterns: A > B > C > A) was small. Where necessary, corrections for these triads were made.

To gain insight into the evaluation of the general objectives by the subjects we tallied how often each general objective was preferred in the pair comparisons. In this way it is possible to achieve a first impression of the priorities. The results of the tally can be seen in Figure 1.

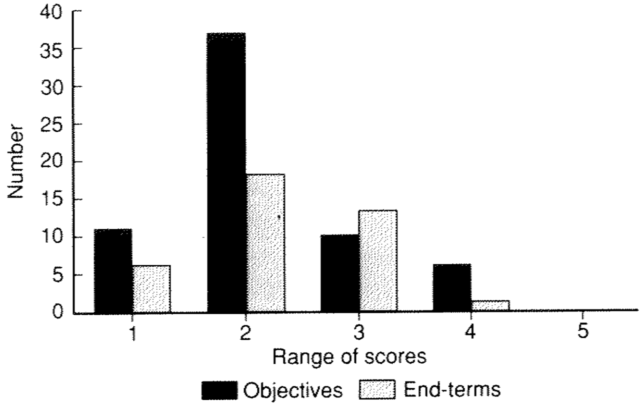

Figure 1. Frequencies of the preferences of the general objectives from the pair comparison inventory. The maximum is 84.

The list of objectives, rearranged according to their rankings along with the average score attributed to the objectives by the faculty members, is shown in Table 3.

Table 3

General Objectives Ranked in Descending Order of Importance

Rank	Average score[a]	Objective
1	5.25	To use knowledge and skills in unfamiliar situations (c)[b]
2	5.00	To interpret experimental data (f)
3	4.50	To formulate hypotheses (a)
4	4.00[c]	To design (simple) experiments to test hypotheses (d)
5	4.00[c]	To solve problems (b)
6	2.17	To remember the central idea of an experiment over a significantly long period of time (h)
7	1.92	To describe experiments clearly (g)
8	0.83	To use laboratory skills in performing (simple) experiments (e)

[a]The average score is the sum of the positive responses to a certain objective in the pair comparison inventory divided by the number of subjects.
[b]The letters in parentheses correspond with the letters in Table 1.
[c]Although the average score of these two general objectives is the same, a scale separation matrix of normalized (Z) scores showed a slight difference in preference.

Table 4 presents an overview of the significance levels of a paired samples *t*-test of the differences between the weightings of the general objectives. There appears to be a concrete cut-off point between the five highest ranked objectives (up to and including "To solve problems") and the three lowest ranked objectives.

Table 4
Significance Levels of a Paired Samples T-Test of the Difference between the Weightings of the General Objectives

	General objective							
General objective	*(c)*	*(f)*	*(a)*	*(d)*	*(b)*	*(h)*	*(g)*	*(e)*
Use knowledge/skills (c)	—	.742	.389	.183	.049	.002	.000	.000
Interpret experimental data (f)		—	.455	.146	.332	.000	.000	.000
Formulate hypotheses (a)			—	.477	.615	.012	.001	.001
Design experiment to test (d)				—	1.000	.025	.007	.000
Solve problems (b)					—	.078	.023	.002
Remember central idea (h)						—	.667	.058
Clearly describe experiment (g)							—	.059
Use lab skills (e)								—

Specific Objectives

The objectives inventory, which contained both the specific objectives and the end-terms, was split into its component parts to allow for the analysis of the specific objectives and the end-terms separately.

A quick look at the average ratings of the 64 specific objectives leads to the conclusion that the number of objectives considered to be important (indispensable or important) far outnumbers those considered to be unimportant (not really necessary or superfluous). This is highly evident if one divides the scale into five equal ranges and compares the number of objectives falling into each range (see Figure 2).

The results of the inventory make it clear that the subjects place a great emphasis on what may be called the acquisition of academic skills. These skills may be defined as "learned skills which manage (the student's) own learning, remembering, and thinking...certain techniques of thinking, ways of analyzing problems, (and) approaches to the solving of problems" (Gagné, 1977, pp. 27–28).

