Interim report on the first round of the Delphi study

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Updated version

incorporating extra data

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1 Framework and procedure of the first round – participation rate

1.1 First attempt

Group	Subgroups included	Total
Students	School students and university students	53
Teachers	Teachers (primary & secondary) and trainees	74
Teacher Educators	-	21
Scientists	Scientists and science employers	25
	Total	**173**

Table 1: Structure of the sample, amount of participants for each group and participation rate after the first attempt

1.2 The questionnaire

The questionnaire contained three questions each of which had two parts. These addressed the following areas:

1.(a) **reasons** for teaching science

1.(b) **contexts** for science lessons

2.(a) preferred **topics** or 'themes' in school science

2.(b) preferred **methods** for teaching science

3.(a) **skills** that should be developed in school science

3.(b) **attitudes** that should be developed in school science

2 Qualitative analysis

2.1 Method

- Formulation of the questions
- Trials and revisions
- Distribution of the questionnaire
- Collection of responses
- Tabulation and analysis of responses

2.2 Results

There were 173 responses from four different groups. In **Table 1** the number of responses from each group is shown.

Students	53
Teachers	74
Teacher educators	21
Scientists	25
Total	**173**

Table 1: Groups and numbers of respondents

3 Quantitative analysis

3.1 Method

- Tabulation of the data
- Use of WinMAX, Excel and Word
- Frequencies and relative frequency of the categories

The data was compiled in a Word document. It was then pre-formatted in preparation for transfer to winMAX for coding of various categories. Pre-formatting ensured that the individual responses were coded by question number and respondent identifier.

The data was also examined in Excel where frequencies of keywords were identified. This process facilitated the construction of a list of codes for use in winMAX. The winMAX software facilitates the allocation of identifiers to qualitative data in order to produce quantitative statistics.

Once the categories were assigned to the responses the coded text was transferred to Excel where totals of all the responses were calculated. The total number of responses in each category, to each question by each group of respondents, was divided by the number of respondents in that group in order to find a percentage response.

3.2 Results

For ease of comparison, in all the tables in this section raw frequencies in each group of respondents have been converted into **percentages** of the number of respondents in that group.

Note: The bars in the graphs in this section are quantised and so small differences in percentages (of <2%) may not be evident. They do however clearly show differences in patterns of responses.

Question 1 concerned the aims and context of science education. It had two parts:

(a) What do you see as the **main reasons** for teaching science subjects in school?

(b) In what **contexts** do you think that science lessons should be taught to pupils in order to encourage them to take an interest in additional science-related educational activities?

Using the set of codes the responses were categorised and sorted by frequency.

From the responses to **Question 1(a)** as shown in Table 3.1, the four main reasons respondents gave for teaching science were:

1. to develop **understanding** of the physical and natural world
2. to learn the **basics** of science
3. as preparation for a **career** in science
4. to develop questioning, **enquiring** mind

Responses to Q.1a: reasons for teaching science	% of total
to understand the world; how things work; why things are as they are	43
to learn basics of science	18
preparation career in science	17
to develop an enquiring mind, curiosity; to learn to question things	16
preparation for life	12
preparation for work; economy	12
develop and interest in science	12
learn to think logically, to analyse	11
preparation for science courses in college	10
understanding	10
preparation for technological future	7
understand the working of the human body/ health	5
general knowledge	5
problem solving	4
to be able to discover new things; to be creative	3
to learn to apply their learning	3
learn to observe	3
understand the place of science in society/the significance of science	3
develop awareness of global issues	2
to develop a love of learning; lifelong learning	2
develop a sense of wonder/appreciation	2
develop or expand their knowledge	2
learn practical skills	2
learn to discuss/communicate	1.2
to learn to inquire	1.2
develop intellectually	0.6
knowledge of historical development of ideas	0.6
to pass examinations	0.6

Table 3.1: The main reasons for teaching science in school and the percentage of all 173 respondents who mentioned them.

The last five items in table 3.1 were mentioned only once or twice.

Table 3.2 shows the breakdown of the responses to Question 1a as percentages of the four groups.

