Working paper n°3

Project *PL 95-2005*

LABWORK IN SCIENCE EDUCATION

* WORKING PAPER N 3 *

Analysis of labwork sheets used at the upper secondary school and the first years of university

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1998

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Improving Science Education: Issues and Research on Innovative Empirical and Computer-Based Approaches to Labwork in Europe

Short Title : Labwork in Science Education

Funded by DGXII of the European Commission between February 1996 and April 1998.

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Outcomes

A list of the full set of Working Papers from the project can be found at the end of this document. Further results from this work can be found on the Internet via the CORDIS site of the European Commission : http://www.cordis.lu/
The abstract of the project provided on this site is given on the next page.

 ISBN: 2 912 101 - 02 - 6

ABSTRACT: *'Labwork in Science Education '*

This project stems from a concern to recognise science education as an important component of a general education, not only for future scientists and engineers, but also for any future citizen in a European society which is increasingly dependent upon science and technology.

Research has focused upon the role of laboratory work ('labwork') in science teaching at the levels of **upper secondary school and the first two years of undergraduate study**, in physics, chemistry, and biology. Various forms of labwork have been identified and investigated, including 'typical' activities in which pairs of students work on activities following precise instructions, open-ended project work in which students design and carry out empirical investigations, and the use of modern technologies for modelling, simulating and data processing.

The main objectives of the project were to clarify and differentiate learning objectives for labwork, and to conduct investigations yielding information that might be used in the design of labwork approaches that are as effective as possible in promoting student learning.

A survey was conducted to allow for better description of existing labwork practices in the countries involved. There are great variations from country to country in the time devoted to labwork, the assessment of students' performance in labwork and the equipment available. However, the forms of labwork activity used between countries are remarkably similar. In each country, the most frequent activity involves students following precise instructions in pairs or threes. A document has been produced describing the place of labwork in science education in each country.

A second survey was conducted to study the learning objectives attributed to labwork by teachers. There are some differences between countries in terms of the relative importance given to the teaching of laboratory skills. Motivation for science learning is not attributed particularly high status as an objective for labwork learning. In each country, the main goal for labwork teaching in the view of teachers surveyed concerns enabling students to form links 'between theory and practice'.

A third piece of survey work was conducted to investigate the images of science drawn upon by students during labwork, and the image of science conveyed to students by teachers during labwork. These surveys were based upon the hypothesis that epistemological and sociological ideas about science are prominent during labwork.

22 case studies were carried out in order to clarify the variety of knowledge, attitudes and competencies that can be promoted through labwork. The case studies focused upon both empirical labwork and labwork involving computer modelling and simulation. The work has resulted in an analysis of the **effectiveness of labwork**, leading to recommendations about policy. It is hoped that teachers and policy makers with responsibilities in science education generally, and labwork in particular, will find these useful in informing future practice with respect to possible objectives for labwork, links between objectives, methods of organisation of labwork and ways of observing and evaluating the effectiveness of labwork in promoting student learning.

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Abstract

This work is a part of the survey 1 which aims at providing a better description of existing labwork practices in the countries involved at the upper secondary school and the first two years of university. In this perspective, the whole survey was conducted to study : (1) the science teaching organisation at the upper secondary school level in each country, this information was obtained from the partners of the project and from the literature (working paper 2, volume 1); (2) the specific teachers' practices from written questionnaires given in each country by the partners both at secondary and university levels (working paper 2, volume 2); (3) the characteristics of usual labwork sheets by using a typology of labwork, called "the map" (working paper 1), to analyse usual labwork sheets collected by the partners of the project (this working paper).

165 labsheets were collected from all partners of the LSE project, Denmark, England, France, Germany, Greece and Italy, and from Spain: 75 labwork sheets used at school level in Denmark, England, France, Germany and Spain, along with 90 instruction sheets used at early university level in Denmark, England, France, Germany, Greece and Italy. Each partner were asked to identify five labwork tasks representative of current practice in their country at upper secondary school and first-year university level in biology, chemistry and physics. An example of these sheets for each country, each discipline and each level is given in the appendix.

These 165 sheets were coded with the "map" by each partner and then a global statistical treatment (Excel) produced the results presented in this working paper. It appears that, in the countries where there is usual labwork at secondary school and for all countries at university level, the practice is similar from the point of view of the organisational aspects: duration (about 1 - 2 hours at secondary school and 2 - 5 hours at university), work in small groups. There is an exception for "project activity", in this case the duration lasts a longer period of time, its practice is not usual, however in some countries it is increasing. In most of the countries, the subjects of labwork are much more closely related to the lectures at secondary level than at university level. The use of computers for simulation, and of videos is very rare in all countries and at all levels.

Concerning the characteristics of the labwork, a non surprising result is that, the students activity depends on the discipline, for example physics labwork involves the establishment of relations and chemistry labwork involves the use a standard procedure. However it appears a rather strong similarity between the labwork sheets. For example it seems rare that labwork activity, whatever the disciplines, asks "to do account for observations in terms of law or theory" or "to choose between explanations". This similarity deals not only with what the labwork activity is, but also with what labwork activity is not. In conclusion a global result appears, in spite of the diversity of organisation of the science education, general characteristics of labwork would be rather similar from one country to another and even from on discipline to another. Labwork would involve rather few types of activities. Recognising this similarity on what the labwork activity is, could help to design a larger variety of labwork than it is usually practised. These similarities, both in terms of what is common in labwork activities and in what is uncommon, may provide a useful starting point in considering how to design a variety of forms of labwork.

An appendix to this working paper gives a labsheet for each level and each discipline from the European countries represented in this project.

Analysis of labwork sheets used at the upper secondary school and the first years of university

Labwork sessions can be very different one from another, learning objectives and the related types of activities can vary even if, in every cases, experiments are involved. The question of knowing to what extent the usual labwork in different European countries and in several disciplines varies was raised. To study such a question, it is necessary to characterise labwork activities. For that, the tool called "the map", elaborated during the first part of the project has been used (Millar et al. 1997, 1998). The 'map' identifies three main dimensions of any labwork task: the learning objectives which the teacher has in mind in designing the activity; what the student is expected to do with physical objects and with ideas; and more pragmatic aspects of the context of the task, such as the time available, the kind of equipment supplied, and so on. For each of these, the 'map' then provides a set of coding categories which can be used to produce a descriptive profile of the task.

This work aims to acquire a more specific knowledge about the activities asked to students during labwork. This is why labwork sheets of several European countries have been selected by the research groups participating to the project as representative of usual and frequent labwork. These sheets were analysed by each research groups with "the map". The COAST group collected these analyses and treated them (with Excel). This treatment involves a rather low number of labwork sheets by countries and by level. It shows the main tendencies and it identifies the similarities and differences of the labwok sheet characteristics among disciplines. This is a way of establishing the comparison of labwork activity at upper secondary school and beginning of university in different countries or in different disciplines.

More specifically, five labwork sheets according to the level (secondary or university) of each of the following disciplines: biology, chemistry, physics were selected by research groups as representative of the current practice in their country. At secondary level among the countries involved in the European project LSE only those where labwork corresponds to a regular practice contributed, that is : Denmark, England, France, Germany. Moreover Spain, even if no research group of this country participates to the LSE project, contributed. At university level the countries involved are Denmark, England, France, Germany, Greece, Italy.

This analysis was done with the contribution of the partners of each country involved in the project, in particular Dimitris Evangelinos, Dorte Hammelev, John Leach, Naoum Salamé, Florian Sander, Carlo Tarsitani.

Robin Millar (University of York), who initiated the map, particularly contributed to this report through discussions on the intermediate writing.

The results are presented in the order of the map. This map consists of three main dimensions (A, B1 and B2), with the second and third sub-divided into several sub-dimensions:

A Intended learning outcome (learning objective)

B1 Design features of the task
- B1.1 What students are intended to do with objects and observables
- B1.2 What students are intended to do with ideas
- B1.3 Whether the task is observation- or ideas-driven
- B1.4 The degree of openness/closure of the task
- B1.5 The nature of student involvement in the task

B2 Context of the task
- B2.1 The duration of the task
- B2.2 The people with whom the student interacts whilst carrying out the task
- B2.3 The information sources available to the student
- B2.4 The type of apparatus involved

Within each sub-dimension, a labwork task is characterised by selecting the most appropriate descriptor (or descriptors) from a given list, or by ticking a number of boxes in a table. Here we will simply provide brief summaries in the form of keys presented alongside the bar graphs which present the results of our analysis of the set of typical labwork tasks.

Intended learning outcome (learning objectives) (A)

In this part, the aim is to specify the main objectives of the labwork session.

Secondary level

Figure 1 and Figure 2 give the results by disciplines for two series of objectives, those related to the teaching content and those related to the processes. An important similarity between disciplines appears for some objectives. One objective is common for all disciplines: "*identify objects and phenomena and become familiar with them*" whereas the objective : "*learn how to plan an investigation to address a specific question or problem*" is infrequent in all disciplines, though slightly more common in biology.

Two differences between disciplines appear, one differentiating physics from chemistry and biology, and the other chemistry from physics and biology. Almost all physics labwork sheets presented the objective to "*learn a relationship*" whereas this objective corresponds to a very low level for chemistry and biology. The objective "*to learn how to carry out a standard procedure*" is more important for chemistry. These differences among disciplines are not surprising, but correspond to the characteristics we might expect of labwork in these subjects.

Few differences between countries emerged. The main ones did concerned the objectives : "*how to use data to support conclusion*" and "*how to communicate the results of their work*". The French sheets put more emphasis on "using data which support conclusion", whereas Denmark and Germany gave more emphasis to "*the communication of results*".

University Level

At university level, differences between disciplines for the objectives dealing with the content are smaller than for secondary level (Figure 3 and Figure 4). It still appears that, for all disciplines, labwork tasks more frequently ask students "*to identify objects and phenomena*" than "*to learn a theory/model*". As regards the process objectives, the pattern is similar to that in secondary school tasks. The students are supposed to learn "*how to process data*" more in physics than in chemistry and biology. Concerning the objective "*how to carry out a standard procedure*" there is a greater emphasis in chemistry than in biology and in physics.