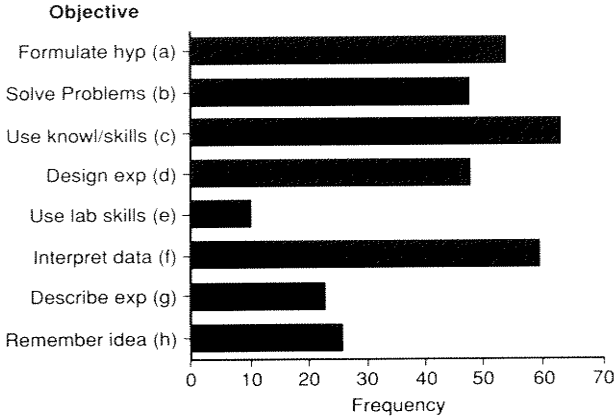

Figure 2. Number of objectives and end-terms falling into the five ranges of importance.

Range 1 (m = 1.00–1.79) is indispensable; range 2 (m = 1.80–2.59) is important; range 3 (m = 2.60–3.39) is neutral; range 4 (m = 3.40–4.19) is not really necessary; range 5 (m = 4.20–5.00) is superfluous.

Of the *eleven* most highly rated specific objectives ($1.0 < m < 1.8$, $Z > .85$), *six* are specifications of the general objective "to interpret experimental data," which was ranked second by the subjects

- to interpret the reliability and meaning of results
- to assess the relevance of experimental data with regard to hypotheses
- to apply elementary notions of statistics
- to evaluate differences between expected and actual results
- to relate experimental outcomes to a particular theory
- to make order-of-magnitude calculations and estimates;

three are specifications of another highly ranked global objective, "to solve problems"

- to decompose large problems into smaller ones
- to understand what is to be measured in an experiment
- to understand the purpose of an experiment;

and *two*, which are "indispensable" specific objectives,

- to derive testable hypotheses from theories
- to describe central aspects of an experiment

are specifications of the general objectives "to formulate hypotheses" and "to describe the experiment clearly," respectively. Of these only the latter is not one of the five most important general objectives.

A noteworthy anomaly, which we shall return to in the discussion section, is the fairly high regard for the specific objectives pertaining to describing an experiment. General objective (g), "to describe the experiment clearly," was ranked next to last in importance by the subjects. The specifications of this general objective:

- to describe the central aspects of an experiment (see above)
- to communicate experimental findings in written and oral form
- to summarize an experiment based on results

are, however, all ranked above the average of all the specific objectives ($m < 2.29$, $Z > 0.00$).

On the other end of the spectrum, it should be noted that all five of the lowest rated specific objectives ($3.4 < m < 4.19$, $Z < -1.57$) pertain to simple manual and/or recording skills. These skills are:

- to calibrate instruments
- to develop measurement techniques
- to set up lab equipment quickly and correctly
- to handle modern equipment
- to manipulate apparati.

Again there is agreement between the rating of the specific objectives and the ranking of the general objectives. If one uses the same Z-scores as a cut-off point for the lowest rated objectives ($Z < -.85$), then this list of five simple manual and recording skills is expanded to include four new lower order objectives (collect experimental data, use practical laboratory skills, put basic laboratory techniques to use, know and apply alternative measurement techniques) plus two "cookbook" skills (confirm already known facts and laws; confirm principles and theories discussed in lectures or books).

Specific End-terms

A similar pattern can be seen with respect to the average ratings of the 38 end-terms. These end-terms are specifications of the two general end-terms in Kirschner & Meester (1988), namely:

1) to obtain good scientific attitudes
2) to understand the scientific method.

As was the case with the specific objectives, the curve is skewed to the left with the number of end-terms considered to be important far outnumbering those which are considered to be unimportant (see Figure 3).

Here again, the end-terms which relate to academic skills are clearly the most important. The six highest ranking end-terms ($1.0 < m < 1.79$, $Z > 1.0$) all deal with some aspect of critical academic or mental skills (solve problems in a critical, academic way; approach observed phenomena from a scientific point of view; make decisions while solving problems; have a critical attitude to experimental results; survey literature relevant to a problem; interpret data in literature).

Of the five end-terms rated as being least important ($Z < 1.0$), three have to do with an aesthetic/romantic view of science practicals (experience the joys and sorrows...) and two with a possibly unrealistic or highly idealistic view of undergraduate practicals (work in research and development laboratories, use motor skills inherent to professionals).