Reasons for teaching science	% of total (*n*=173)	Students (*n*=53)	Teachers(*n*=74)	Teacher educators (*n*=21)	Scientists(*n*=25)
to understand the world; how things work; why things are as they are	42.8	47.2	39.2	47.6	40.0
to learn basics of science	18.5	24.5	20.3	14.3	4.0
preparation career in science	16.8	13.2	13.5	28.6	24.0
to develop an enquiring mind; to learn to question things; curiosity	15.6	5.7	25.7	19.0	4.0
preparation for life	11.6	5.7	18.9	4.8	8.0
preparation for work; economy	11.6	11.3	8.1	23.8	12.0
develop and interest in science	11.6	13.2	6.8	19.0	16.0
learn to think logically, to analyse	11.0	1.9	23.0	4.8	0.0
preparation for science courses in college	10.4	13.2	9.5	14.3	4.0
understanding	9.8	1.9	20.3	4.8	0.0
preparation for technological future	6.9	3.8	5.4	23.8	4.0
understand the working of the human body/ health	5.2	9.4	5.4	0.0	0.0
general knowledge	5.2	5.7	5.4	0.0	8.0
problem solving	4.0	0.0	8.1	0.0	4.0
to be able to discover new things; to be creative	3.5	0.0	6.8	0.0	4.0
to learn to apply their learning	2.9	1.9	5.4	0.0	0.0
learn to observe	2.9	0.0	5.4	0.0	4.0
understand the place of science in society/the significance of sci.	2.9	0.0	4.1	0.0	8.0
develop awareness of global issues	2.3	0.0	4.1	0.0	4.0
to develop a love of learning; lifelong learning	2.3	0.0	4.1	4.8	0.0
develop a sense of wonder/appreciation	2.3	1.9	1.4	9.5	0.0
develop or expand their knowledge	1.7	1.9	1.4	0.0	4.0
learn practical skills	1.7	0.0	1.4	9.5	0.0
learn to discuss/communicate	1.2	0.0	2.7	0.0	0.0
to learn to inquire	1.2	0.0	0.0	9.5	0.0
develop intellectually	0.6	0.0	1.4	0.0	0.0
knowledge of historical development of ideas	0.6	0.0	1.4	0.0	0.0
to pass examinations	0.6	1.9	0.0	0.0	0.0

Table 3.2: The reasons for teaching science in school and the percentage of each group of respondents who mentioned them.

Examples of responses to Question 1a

> "To give pupils a good **scientific view of the world** i.e. to use logic, ask questions. To find out why things are the way they are. To give pupils the basic knowledge they will need at higher level." (Respondent 8, teacher)
>
> "To produce a future **workforce** with a range of practical skill applicable in many areas, biotechnology, industry etc. Students have a greater **understanding** on

how things work and relate this to aspects in their lives." (Respondent 155, teacher educator)

Many responses were quite comprehensive. For example

> "To feed students' natural **curiosity**. To sustain young people's sense of wonder and awe that comes from exploring and **understanding** the natural and technological world. To motivate the students towards a life-long interest and appreciation in the **world around them**. To prepare the students for their **future careers**, e.g. In medicine, engineering, environmental research. To provide science-based industries and companies with a highly skilled and educated **workforce**. (Respondent 65, student)

It is interesting that the teacher educators and the scientists (*n* = 21 and 25) gave more significance to science education as a preparation for employment than the other groups did. For example:

> "Science is a major employer worldwide — important in terms of **employment**. Opens people's minds and encourages thinking outside the box." (Respondent 119, scientist)

> "To encourage young people to continue science in later life and improve **workforce** entering the technological scientific field." (Respondent 157, teacher educator)

It is also interesting to see that 'to pass examinations' was given by just one respondent (a student) as a reason for teaching (and learning) science in school. This counters the commonly held belief that students (and their parents and teachers) are mainly concerned with examination grades.