Intended learning outcome (learning objective)

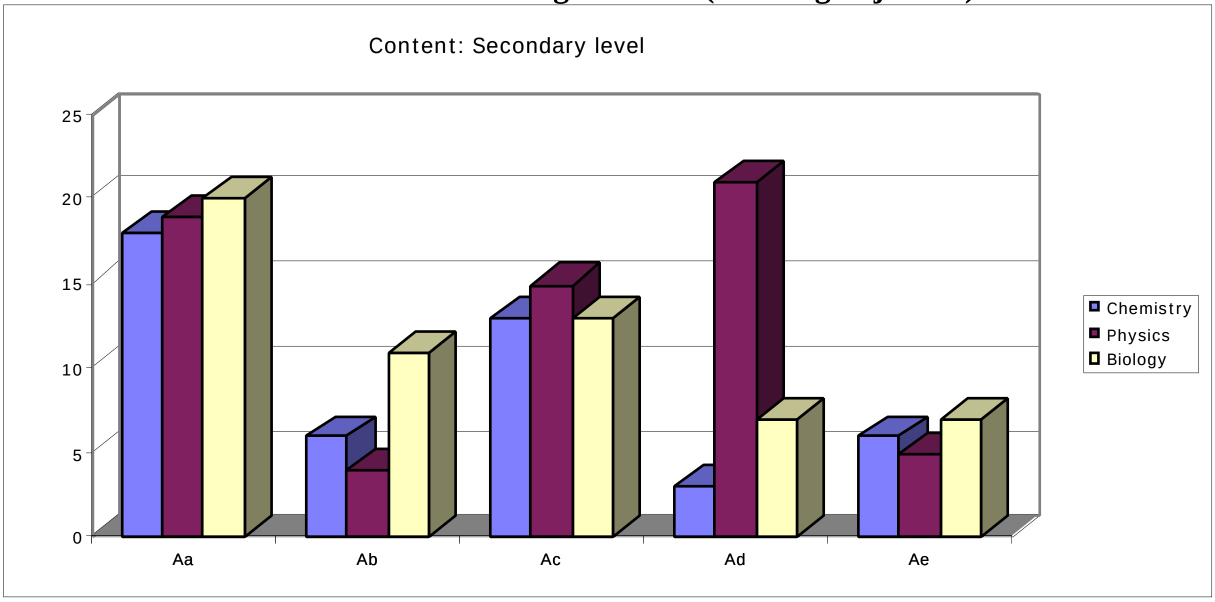


Figure 1: Learning objectives related to the content by discipline (see table 1 for the meaning of the items)

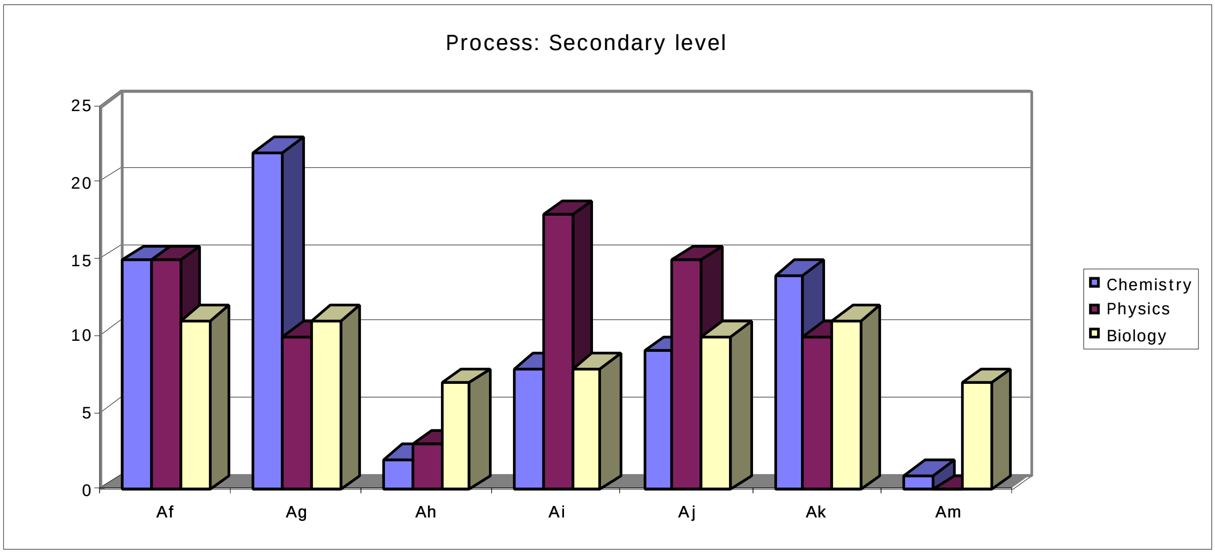


Figure 2: Learning objectives related to the process by discipline (see table 1 for the meaning of the items)

Content	Process
to help	**students to:**
Aa to identify objects and phenomena and become familiar with them	Af to learn how to use a standard laboratory instrument, or to set up and use a standard piece of apparatus
Ab to learn a fact or facts	Ag to learn how to carry out a standard procedure
Ac to learn a concept	Ah to learn how to plan an investigation to address a specific question or problem
Ad to learn a relationship	Ai to learn how to process data
Ae to students learn a theory/model	Aj to learn how to use data to support a conclusion
	Ak to learn how to communicate the results of their work
	Am Miscellaneous

Table 1: Items related to the intended learning outcome (learning objective)

Intended learning outcome (learning objective)

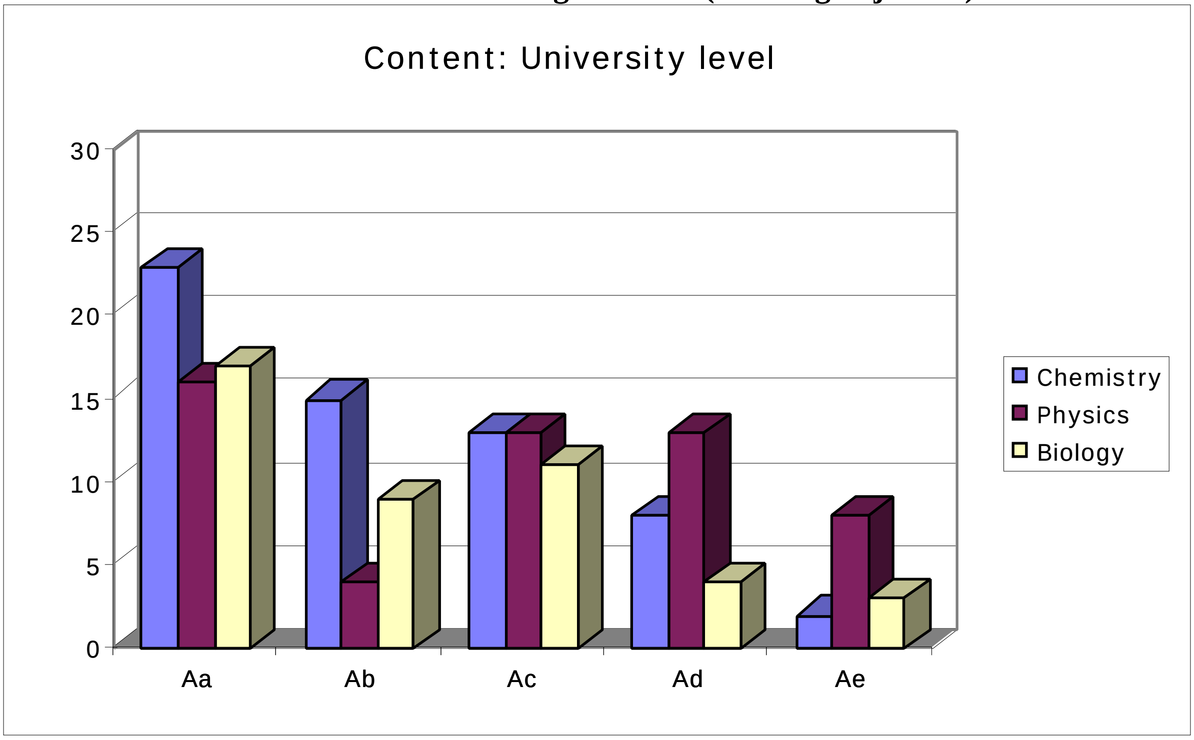


Figure 3: Learning objectives related to the content by discipline (see table 1 for the meaning of the items)

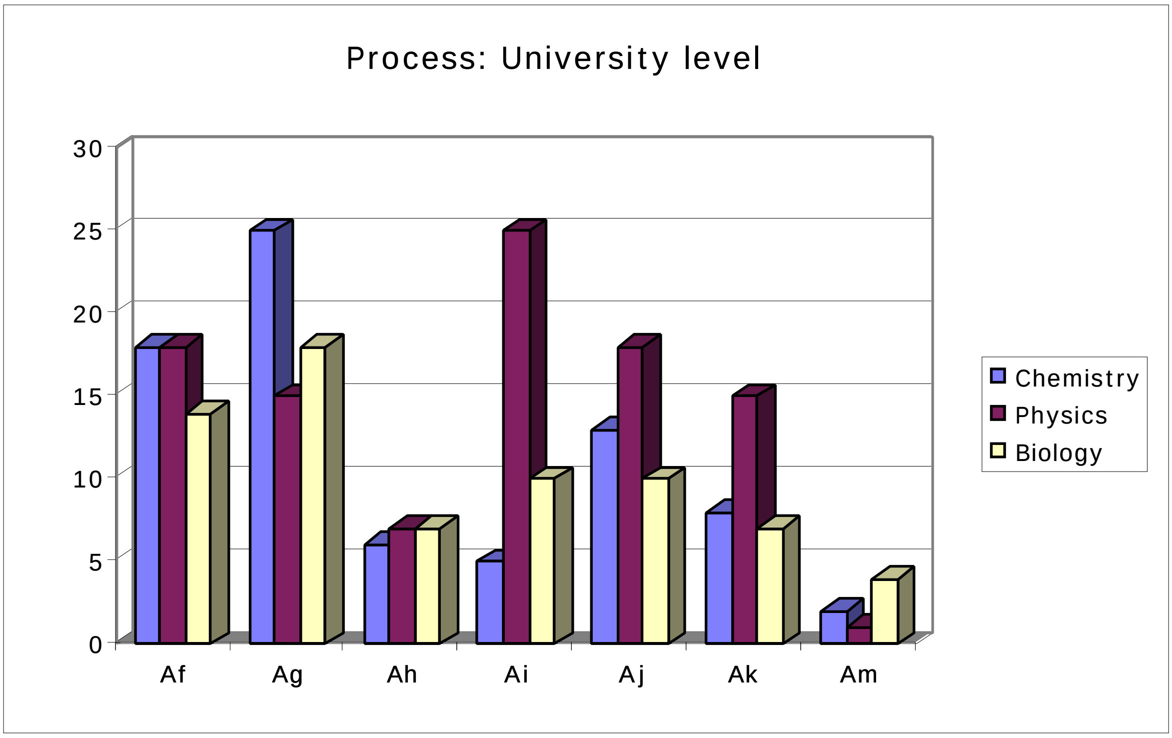


Figure 4: Learning objectives related to the process by discipline (see table 1 for the meaning of the items)

Comparison between upper secondary school and university levels

If the sets of school and university level tasks, regardless of science discipline, are compared, the similarity in objectives is very striking (Figure 5).

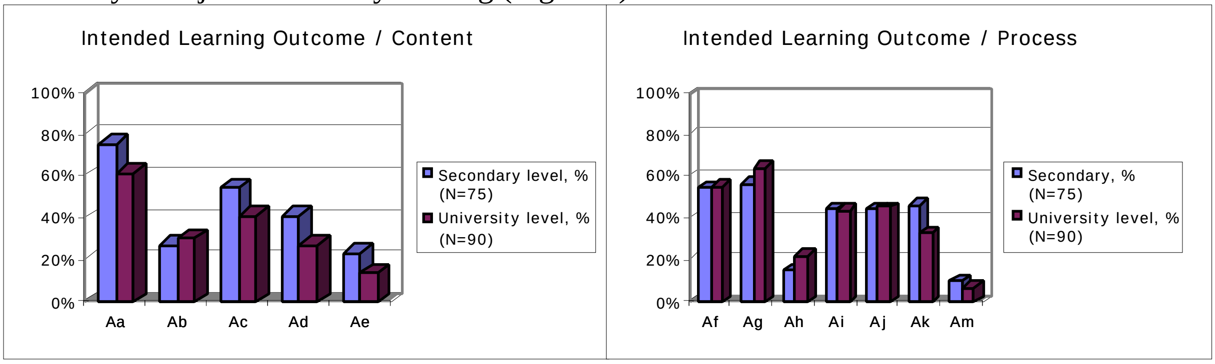


Figure 5 : Learning objectives for secondary and university levels for the three disciplines (see table 1)

The commonest aims of labwork at both levels are to help students " *to identify objects and phenomena and become familiar with them* (Aa)" and "*to learn a standard laboratory instrument* or *to learn a standard procedure (Ag).*
The least common aims are " *to learn a fact or a theory/mode (Ab)l* " and "*to learn how to plan an investigation to address specific question or problem (Ae)*".