Discussion

General Objectives

If one proceeds from the premise that the faculty of Natural Sciences at an institution such as the Open university of the Netherlands should educate its students to become critical, academic thinkers, then it is not surprising that the five most highly regarded general objectives relate to this aim. It is also not surprising that faculty members of such an institution would rank last an objective such as "to use laboratory skills in performing (simple) experiments." What is surprising is the low ranking of the objectives "to remember the central idea of an experiment over a significantly long period of time" and "to describe the experiment clearly."

The low score for the former can possibly be attributed to the verb *to remember.* All the subjects, at one time or another, have been integrally involved in or responsible for the development of learning materials (courses in the Natural Sciences) at the OuN. As such, they are well versed in the explication of concrete, specific objectives and thus are also well acquainted with taxonomies of learning objectives and the rules for formulating them (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956; Gronlund, 1970). Noteworthy in this respect is the "low" ranking for the cognitive category *knowledge*. Bloom et al. (1956) define knowledge as "the remembering of the idea...in a form close to that in which it was originally encountered and represents the lowest level of learning outcomes in the cognitive domain" (pp. 28–29). In this light, it is not at all strange that the general objective "to remember the central idea of an experiment over a significantly long period of time" was not deemed to be of great importance.

Stranger is the low ranking of objective (g), "to describe the experiment clearly." In 1987, the Faculty of Natural Sciences produced a report defining the programs and courses to be developed. They also defined the general end-terms for those studying in the Natural Sciences at the OuN and included in those end-terms that graduates should be able to write reports and make oral presentations of scientific findings. The low ranking is even more remarkable in light of the fairly high ratings of the specific objectives ascribed to this general objective (see the Results section and Appendix I). As was the case with the previous general objective, the low ranking here may be attributed to the way in which the subjects interpreted the word *describe*. To describe, according to Gronlund (1970), is one of the illustrative behavioural terms for stating specific learning outcomes of knowledge objectives. This interpretation was later confirmed in discussions with the subjects. When confronted with the general objective, possibly the subjects interpreted *to describe* in such a manner, while when rating the specific objectives they were clearly aware of the necessity of communicating findings in written and oral forms, summarizing and discussing results, and describing central aspects of an experiment. Description is, as interpreted by Kirschner and Meester (1988), if anything, a higher order cognitive objective belonging to the synthesis category in Bloom et al.'s (1956) taxonomy. Description, as such, is putting "parts together to form a new whole...(involving) the production of a unique communication. Learning outcomes in this area stress creative behaviours, with major emphasis on the formulation of *new* patterns or structures" (Gronlund, 1970, p. 20).

Leopold Klopfer's (1971) "Table of specifications for science education" sheds some light on the rankings of the general objectives in this study. Within the cognitive domain, Klopfer identifies six categories of behaviour, increasing in complexity:

1) knowledge and comprehension
2) processes of scientific inquiry I: observing and measuring (with description as a student behaviour herein)
3) processes of scientific inquiry II: seeing a problem and seeking ways to solve it
4) processes of scientific inquiry III: interpreting data and formulating generalizations
5) processes of scientific inquiry IV: building, testing, and revising a theoretical model
6) application of scientific knowledge and methods.

Along with these six cognitive categories, Klopfer distinguishes one motor category and two attitude categories, namely: manual skills, attitudes and interests, and orientation.

If we place our general objectives and end-terms next to Klopfer's categories, we see a remarkable agreement. If one assumes that the subjects ranked the objectives based upon a preference for academic and thus higher order behaviours, then we arrive at the following table.

Table 5
Correspondence between the Rankings of the Subjects and Complexity according to Klopfer (1971)

General objective	Rank	Klopfer's category	Rank
to describe experiments clearly (g)	7	Processes of scientific inquiry I	II
to remember the central idea of an experiment (h)	6	Knowledge and comprehension	I
to solve problems (b)	5	Processes of scientific inquiry II	III
to design (simple) experiments to test hypotheses (d)	4	Processes of scientific inquiry IV	V
to formulate hypotheses (a)	3	Processes of scientific inquiry IV	V
to interpret experimental data (f)	2	Processes of scientific inquiry III	IV
to use knowledge and skills in unfamiliar situations (c)	1	Application of scientific knowledge and methods	VI

Notes: The general objectives are ordered from the least preferred (7) to most preferred (1).
Klopfer's categories are ranked from least complex (I) to most complex (VI).
The general objective (c) "to use laboratory skills in performing (simple) experiments" has been omitted because it does not belong to the cognitive domain. Thus, there are only seven objectives.