Question 1(b) concerned the **preferred contexts** in which science lessons should be taught to pupils in order to encourage them to take an interest in additional science-related educational activities. May responses are clearly similar (e.g. 'practical experiments' and 'hands-on activities') but were coded separately for the sake of completeness. From the responses shown in Table 3.2, the most frequently suggested by respondents were :

1. through **practical work** or field work
2. **real-life** contexts, relevant, everyday examples
3. **applications** of science
4. **inquiry**-based learning (IBL), investigations, discovery learning

Responses to Q.1b: contexts for teaching science	% of total
practical experiments	46
everyday life; real life situations; relevant	31
application of science	14
hands-on activities	14
enquiry based or investigative approach; discovery based	12
ICT, internet, use PowerPoint presentations, multimedia	11
develop their personal interests in science related areas, more fun	8
discussion or debate, interactive	6
Science, Technology and Society	6
demonstrations	5
activity based learning, variety	3
trips, seminars etc.	3
project work	3
variety	3
show career opportunities	2
fun	2
group work	2
science competitions (e.g. Young Scientist, SciFest)	2

Table 3.3: Contexts for teaching science in school — percentages

The following themes were mentioned once or twice:

cross-curricular approach or integrated approach, current affairs, demonstrations, local context, problem solving, theory as well as practical, continuous assessment, constructivist approach, develop curiosity, hobbies, have a plan; well planned lessons, regular tests, use visual aids, writing.

Table 3.4 shows the breakdown of the responses to Question 1b as percentages of the four groups.

Contexts for teaching science	% of total (*n*=173)	Students (*n*=53)	Teachers(*n*=74)	Teacher educators (*n*=21)	Scientists(*n*=25)
practical experiments	45.7	58.5	28.4	66.7	52.0
everyday life; real life situations; relevant	30.6	7.5	44.6	42.9	28.0
application of science	13.9	5.7	16.2	14.3	24.0
hands-on activities	13.9	13.2	17.6	9.5	8.0
enquiry based or investigative approach; discovery based	12.1	1.9	21.6	9.5	8.0
ICT, internet, use PowerPoint presentations, multimedia	11.0	9.4	10.8	23.8	4.0
develop their personal interests in science, more fun	7.5	5.7	5.4	14.3	12.0
discussion or debate, interactive	5.8	1.9	8.1	9.5	4.0
Science, Technology and Society	5.8	3.8	6.8	4.8	8.0
demonstrations	4.6	11.3	1.4	0.0	4.0
activity based learning, variety	3.5	1.9	5.4	4.8	0.0
trips, seminars etc.	2.9	3.8	2.7	0.0	4.0
project work	2.9	1.9	2.7	9.5	0.0
variety	2.9	3.8	4.1	0.0	0.0
show career opportunities	2.3	0.0	5.4	0.0	0.0
fun	2.3	3.8	1.4	0.0	4.0
group work	2.3	0.0	4.1	0.0	4.0
science competitions (e.g. Young Scientist, SciFest)	2.3	3.8	1.4	4.8	0.0

Table 3.4: Contexts for teaching science in school — percentages by group.

While there was a strong emphasis on practical work in most groups, the responses generally advocated a range of approaches and contexts. Here are some examples:

> "Practicals related to theory so pupils can 'see' what is happening. Investigative approach to science - learn from themselves and peers." (Respondent 9, teacher)
>
> "Practical activities, or any activity which requires them to figure out a solution to a problem." (Respondent 1, teacher)
>
> "Plenty of practical work. Knowing where science is applied in everyday life." (Respondent 89, student)
>
> "Relate it to everyday life. Many practicals." (Respondent 118, scientist)
>
> "In the ideal world students would do projects — IBSE to get them thinking and working as one does in the real world work environment. This pulls in the theory with the practical side." (Respondent 48, teacher)

Question 2 was divided into two parts:

(a) "Please list **scientific themes** (topics) that you think should be taught in science lessons to pupils by the end of their compulsory education."

(b) "Please list **methods** you feel useful for teaching science subjects in secondary school."

The responses to **part (a)** were quite varied. Broad areas such as biology, chemistry or physics were frequently mentioned as well as more focussed topics such as electricity and fuels. Overall percentages are given in Table 3.5.

Responses to Q.2a: themes in school science	% of total
human body, physiology, nutrition	49
general science	25
basic chemistry	24
general biology	22
general physics	17
electricity/ electronics	14
environmental issues; environmental science	14
everyday life and application of science	10
industrial chemistry	8
astronomy; space science	7
basic biochemistry; biotechnology; molecular biology	6
ecology	5
microbiology, biotechnology, genetic engineering…	5
chemistry	3
graphing	3
modern physics	3
fuels; renewable energy; energy conservation	3
practical applications	3
mathematical skills	2.3
scientific method	2.3
agriculture	1.7
geology	1.7
industrial or engineering application of science (hydraulics, electronics…)	1.7
logical thinking	1.7
medical / biomedical	1.7
wiring a plug	1.7

Table 3.5: The most frequently suggested topics for a school science course

The following topics were mentioned only once or twice:

data analysis, forensics, how buildings are constructed, laboratory instrumentation, pharmaceutical industry, scientists.