Design features of task (B)

The second main dimension of the map aims to characterise the design features of labwork tasks: what students are intended to do with objects and observables (B1) and what they are intended to do with ideas (B2).

What students are intended to do with objects and observables (B1)

This sub-dimension of the map (B1) relates to what students are expected to do with objects and observable things. The 'map' also allows us to describe the source of the information acquired by the students : inside or outside the laboratory, from a computer simulation or CD-ROM, or from text.

Origin of information acquired by the students when their activity is related to their material environment

Upper Secondary school level

Figure 6 is very illustrative: there is almost exclusively one single source of information for students in all countries and disciplines: material objects inside the laboratory. Only in biology does it appears that, in a few occasions, information is acquired from outside the laboratory. Information is almost never obtains by text is not important at all, the emphasis is on obtaining using real devices.

University level

At university level, the origin of information is a little more varied (Figure 7). In biology there are few tasks in which information is acquired from outside the laboratory and from video. Also particularly in physics, the role of the text as a source of information becomes more frequent. The most common source of information, by a large margin, remains real objects and devices inside the laboratory.

Possible activities during labwork

Secondary level and university level

The results show that only a sub-set of the categories of activities proposed by the 'map' are expected of the students with any regularity. At upper secondary school level, students are most often expected to (Figure 6 and Figure 7):

- *use a laboratory device in physics* (B1-2, *or a laboratory procedure* (B1-3) in chemistry and (to a lesser extent) in biology;
- *make an event occur* (B1-7), in all three disciplines;
- *observe an event* (B1-10*)*, in all three disciplines, and also, mainly in physics and in chemistry, to *observe a quantity* (B1-11) (that is, to make a measurement);

Only very rarely do the students have "*to present or display something*" (B1-4), "*to make an object, or to observe a material*" (B1-5/8).

There appears to be little difference between countries. Similarly, between the secondary or university levels, the differences are unimportant. However, the activity "*making an event*" is less common in chemistry and biology at university level than at secondary school level.

It also appears that, in physics, some coding categories apply to the majority of labwork tasks, and some never apply. This is less marked in chemistry and much less in biology. For instance, at upper secondary school level, 22 of the 25 labwork sheets ask the students to "*use a laboratory device or arrangemen*t", and 20 ask them to "*observe a quantity*", whilst none asks them to "*present, display or make an object*" or "*observe a material*". In chemistry, 21 labwork sheets ask the students to "*use a laboratory procedure*" , whilst none asks them to "*present or display an object*". In biology, no single coding category arises more than 20 times, and none has zero frequency. So this may be evidence of a tendency for labwork in physics to involve students in carrying out a smaller range of types of activities with objects and observables than corresponding labwork in biology, with chemistry coming somewhere in between.

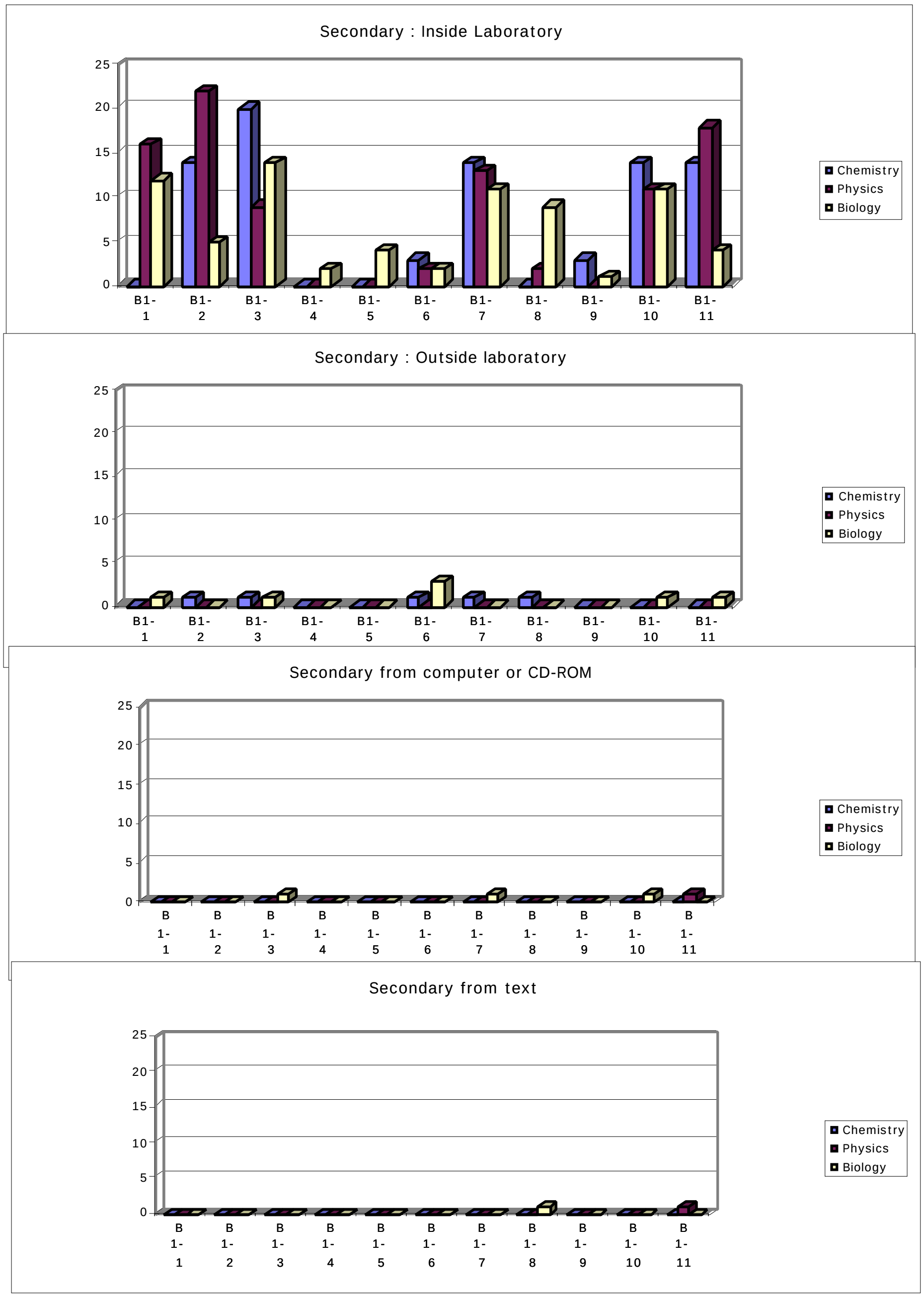


Figure 6 : What students are intended to do with objects and observables including the sources of information at secondary school level (see table 2 for the meaning of the categories)

what students are intended to do		**B1**
use	an observation or measuring instrument	**1**
	a laboratory device or arrangement	**2**
	a laboratory procedure	**3**
present or display	an object	**4**
make	an object	**5**
	a material	**6**
	an event occur	**7**
observe	an object	**8**
	a material	**9**
	an event	**10**
	a quantity	**11**

Table 2: Categories of activities with objects and observables

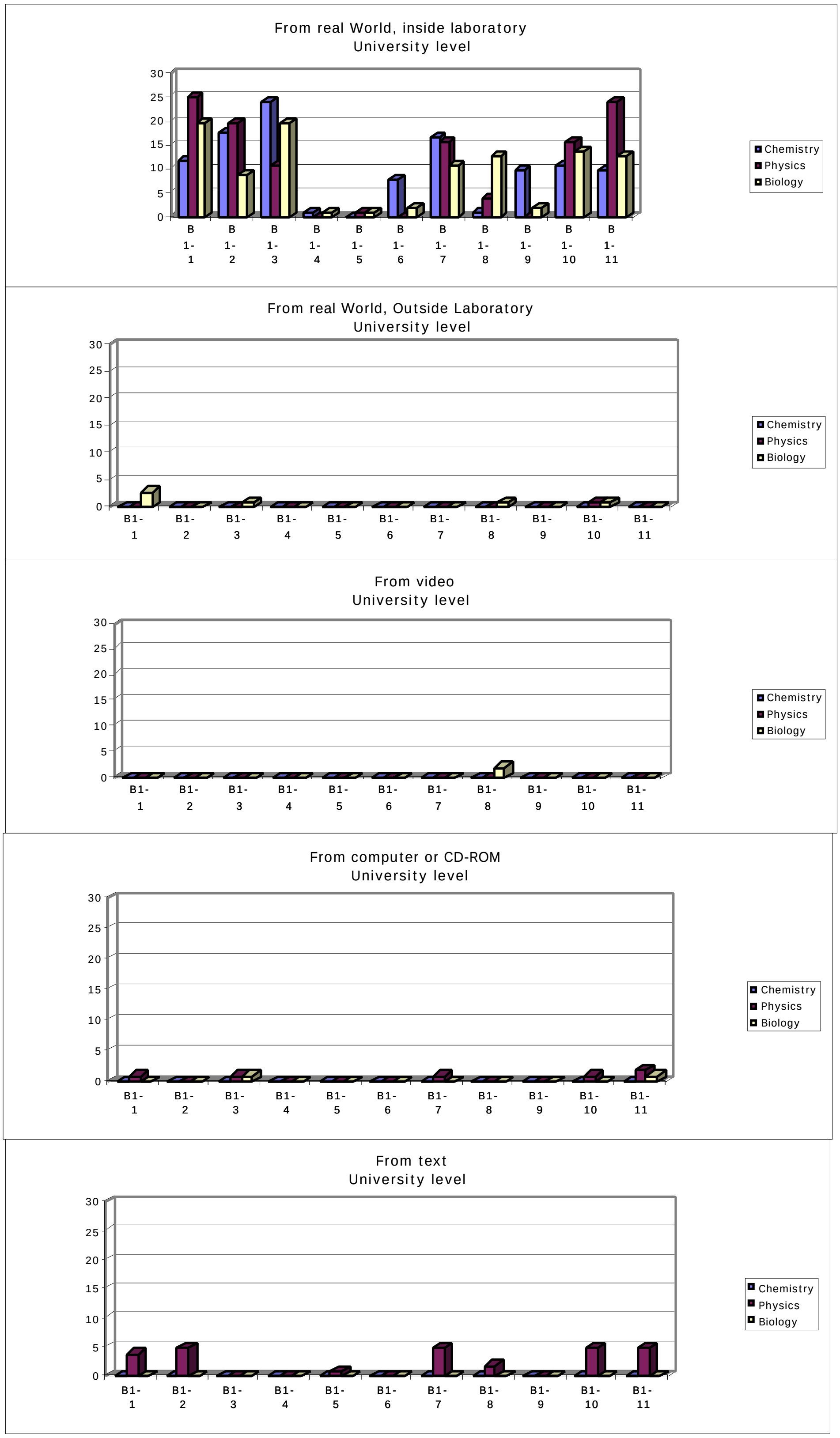


Figure 7: What students are intended to do with objects and observable including the sources of information (see table 2 for the meaning of the categories)

What students are intended to do with ideas (B2)

Secondary school level

Here both common aspects and differences between disciplines appear (Figure 8 and Table 3).
Many labwork sheets ask students *to do a direct reporting of observation.*
Very few labsheets ask students:

- ◊ to explore relation between objects,
- ◊ to invent a new concept (physical quantity, or entity),
- ◊ to test a prediction wherever it comes from (guess, law or theory),
- ◊ to account for observations by proposing a theory,
- ◊ to choose between two (or more) explanations.

The number of aspects which are not taken into account in a majority of labwork sheets is important and noteworthy. Concerning ideas, labwork activity does not appear to require students to engage in as full a range of different activities as might anticipate or hope for.