Klopfer's three other categories show a distinct resemblance to the last general objective and the two general end-terms:

- "to use laboratory skills in performing (simple) experiments" corresponds with Klopfer's category "manual skills," which encompasses the development and performance of laboratory skills with care and safety;
- "to obtain good scientific attitudes" corresponds with Klopfer's category "attitudes and interest;" and
- "to understand the scientific method" corresponds with Klopfer's "orientation," encompassing the development of a multi-faceted orientation (relationships, philosophical limitations, historical perspectives, and moral and social implications) towards science.

Specific Objectives

As stated earlier, the ratings of the specific objectives concur fairly well with the rankings of the general objectives. Within the "top twenty" specific objectives, only three were not classified as a specification of the "top five" general objectives as classified by Kirschner and Meester (1988). This pattern is also visible at the bottom end of the ratings.

However, a few objectives (such as to confirm already known facts and laws and to confirm facts, principles, and theory from lecturers or books) are specifications of the second most highly rated general objectives (to interpret experimental data) but are rated here near the bottom. This again may be because the verb *confirm* implies a "cookbook" approach to practicals, which is undesirable in a modern science curriculum.

End-terms

It was to be expected that most of the end-terms would be ranked somewhere between "indispensable" and "important." The general and specific end-terms are endemic to all science curricula irrespective of the type (open, higher distance or traditional) or nature (interdisciplinary or monodisciplinary) of the curriculum or scientific discipline.

As stated in the results section, the end-terms rated as being the least important were those either overly romantic or unrealistic for undergraduate practicals.

Conclusions and Implications

It is possible to rate objectives according to the preferences and to use these ratings eventually to make choices as to the inclusion of different objectives in a curriculum. The Faculty of Natural Sciences at the OuN shows a clear preference for the achievement of "higher academic skills." Evaluation of the results has led to a restructuring of the general objectives and their concommitant specific objectives so that there remain six general objectives and 38 specific objectives.

Based upon a combination of a criterion average (*m*) and the rating of the general objective to which each specific objective belongs, the 64 specific objectives were reduced in number to 38. Predictably, most of the objectives that were dropped dealt with achieving simple manual or recording skills or with achieving "cookbook" objectives. When these 38 specific objectives were assigned to the eight general objectives, one general objective (*h*: to remember the central idea of an experiment over a significantly long period of time) was empty and one general objective (*a*: to formulate hypotheses) contained only one specific objective that could just as easily be assigned to objective *b* (to solve problems). These two were thus eliminated. Objectives *e* (to use laboratory skills in performing experiments) was kept, but in a trimmed down form. Finally objective *g* (to describe the experiment clearly) was kept, although rated rather low by the subjects, because its specific objectives were rated so highly.

This yields the following list of general objectives:

- 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 describe the experiment clearly.

Since the amount of time and money that can be spent on practicals is limited, this preference must be echoed in the curriculum, at a cost to lower level manual skills dealing with the use of laboratory skills. Practicals at the OuN will be realigned to coincide with these results. At the moment the OuN is developing an upper level (junior/senior) "experimentation" course that will replace smaller monodisciplinary science labs and that will be a prerequisite for entrance to an internship for achieving a Master's degree. This course will shift the emphasis in practicals away from the traditional workbench approach prevalent in most universities toward an integrated laboratory. This shift is based on an approach to implementing practicals for the purpose of achieving academic skills presented by Kirschner (1989). Manipulative laboratory skills take a back seat in this approach, which emphasizes "experimental seminars" and "simulations" outside of the laboratory. "Wet laboratories" or workbench activities will play a secondary role in the course. After developing this upper level course, a lower level (freshman/sophomore) experimentation course will probably be developed to take the place of the present biology, chemistry and physics labs. Both courses will be based, both in content and didactics, on the ratings of the objectives reported here.

Finally, it will be interesting to compare the ratings obtained in this study with those obtained from traditional, monodisciplinary Natural Science faculties. The same instruments used in the present experiment have already been mailed out and a high percentage of responses (70%) has been received. The analyses have already begun. A follow-up article will address the question whether the dimensions discussed in the introduction actually make a difference in the type of objectives to the pursued in higher science education.