Again, we see that physics labwork tasks cluster in a relatively small number of coding categories, to a greater extent than those in chemistry and in biology. Only in physics many labwork sheets ask students to "*explore relation between physical quantities*", also in physics more often than in chemistry and biology, the students have "*to account for observations in terms of a given law*".
The two most common important aspects for chemistry are the "*direct report of observation*" and "*to determine the value of a quantity which is not measured directly*". In biology one aspect seems more common than in physics and to a less extent in chemistry: "*to identify a pattern".*

University level

The most striking feature of the university level data) is its similarity to the secondary school data, for all disciplines (Figure 9 and Figure 10). However, in chemistry the ‘direct reporting of observation’ is less frequent at university level, whereas in physics "to test a prediction" and "to explore relationships between objects and physical quantities" appear to be more frequent at university.

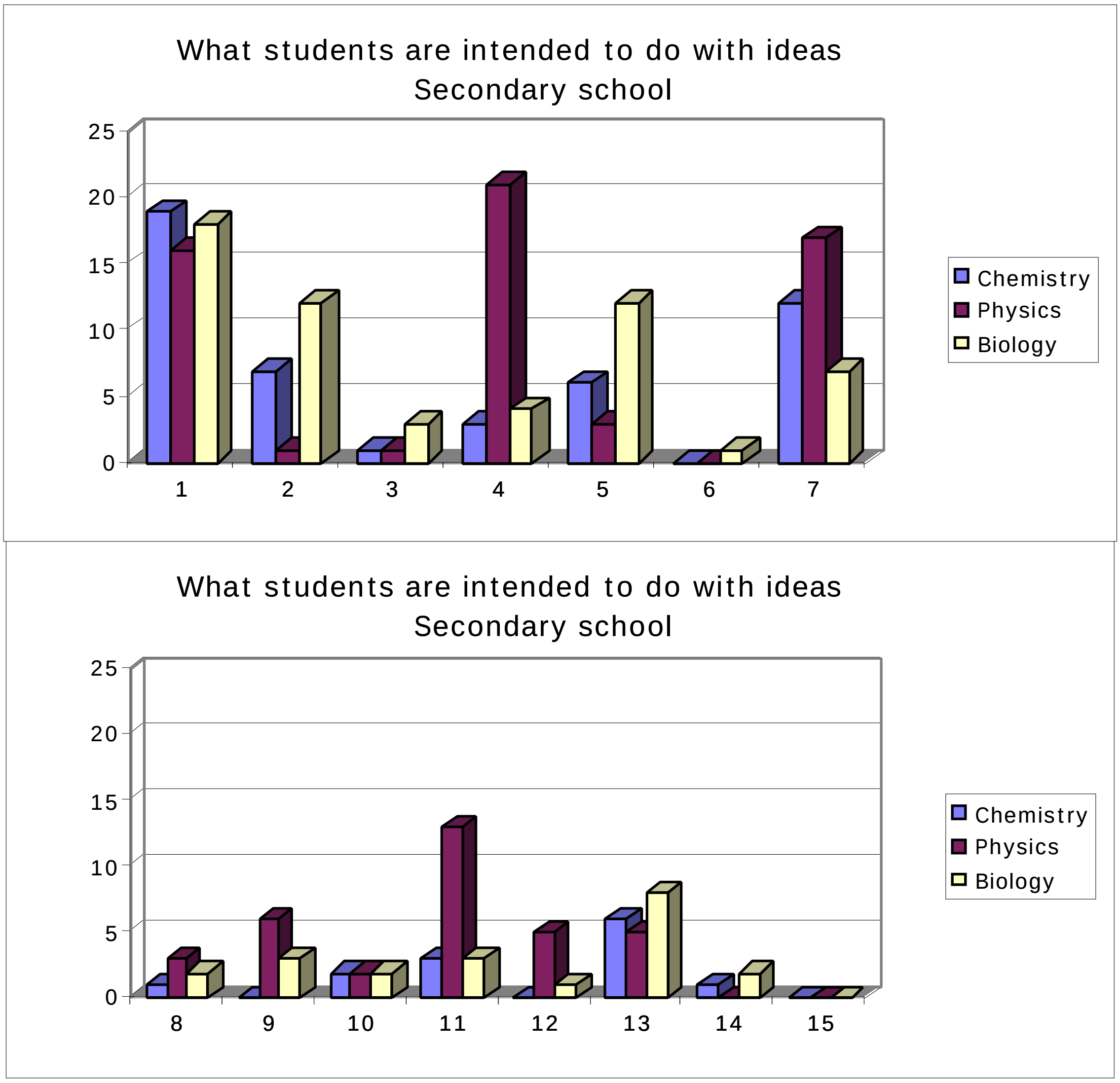
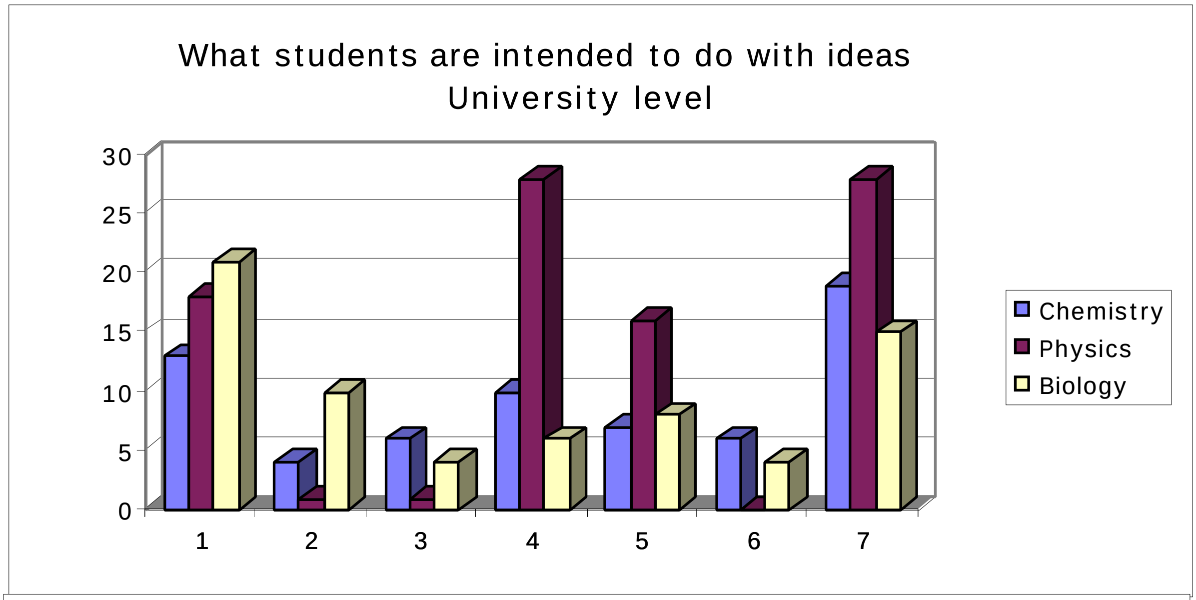


Figure 8: Aspects related to what students are intended to do with ideas (secondary level). The categories are given in table 3.

what students are intended to do	**B2**
direct reporting of observation (s) **1**	
identify a pattern **2**	
explore relation between	objects **3**
	physical quantities **4**
	objects and physical quantities **5**
'invent' a new concept (physical quantity, or entity) **6**	
determine the value of a quantity which is not measured directly **7**	
test a prediction	from a guess **8**
	from a law **9**
	from a theory **10**
account for observations	in terms of a given law **11**
	by proposing a law **12**
	in terms of a given theory **13**
	by proposing a theory **14**
choose between two (or more) explanations **15**	

Table 3: Categories related to what students are intended to do with ideas



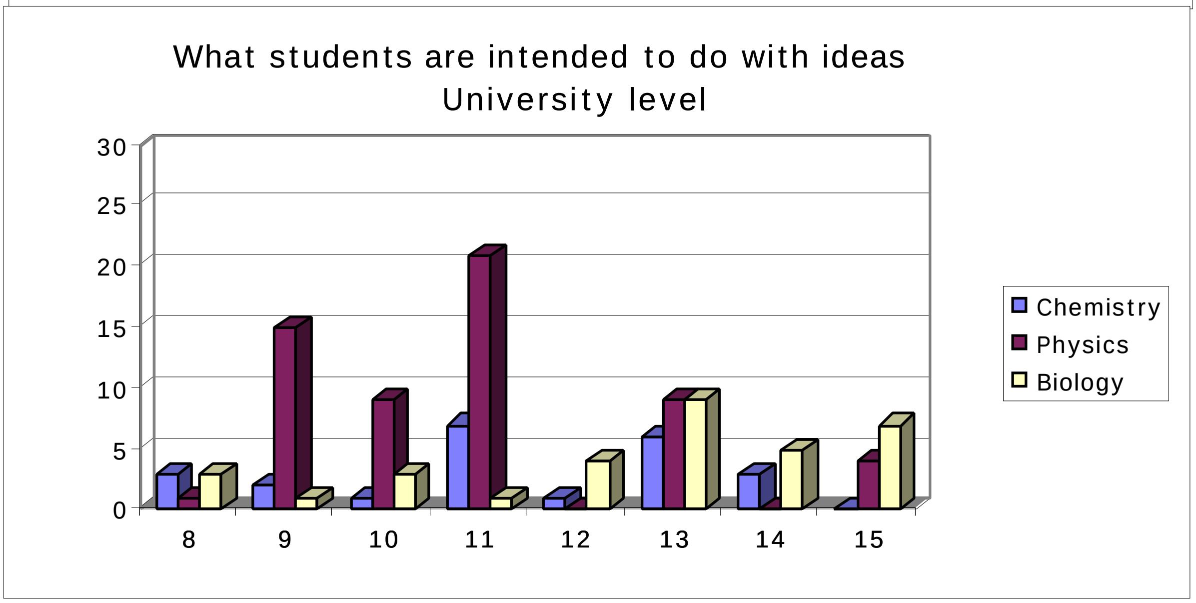


Figure 9: Characteristics of what student are intended to do with ideas (for categories see table 3).

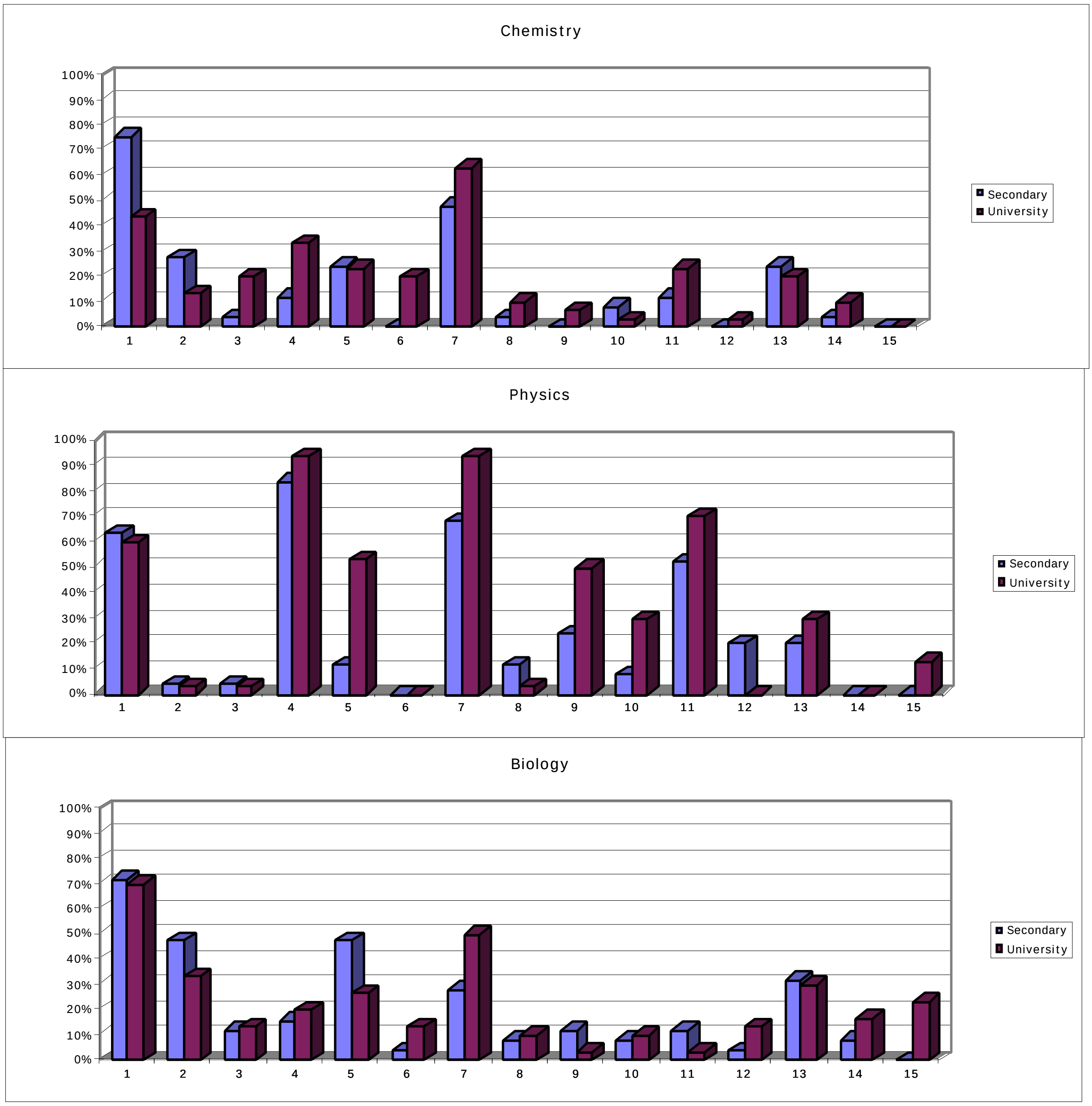


Figure 10: Comparison between secondary and university levels for the three disciplines concerning what the student are intended to do with ideas. The categories are given in table 3.

Use of computer in relationship with what students are intended to do with ideas

Concerning what students are intended to do with ideas, coding categories allow to note if the students have expected to use a computer or a pocket calculator, or to process data manually. In the sample of labwork sheets analysis, if we look at those involve in the use of computer for data analysis, then differences appear between disciplines and between levels.

Only physics at university was there more than one labwork sheet which asked students to use a computer. The computer is mainly used for "*exploring relation between physical quantities*" and for *testing a prediction"* (10 out of 30), with the majority being the latter category. Indeed, this was the only activity in which the number of labwork sheets involving the use of computer is similar to or

greater than the number of activities involving calculations made manually or using a pocket calculator.
We can also see a striking difference in the frequency with which computers are used for data analysis as compared to their use as a data source (for example, through a simulation, or data on a CD-ROM). The former use of computers is common in physics at university level but the latter is not.

Observation or ideas driven (B3)

It was interesting to know whether a labwork task starts from operations on objects and leads towards ideas (objects-driven), or vice versa (ideas-driven) (Figure 11). There is no clear pattern here, though physics labwork tasks seem more ideas-driven than objects-driven at both levels, more noticeably so at university level.

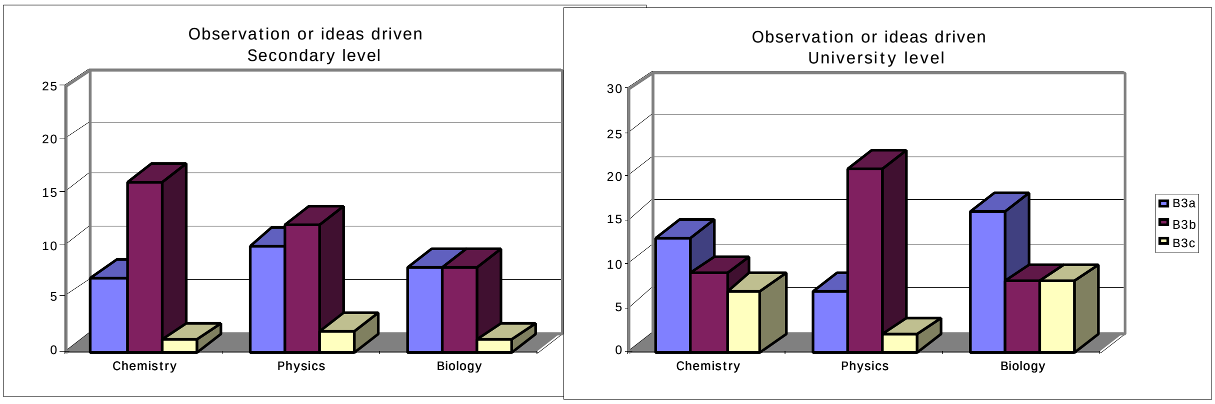


Figure 11: students' activities driven by observation or ideas (see table 4 for the meaning of the categories)

B3	
(a) What the students are intended to do with ideas arises from what they are intended to do with objects	**a**
(b) What the students are intended to do with objects arises from what they are intended to do with ideas	**b**
(c) There is no clear relationship between what the students are intended to do with objects and with ideas	**c**
Miscellaneous	**d**

Table 4: Categories corresponding to students' activities driven by observation or ideas

Degree of openness / closure (B4)

This categorisation aims to know who takes the initiative in labwork activity. Is it the teacher, the student or the result of a negotiation between them? Five different aspects of the labwork task are considered:
- the question to be addressed
- the equipment to be used
- the procedure to be followed
- the methods of handling data collected
- the interpretation of results

At secondary school level, the results are very clear (Figure 12): most of the time the teachers take the initiative.

At university level, the teacher is still the main initiator (Figure 13). However, particularly in chemistry and biology, the students are increasingly likely to take some decisions mainly on the procedure, method and interpretation.

The results can be interpreted with regards to the successive activities during usual labwork. The two first activities concern the question to be addressed and the equipment to be used. In many cases, both at secondary and university levels, the teacher is the main initiator. However, particularly in chemistry and biology, the students are increasingly likely to take some decisions as we move from the choice of equipment, to procedures, to data analysis to interpretation. In physics, students appear to be given fewer opportunities to make choices about the conduct of labwork tasks.

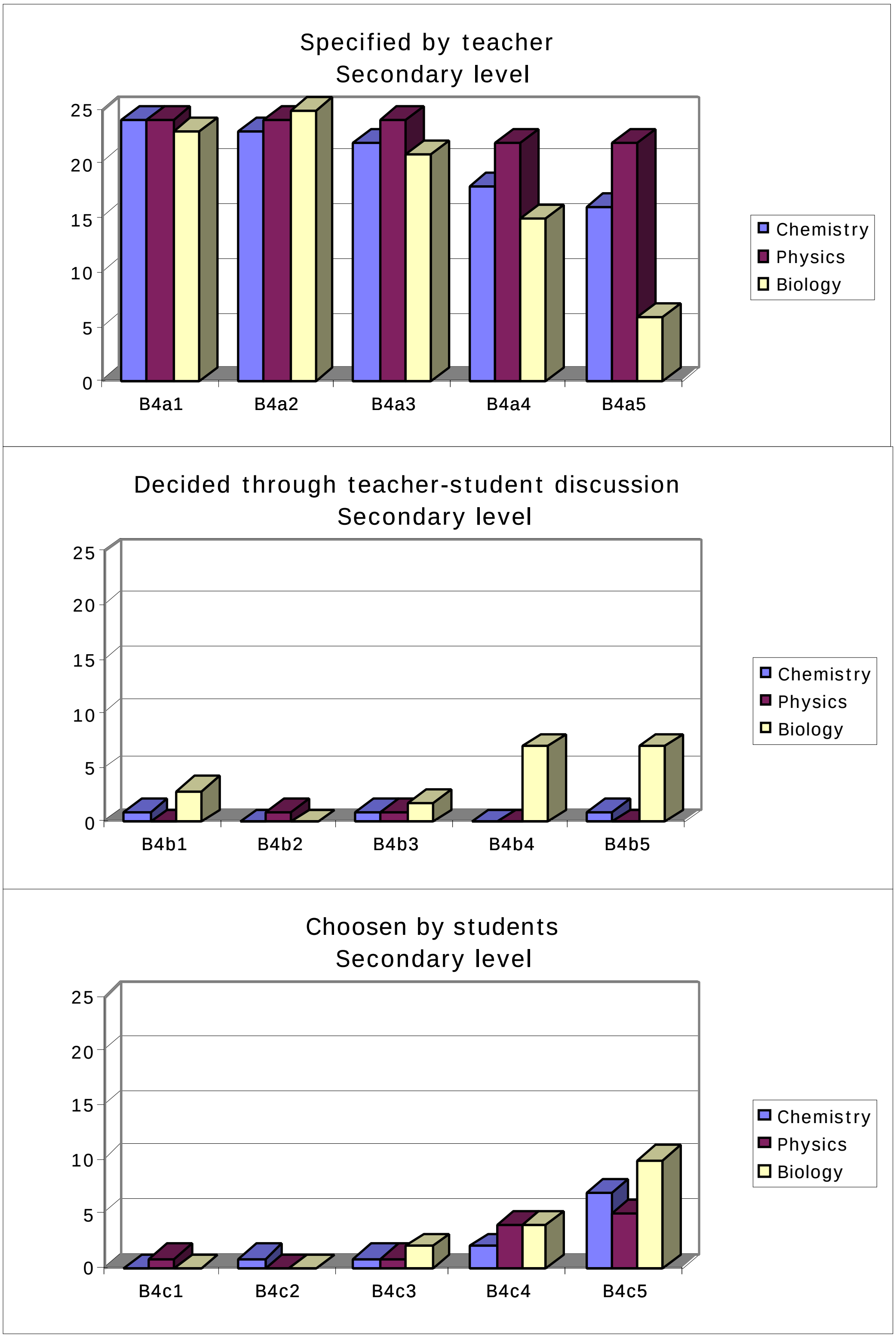


Figure 12: Importance of students' initiative (see table 5 for the meaning of the categories)

Question to be addressed	**B4a, b or c, 1**	**a** = specified by the teacher
Equipment to be used	**B4 a, b or c,2**	**b** = decided through teacher-student discussion
Procedure to be followed	**B4 a, b or c,3**	**c** = chosen by students
Methods of handling data collected	**B4 a, b or c,4**	
Interpretation of results	**B4 a, b or c,5**	