Notes

The authors would like to thank Henry Hermans for his tireless help in the computation and statistical analysis of the raw data. They would also like to express their special thanks to Peter Sloep and Peter Vos for their comments and suggestions for revising the specific objectives inventory. Finally, they would like to thank the members of the Faculty of Natural Sciences for their time, efforts, and constructive comments during the course of this study.

References

Beatty, J. W., & Woolnough, B. E. (1982). Why do practicals work in 11–13 science? *School Science Review, 63*, 768–770.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (Eds.). (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.* New York: David McKay.

Boud, D. J., Dunn, J., Kennedy, T., & 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.

Gagné, R. M. (1977). *The conditions of learning* (3rd ed.). New York: Holt, Rinehart and Winston.

Gould, C. D. (1978). Practical work in sixth-form biology. *Journal of Biological Education, 12*(1), 33–38.

Grobman, A. B., & Mayer, W. V. (1968). In C. A. Welch (Ed.), *Biological science: Molecules to man (BSCS blue version).* Boston: Houghton Mifflin.

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

Guilford, J. P. (1954). *Psychometric methods.* New York: McGraw-Hill.

Gunning, D. J., & Johnstone, A. H. (1976). Practical work in the Scottish 0-grade. *Education in Chemistry, 13*, 12–14.

Haber-Schaim, U., Cross, J. B., Dodge, J. H., & Watter, J. A. (1976). *PSSC Physics* (4th ed.). Lexington: D.C. Heath.

Hodson, D. (1988). Experiments in science and science teaching. *Educational Philosophy and Theory, 20*(2), 53–66.

Hurd, P. D. (1982). Transformation of science education: Challenges and criteria. *Science Education, 66*(2), 281-285.

Joosten, G., & Van Meurs, C. (1988). *Studenten: Algemene kenmerken, inschrijving, naar cursus en naar studiecentrum tot mei 1988* [Students: General characteristics, admission per course and per study centre through May 1988]. Internal report number 12, Bureau for Research and Evaluation. Heerlen: Open universiteit.

Kendall, M. G. (1955). *Rank correlation methods.* London: Griffin.

Kerlinger, F. N. (1973). *Foundations of behavioral research.* London: Holt, Rinehart and Winston.

Kerr, J. F. (1964). *Practical work in school science.* Leicester: Leicester University Press.

Kirschner, P. A. (1989). *Practicals and the acquisition of academic skills.* Paper presented at the National Association for Research on Science Teaching, San Francisco, CA.

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

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

Kuenen, D. J. (1983). *Programmeringswerkgroep natuurwetenschappen: Advies* [Programme working group: Advice]. Heerlen: Open universiteit.

Lynch, P. P., & Ndyetabura, V. L. (1983). Practical work in schools: An examination of teachers' stated aims and the influence of practical work according to students. *Journal of Research in Science Teaching, 20*(7), 663–671.

Nuffield Biology. (1966). *Introducing living things.* Essex: Longman House.

Ogborn, J. (Ed.). (1977). *Practical work in undergraduate science.* London: Heinemann Educational Books.

Programmering van het leerstofgebied Natuurwetenschappen [The programming of the Faculty of Natural Sciences]. (1987). Internal report U86/435 JWI. Heerlen: Open universiteit.

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

Swain, J. R. L. (1974). Practical objectives—A review. *Education in Chemistry, 11*, 152–154.

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

Paul Kirschner received his Baccalaureate in Psychology from the State University of New York at Stony Brook and State University of Amsterdam, The Netherlands. He received his Master's in Educational Psychology from the City University of Amsterdam. He has worked as educational technologist at the Open university of the Netherlands since 1983, primarily with the faculties of Natural Sciences and Engineering.

Marthie Meester received her Baccalaureate, Master's, and Ph.D. in Chemistry from the State University of Amsterdam, The Netherlands. She has worked since 1983 at the Faculty of Natural Sciences of the Open university of the Netherlands as course team chair for a number of undergraduate and graduate level chemistry courses.

Evert Middelbeek received his Baccalaureate and his Master's at the State University of Utrecht, The Netherlands. He received his Ph.D. at the department of Microbiology at the University of Nijmegen, The Netherlands. From 1980 to 1985 he was a teacher of biochemistry and microbiology in higher laboratory education. He has worked since 1985 at the Faculty of Natural Sciences of the Open university as laboratory coordinator/course team chair.