Table 5 : Categories related to the degree of openness or closure of the labwork

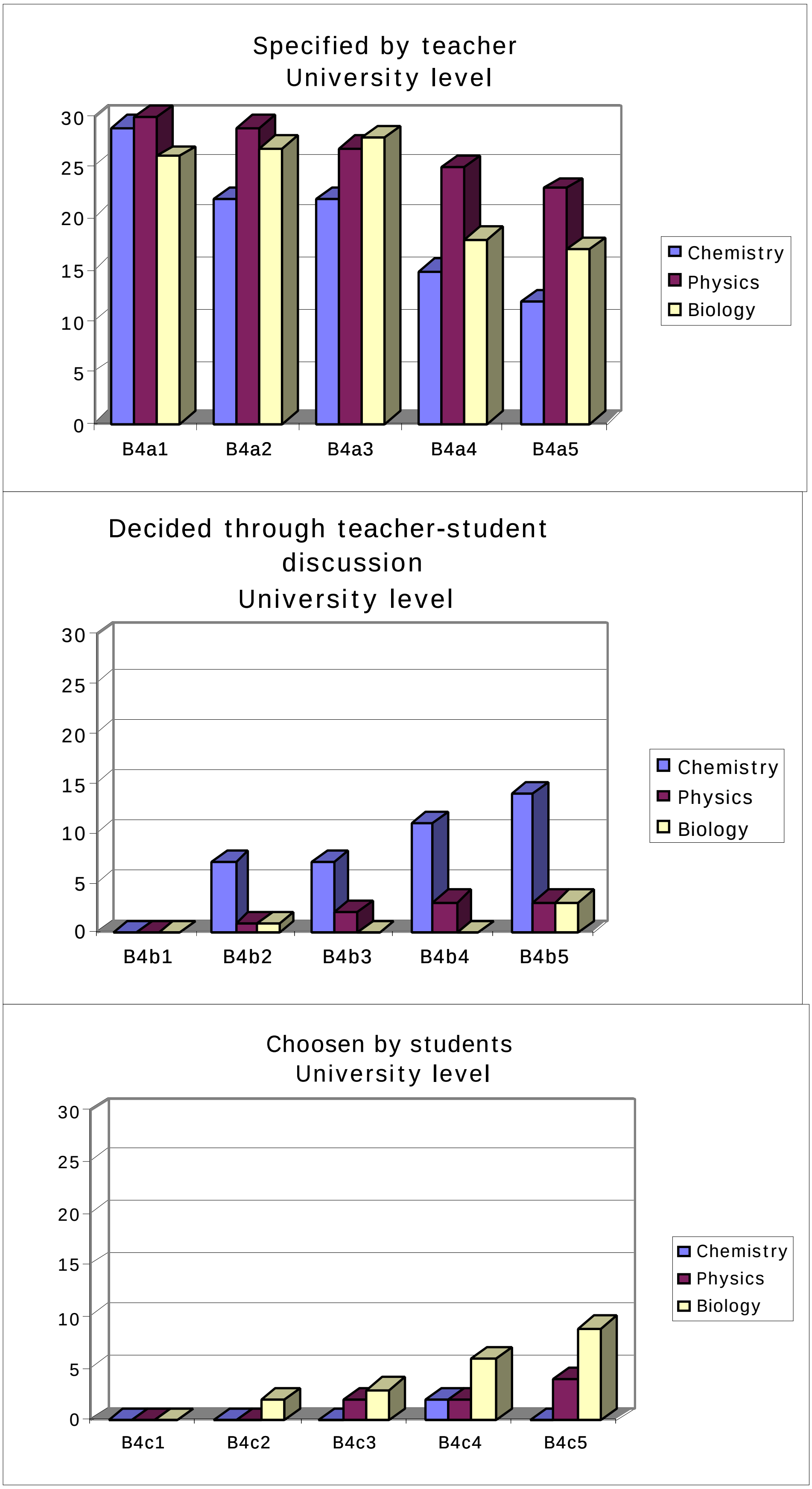
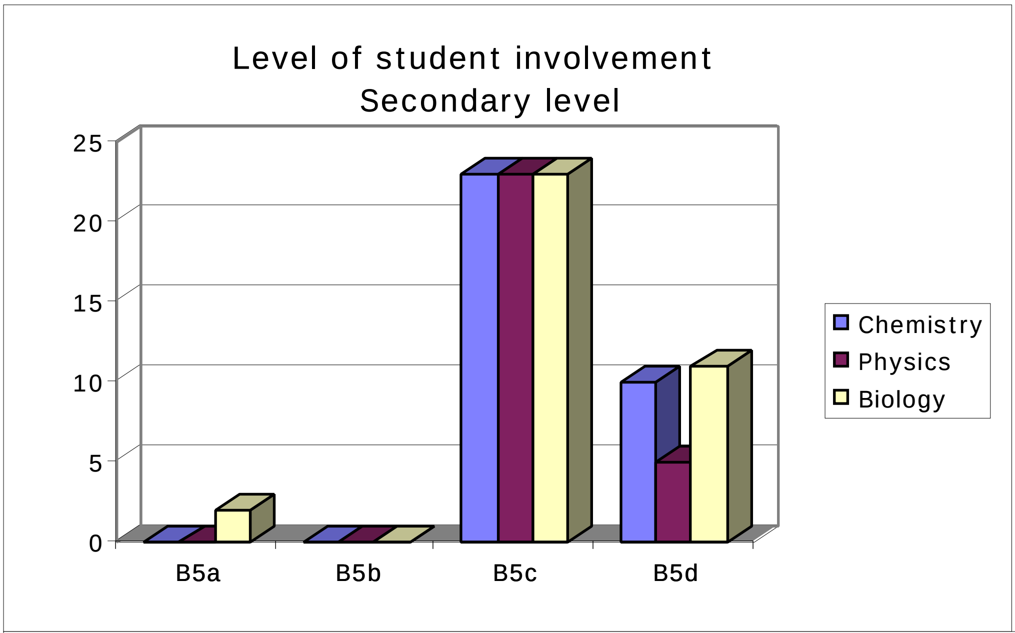


Figure 13: Importance of students' initiative (see table 5 for the meaning of the categories)

Level of student involvement (B5)

This aspect deals with the level of student involvement: as observer, as assistant, or as executor of the task with other students or on one's own. The results of analysis of the sample of tasks on this sub-dimension are shown in Figure 14. This shows that the majority of labwork tasks are carried out by students working in small groups, or individually. Very few labwork tasks in this sample are carried out by the teacher with students observing, or assisting. This may, however, underestimate the frequency of demonstrations of this sort in practice. It is more likely that these were not considered by those selecting the sample of labwork tasks for analysis, either because they did not immediately consider them as 'labwork' or because they often do not have associated instruction sheets (the source of the primary data for our analysis).



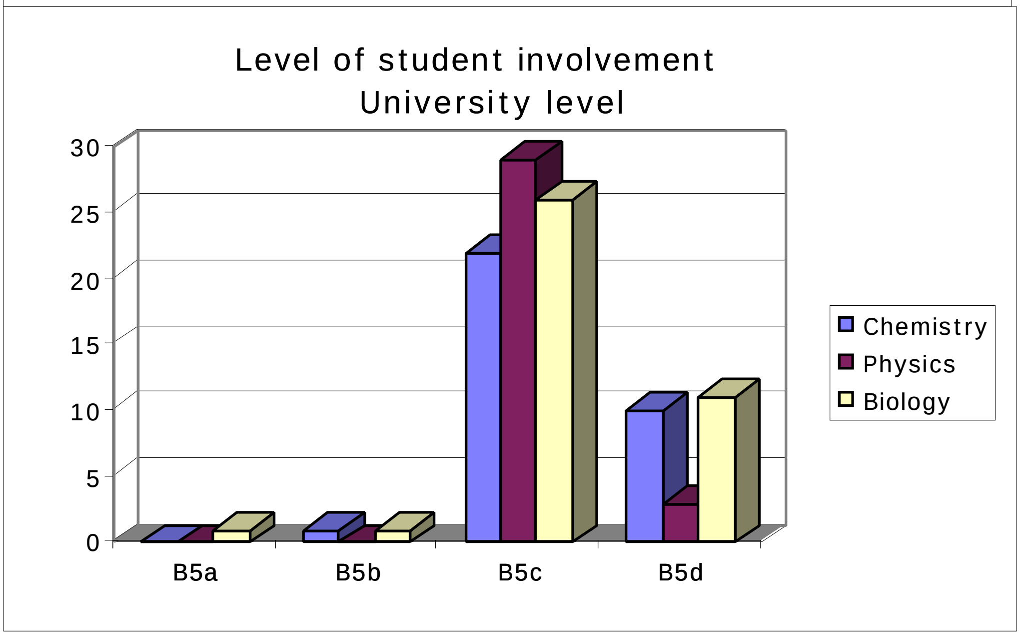


Figure 14: Level of student involvement (see table 6 for the meaning of the categories)

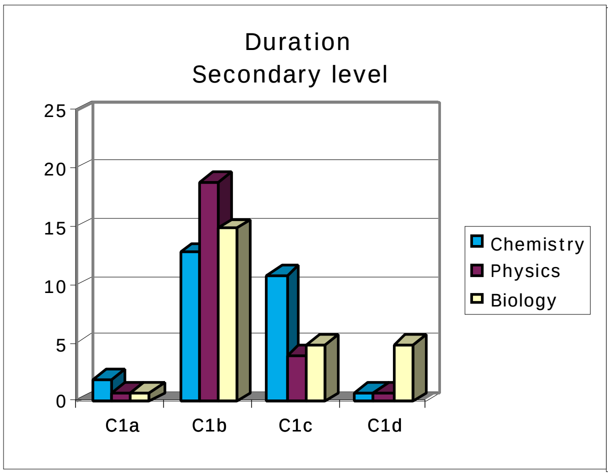
demonstrated by teacher; students observe	**B5a**
demonstrated by teacher; students observe and assist as directed (e.g. in making observations or measurements)	**B5b**
carried out by students in small groups	**B5c**
carried out by individual students	**B5d**

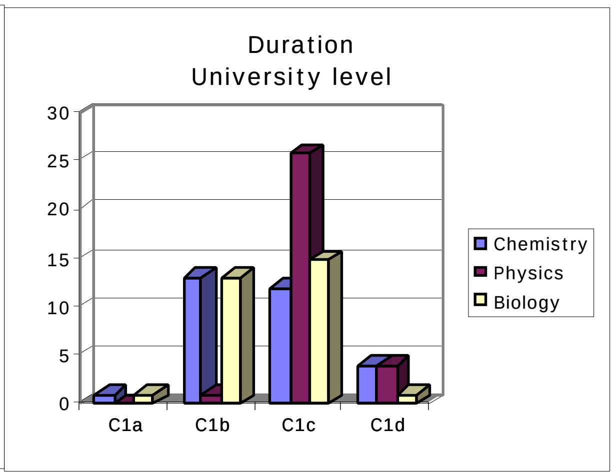
Table 6: Level of students' involvement

Details of context (C)

Duration

At upper secondary school level, the majority of labwork sessions lasts about 80 minutes session (Figure 15). In chemistry, it is almost equally common for a task to cover several lessons of this duration, but this is not the case for physics or biology. At university level, particularly in physics, a duration of 2 or 3 sessions seems the most common. Although extended projects are, as we might expect, a less common form of labwork, they are used in all three sciences (more commonly in this sample at school level in biology, and at university level in physics and chemistry).



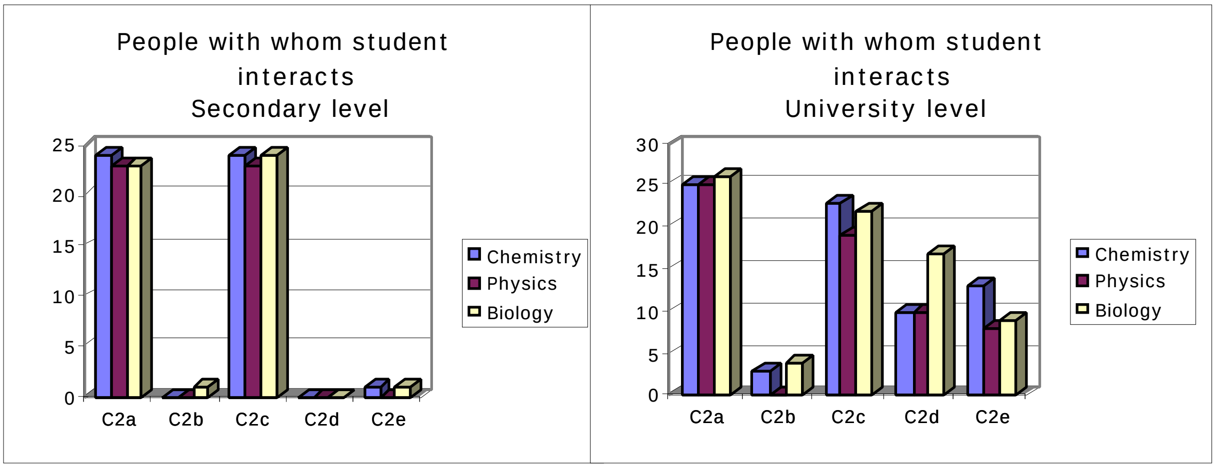


C1a very short (less than 20 minutes)
C1b short (one science lesson, say, up to 80 minutes)
C1c medium (2-3 science lessons)
C1d long (2 weeks or more)

Figure 15 : Duration of labwork session

People with whom student interacts

The effective students' interaction during labwork at secondary school level is very typical whatever the country (Figure 16). Students interact with their partner and with their teacher only. At university there are clear differences, the students also interact with more advanced students or with technicians. This is a case for which the difference between secondary level and university is important.

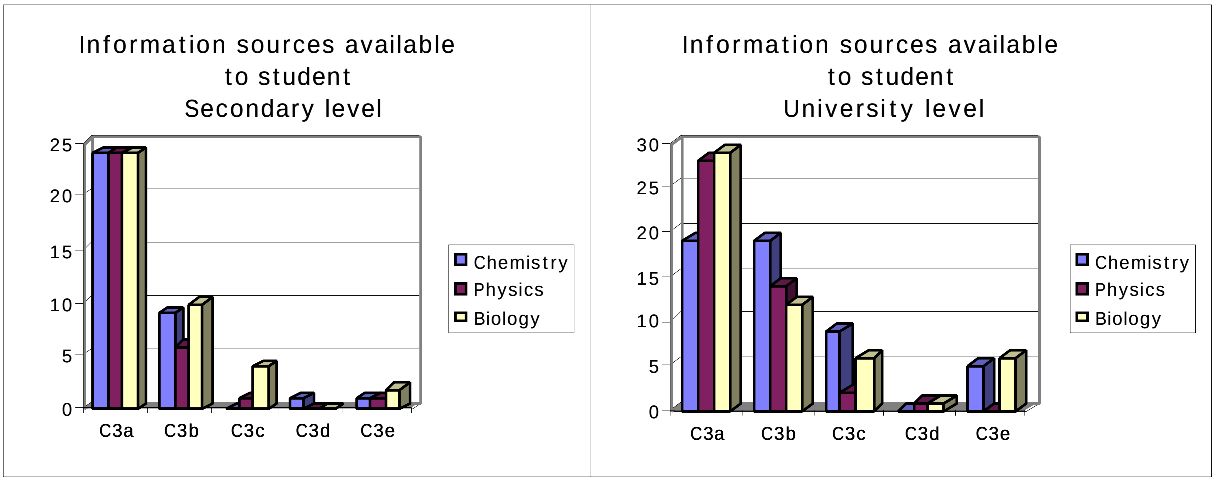


C2a other students carrying out the same labwork task
C2b other students who have already completed the labwork task
C2c teacher
C2d more advanced students (demonstrators, etc.)
C2e others (technician, glassblower, etc.)

Figure 16 : Kind of persons with whom the student interacts during labwork

Information sources available to student

These results (Figure 17) confirm those obtained concerning what the students are intended to do with objects. At secondary school the worksheet is the main source of information and often the only one. At university, books are a very frequent source of information. Computerised databases are not widely used as data sources at either level.

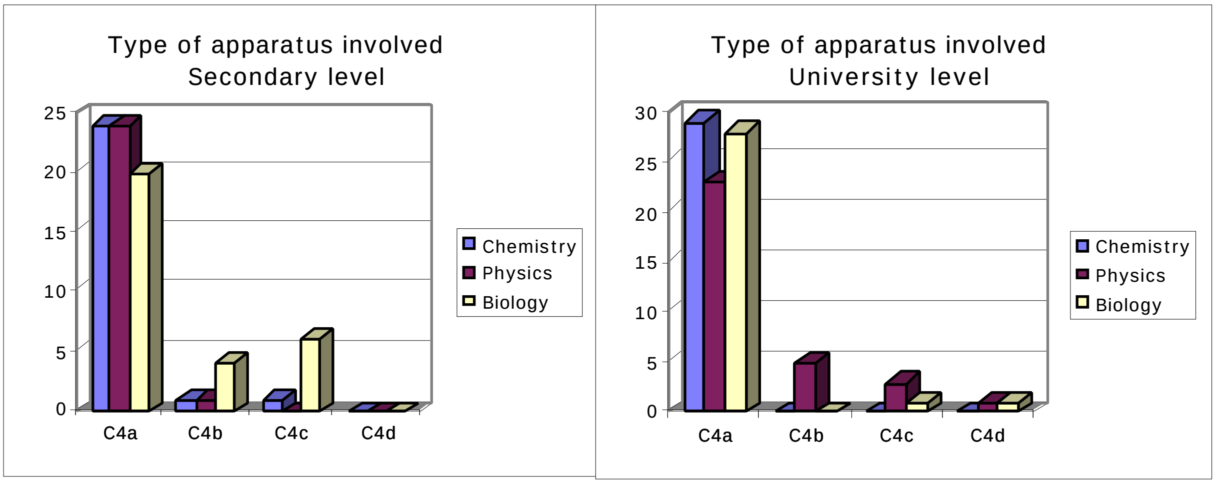


C3a guiding worksheet
C3b textbook(s)
C3c handbook (on apparatus), data book, etc.
C3d computerised database
C3e other

Figure 17: Kind of sources of information available to student during labwork

Type of apparatus involved

The results here confirm those obtained for the categories related to what the student intended to do with ideas (Figure 18). Computer is not used very often, the standard laboratory equipment is by far the commonest type of equipment used.



C4a standard laboratory equipment
C4b standard laboratory equipment + interface to computer
C4c everyday equipment (e.g. kitchen scales, domestic materials or equipment, etc.)
C4d other

Figure 18: Type of apparatus involved

Conclusion

We first present a summary of the main results and then we give our comments.

Summary

In this summary, we present the characteristics which are present and those which are absent in a majority of the labwork sheets for any discipline. The purpose is to indicate the most striking features of the data. The criteria we will use are that a characteristic is present in 80% (20/25 or 24/30) or more of the example considered or appears in 20% (5/25 or 6/30) or less of the examples considered. Moreover when the three disciplines together are very close to these limits for a given item, we take it into account.

Learning objectives

At secondary school, the main learning objectives

• are:
- in all disciplines, to identify objects and phenomena and become familiar to them
- in physics only to learn a relationship.

• are not:
- in all disciplines, students learn a theory/model
- in all disciplines but less in biology, to learn how to plan an investigation to address a specific question or problem.

At university level, the main learning objectives

• are:
- for chemistry, how to carry out a standard procedure
- for physics, how to process data.

• are not:
- mainly in chemistry and biology to learn a theory/model, (it is still not important in physics);
- how to plan an investigation to address a specific question or problem.

Design feature of tasks

At secondary school, the sources of information in all disciplines:

• are :
- inside the laboratory

• are not :
- outside the laboratory
- from computer or CD-ROM
- from text.

At university level, the only difference is that the information from text is used in some cases.

Concerning what the students are intended to do with objects and observables, at secondary school and university levels, the students

• are supposed:
  - to use a laboratory device in physics or a laboratory procedure in chemistry and in a less extent in biology;
  - to observe a quantity in physics.

• are not supposed
  - to present or display something,
  - to make an object, or a material (except in chemistry at university level)
  - to observe a material (except in chemistry at university level).

What students are intended to do with ideas

Concerning what students are intended to do with ideas,
at secondary school level, the students

• have to:
  - direct report of observation
  - only in physics, explore relation between physical quantities.

• do not have to:
  - explore relation between objects
  - 'invent' a new concept (physical quantity, or entity)
  - test a prediction from a guess, a law or a theory
  - account for observations by proposing a theory
  - choose between two (or more) explanations.

At university level, the students

• have to:
  - only in physics, explore relation between physical quantities
  - only in physics, determine the value of a quantity which is not measured directly
  - only in physics, account for observations in terms of a given law

• do not have to:
  - identify a pattern
  - explore relation between objects
  - 'invent' a new concept (physical quantity, or entity)
  - test a prediction from a guess for all disciplines and, only in chemistry and biology to test a prediction from a law or a theory
  - account for observations by proposing a theory
  - choose between two (or more) explanations.

As regards the degree of openness/closure of labwork tasks and the extent to which students are expected or required to make decisions and choices, at both secondary school and university levels, the teacher plays the major role. The question to be addressed and the equipment to be used are normally specified by the teacher. For the remaining aspects, procedure, methods of handling the data collected and interpretation of results, students are given less freedom in physics than in chemistry or biology. For all these aspects, however, and particularly in physics and chemistry, teachers play the major role in most labwork tasks.

Concerning the context, the same tendencies appear. The commonest duration for a labwork session is about 80 minutes at secondary school level, and 2 or 3 sessions of this length at university level. At secondary school level, the students only interact with their teacher and with the other students carrying out the same labwork task. At university, students also often interact with two other groups of people : more advanced students and technicians.

The specificity of the disciplines emerge for a few aspects. Physics has perhaps the greater number of such characteristics. Physics labwork also has the strongest similar aspects across countries the levels, in particular :
- to use a laboratory device or arrangement
- to observe a quantity.

In chemistry, most of the labwork sheets, particularly at secondary level, require the students to use a laboratory procedure. In biology, the commonest aspect does not attain the 80% criterion we have adopted.

Comments

This method of characterising a labwork task using the ‘map’ and the coding categories associated with each of these is, in our view, useful for highlighting the major features of such activities. It is able to indicate the main similarities and differences between labwork activities.

So for example, the duration, the people with whom students interact, the specification by the teachers of the question to be addressed and the equipment to be used all emerge as very common features of all the labwork sheets analysed. Similarly, in almost all cased the source of information acquired by the students is the real world inside the laboratory, with little information collected outside the laboratory, or from video recorded events, computer simulations, or CD-ROMs. Students' investigations are carried out predominantly in a laboratory setting. The labwork is only infrequently an opportunity to study the everyday world directly or the industrial world.

There are striking patterns both in what students have to do but also in what they do not have to do. At secondary school, the students often have to make direct reports of observations but they do not have to present or display or make an object. They seldom have to explore relationships between objects, to test a prediction, to choose between two (or more explanations) and to invent a new concept (or entity). Even at university, it is rare for students to have to test a prediction from a guess or from a theory (in physics they can have to test a prediction from a law) or to account for observations in terms of a law or a theory.

The similarity between countries are perhaps greater than could have been expected, bearing in mind the differences between the educational systems of the countries involved. So too perhaps are the similarities between disciplines. A main conclusion which we can draw from our results is that labwork appears to require students to undertake a rather limited number of activities. Some very important activities in the practice of the experimental disciplines appear to be only occasionally reflected in typical labwork. So for example whilst learning to establish relations between quantities is common in physics, and learning to use a standard procedure, is common in chemistry, it appears to be very rare for labwork to involve accounting for observations in terms of law or theory or choosing between explanations. These similarities, both in terms of what is common in labwork activities and in what is uncommon, may provide a useful starting point for us in considering how to design new forms of labwork.

Reference

Millar, R., Le Maréchal, J.F. and Tiberghien, A. (1997). *A 'map' of the varieties of labwork - and its possible uses as a research tool.* Communication at the ESERA conference. Rome

Millar, R., Le Maréchal, J.F. and Buty,C. (1998). *A 'map' of the varieties of labwork - and its possible uses as a research tool.* Woking paper n°1. (this project).

From the common work of the project

'LABWORK IN SCIENCE EDUCATION',

some policy implications :

A summary

The following research themes have been addressed at European level by the project :
- the current practice of labwork in Europe [Working papers 2, 3] using a specific tool of description of labwork sessions [Working Paper 1]
- the identification of labwork objectives as defined and ranked by teachers in order of importance [Working Paper 6]
- the image of science as it is related to labwork [Working Papers 4 and 5]
- the effectiveness of labwork which has been documented by 22 case-studies [Working Papers 7 and 8]

These pieces of work showed that there is in Europe a common paradigm of labwork, but that some choices for Education and Science Education are stemming from national traditions. However some implications could be drawn from the work done in six countries, which are summarised below.

1 - Some objectives are not achieved if not addressed specifically. A number of potential objectives are very rarely addressed currently. If these issues were addressed, there is a potential for students to learn more from labwork.

The objectives being defined carefully, it is necessary to attribute a specific place and role to each of them.

❖Although ***conceptual knowledge*** underpins all labwork activities, this should not be taken as implying that doing labwork activities necessarily leads to improved conceptual understanding. Indeed, scientific concepts are not usually learned effectively through labwork if the labwork activity is not designed towards this aim

Some case studies show the proportion of time devoted to "talk" about the conceptual and theoretical basis of labwork tasks. In general, the amount of time spent by students in this way is very small, suggesting a need for improvement.

One of the most effective ways of focusing students on the corresponding knowledge, is to address issues of modelling directly. This is made possible in activities such as constructing a model, discussing a model in relation to events, using a model in particular situations, comparing models and searching for the value of a parameter to fit a model. Computers are of great help in such cases, as can videos designed to focus on the theoretical underpinnings of labwork.

The context of open-ended project work is also a powerful strategy because it requires students to draw upon conceptual knowledge in order to solve a given problem, even if the project is introduced before formal teaching of ‘theory’.

Another possibility is to ask students to make predictions more often about the behaviour of events, or alternatively about orders of magnitude before actually making measurements. To be meaningful, this requires renewed types of organisation.

❖ Any piece of labwork requires students to undertake ***procedures***. However teachers cannot expect students to learn about procedures effectively if these are not taught explicitly, and explained and used in a variety of contexts. An argument supporting the teaching of procedures is that, once understood, such procedures are powerful tools to be used in designing experiments, one of the most creative processes in science. Experimental design is a particularly effective context for teaching epistemological knowledge. If students are not taught procedures, then their autonomy for designing experiments will inevitably be reduced.

❖ During labwork there should be a constant interplay between the ***collection of data*** (observations, measurements etc.) and theory. During the project, the place of measurement was increasingly questioned. If measurement is undertaken as an activity, it should be carefully 'targeted': clear objectives for the activity should be set, and consideration should be given to other activities that might follow on from measurement such as data processing, the evaluation of theories, drawing conclusions and evaluating experimental techniques and apparatus.
Obviously, computers and sensors can play an important role in saving time during these tasks and in some cases it is only possible to make measurements with the aid of computers. But, the significance of the measurement must be addressed directly in teaching and not hidden behind routines.

❖ ***Data processing and the development of conclusions*** provide opportunities for the development of conceptual and epistemological understanding by students. Our work underlines the very different choices that can be made by teachers. Data processing can be treated as an algorithm, or alternatively can be treated as an opportunity to teach about one of the most important aspects of epistemology: the confidence that can be attributed to data and the uses to which data can be put.

❖ The development of ***epistemological knowledge*** is rarely addressed in most countries, and in countries where it is addressed, labwork is not the teaching method used. There are opportunities in labwork to promote a reflection on the part of students upon links between theory and data. One approach involves addressing experimental design. Another approach involves the selection of real situations from ongoing research, addressing how the research was operationalised and the main issues addressed during the work as it proceeded.
This raises the issue of the extent to which an unique epistemology can and should be presented to students through labwork, and indeed through the science curriculum more generally. It is necessary to address at a policy level the relative placing of examples from the history of science in the curriculum, and the treatment of epistemology in students' labwork.

2 - Each labwork session should be reasonably ambitious and targeted, the strategy being a clear orientation towards certain objectives.

In fact there is frequently a mismatch between teachers' objectives and what is achieved by students. Students *'do'* what they are intended to do but they do not necessarily *'think'* or *'learn'* as they are intended to think and learn. Teaching strategies ought therefore to be adapted to address selected objectives, putting other possible objectives aside. This is what we call *'targeted'* labwork sessions.
With this choice, it becomes necessary to organise students' overall programme of labwork activities within a coherent long-term programme and this assumes that the types of labwork undertaken by

students should be varied. For example, selected part of the whole experimental process, studies of identified cases encountered in labs to teach images of science, qualitative observations, software used simultaneously with an experiment, computer simulations and projects might all be included within a sequence.
Projects are particularly useful in ensuring that students work under their own direction. If this is to happen a generous time allocation has to be given to project work, possibly several weeks. This supposes to accept to diminish a curriculum crowded by content.

3 - A major outcome of the project is recognising the importance of differentiating between the effectiveness of labwork in terms of promoting learning outcomes, and in terms of the success of labwork at engaging students in particular activities. Both types of effectiveness should be involved in labwork.

It is particularly important for students to be given the opportunity to undertake experimental approaches for themselves, to design experiments, to go through a complete sequence of data processing and to make corresponding decisions about the choice of apparatus, mathematical tools or software. Such activities during labwork cannot be directly linked to specific learning outcomes. However they are crucial for the development of students' scientific understanding in the broader sense.
Linked to effectiveness, specific assessment strategies have to be implemented. Some suggestions about the wording of questions allowing the assessment of specific objectives such as procedures or epistemological meta-knowledge, can be found in case studies from the project.

4 - A condition for improved effectiveness is a different focus for teacher education and a deep change in the focus of resources, labwork sheets and the types of guidance available to students during labwork

The critical role of teachers in ensuring that labwork is effective was emphasised.
For instance, some teachers have a role of labwork developers : they should work in collaboration to identify learning objectives, possibly consulting literature and/or the Internet. They should also abandon some possible learning objectives to promote others identified as being particularly important. They have to design lectures to be done at a level and with objectives consistent with labwork. In addition, during labwork, teachers have to ask questions to students, and require them to make observations or measurements, calculations of orders of magnitude, mathematical modelling, predictions, etc. as described previously.
The multiple tasks of teachers suggest that it requires specific input during initial and in service training.

The general objectives of promoting student ***autonomy and motivation*** have not been addressed directly in this project. However there is agreement that student autonomy is not only obtained during open ended labwork, but rather that it can be obtained during labwork organised in various different ways in which specific questions are raised in students' minds, and particular guidance is given to students.

Autonomy and motivation are expected as consequences of targeted labwork.

Working Papers
of the project
'LABWORK IN SCIENCE EDUCATION'

1998

∗ Working paper 1 ∗

A MAP FOR CHARACTERISING THE VARIETY OF LABWORK IN EUROPE

Authors : Robin Millar, Jean-François Le Maréchal and Christian Buty

Language: English .

Annex : The 'map' in one of the national languages

∗ Working papers 2 and 3 ∗

SCIENCE TEACHING AND LABWORK PRACTICE IN SEVERAL EUROPEAN COUNTRIES

Volume 1 Description of science teaching at secondary level
Authors : Andrée Tiberghien, Karine Bécu-Robinault, Christian Buty, Manuel Fernandez, Hans Fischer, John Leach, Jean-François Le Maréchal, Anastasios Molohides, Albert Chr.Paulsen, Didier Pol, Dimitris Psillos, Naoum Salame, Carlo Tarsitani, Eugenio Torracca, Laurent Veillard, Stefan v. Aufschnaiter and Jean Winther

Volume 2 Teachers' labwork practice, an analysis based on questionnaire at secondary and university levels

Authors : Andrée Tiberghien, Karine Bécu-Robinault, Christian Buty, Hans Fischer, Kerstin Haller, Dorte Hammelev, Lorenz Hucke, Petros Kariotoglou, Helge Kudahl, John Leach Jean-François Le Maréchal, Jenny Lewis, Hans Niedderer, Albert Chr.Paulsen,Dimitris Psillos, Florian Sander, Horst Schecker, Marie-Genevieve Séré, Carlo Tarsitani, Eugenio Torracca, Laurent Veillard, Stefan v. Aufschnaiter, Manuela Welzel and Jean Winther

Volume 3 Analysis of labwork sheets used in regular labwork at the upper secondary school and the first years of University

Authors : Andrée Tiberghien, Laurent Veillard, Jean-François Le Maréchal and Christian Buty

Annexes: Examples of labsheets translated into English from several European countries

Language **:** English

∗ Working paper 4 ∗

SURVEY 2 : STUDENTS' 'IMAGES OF SCIENCE' AS THEY RELATE TO LABWORK LEARNING.

Authors : John Leach, Robin Millar, Jim Ryder, Marie-Geneviève Séré, Dorte Hammelev, Hans Niedderer , and Vasilis Tselfes

Language: English

∗ Working paper 5 ∗

TEACHERS' IMAGE OF SCIENCE AND LABWORK. HYPOTHESES, RESEARCH TOOLS AND RESULTS IN ITALY AND IN FRANCE

Authors : Milena Bandiera, Francisco Dupré, Carlo Tarsitani, Eugenio Torracca, Matilde Vicentini and Marie-Geneviève Séré

Language: English

∗ Working paper 6 ∗

TEACHERS'OBJECTIVES FOR LABWORK. RESEARCH TOOL AND CROSS COUNTRY RESULTS

Authors : Manuela Welzel, Kerstin Haller, Milena Bandiera, Dorte Hammelev, Panagiotis Koumaras, Hans Niedderer, Albert Paulsen, Karine Bécu- Robinault and Stephan von Aufschnaiter

Language: English

∗ Working paper 7 ∗

CASE STUDIES OF LABWORK IN FIVE EUROPEAN COUNTRIES

Editors : Dimitris Psillos and Hans Niedderer

Language: English

∗ Working paper 8 ∗

THE MAIN RESULTS OF CASE STUDIES : ABOUT THE EFFECTIVENESS OF DIFFERENT TYPES OF LABWORK

Authors : Dimitris Psillos, Hans Niedderer and Marie-Geneviève Séré

Language: English

∗ Working paper 9 ∗

CATEGORY BASED ANALYSIS OF VIDEOTAPES FROM LABWORK : THE METHOD AND RESULTS FROM FOUR CASE-STUDIES

Authors : Hans Niedderer, Andrée Tiberghien, Christian Buty, Kerstin Haller, Lorenz Hucke, Florian Sander, Hans Fischer, Horst Schecker, Stefan von Aufschnaiter and Manuela Welzel.

Language: English

∗ Working paper 10 ∗

LES TRAVAUX PRATIQUES DANS L'ENSEIGNEMENT DES SCIENCES DE LA VIE ET DE LA TERRE DANS LES LYCÉES FRANÇAIS

Editors : Didier Pol , Naoum Salamé et Marie-Geneviève Séré

Language: French.

The part concerning the survey *Science Teaching and Labwork Practice in Several European countries,* in English

∗ Working papers in each country (France, Denmark, Germany, Great Britain, Greece, Italy)∗

THE MAIN RESULTS OF THE SURVEYS OF THE EUROPEAN PROJECT *'LABWORK IN SCIENCE EDUCATION'*

Language: the national language in each country .

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Scientific papers, communications, proceedings and theses concerning the project, can be found in the ANNEX 11 to the final report of the project.
All these publications are available at the following address : Marie-Genevieve.Sere@didasco.u-psud.fr, or at the electronic address of one of the authors, to be found via the CORDIS site of the European Commission.
http ://www.cordis.lu/

ISBN 1 912 101 - 02 -6