Table 3.6 shows the percentage of respondents in each group who mentioned each theme or topic.

Themes in school science	% of total (*n*=173)	Students (*n*=53)	Teachers(*n*=74)	Teacher educators (*n*=21)	Scientists(*n*=25)
human body, physiology, nutrition, health	49.1	50.9	52.7	57.1	28.0
general science	24.9	17.0	14.9	71.4	32.0
basic chemistry	24.3	22.6	35.1	9.5	8.0
general biology	22.0	32.1	24.3	4.8	8.0
general physics	17.3	11.3	27.0	9.5	8.0
electricity/ electronics	14.5	20.8	16.2	0.0	8.0
environmental issues; environmental science	13.9	7.5	18.9	19.0	8.0
everyday life and application of science	9.8	5.7	12.2	4.8	16.0
industrial chemistry	8.1	1.9	12.2	9.5	8.0
astronomy; space science	6.9	0.0	13.5	4.8	4.0
basic biochemistry; biotechnology; molecular biology	6.4	3.8	8.1	4.8	8.0
ecology	5.2	3.8	8.1	4.8	0.0
microbiology, biotechnology, genetic engineering…	4.6	1.9	9.5	0.0	0.0
chemistry	3.5	1.9	0.0	9.5	12.0
graphing	3.5	9.4	1.4	0.0	0.0
modern physics	3.5	0.0	5.4	4.8	4.0
fuels; renewable energy; energy conservation	2.9	5.7	0.0	0.0	8.0
practical applications	2.9	0.0	2.7	0.0	12.0
mathematical skills	2.3	0.0	2.7	0.0	8.0
scientific method	2.3	0.0	5.4	0.0	0.0
agriculture	1.7	3.8	1.4	0.0	0.0
geology	1.7	0.0	2.7	0.0	4.0
industrial or engineering application of science	1.7	0.0	2.7	0.0	4.0
logical thinking	1.7	1.9	2.7	0.0	0.0
medical / biomedical	1.7	0.0	2.7	4.8	0.0
wiring a plug	1.7	5.7	0.0	0.0	0.0

Table 3.6: Themes proposed for school science — percentages by group.

Although the results might not appear particularly useful from a statistical point of view they do indicate a wide range of topics that might be used as building blocks for an **'alternative' science course**.

The predominant theme was the human body (human body, physiology, nutrition, health); this was mentioned by over 50% of students, teachers and teacher educators and by a smaller percentage of scientists (28%). Some responses addressed specific areas of concern. For example:

> "Healthy living — detail of the effects of alcohol and cigarette smoking. Agriculture. How CPR (cardiopulmonary respiration) works." (Respondent 47, teacher)

Many responses were quite lengthy and listed a wide range of topics. For example:

> "Biology: human anatomy, environmental science, plants, cells, genetics, biotechnology. Chemistry: classification of substances, the chemistry of the everyday substances we need and use, atomic structure, chemical reactions, compounds, and the composition of the air we breathe. Physics: mechanics, measurement, electronics, electricity, forces, energy, light heat and sound." (Respondent 65, student)

In **Question 2(b)** respondents were asked to list useful **methods** for teaching science subjects in secondary school. The main results are summarised in Table 3.5.

The dominant suggestion here was to use a **variety of methods** involving not only textbooks but also discussion, computer-based presentations, Internet resources especially video, practical laboratory / field work and problem-solving investigations.

Proposed methods for school science teaching	% of total
practical experiments; active learning, experiments	58
ICT, virtual labs, multimedia	46
PowerPoint presentations	18
demonstrations, models	17
discussion or debate; brainstorming; interactive learning; thinking	15
group work; peer teaching; cooperative learning	14
enquiry based or investigative approach; discovery learning	13
everyday life; real world applications; concrete/relevant examples	11
field trips	10
trips, seminars etc., competitions	10
project work	8
quizzes, questionnaires, Q&A, games, crosswords	8
hands-on activities	5
interactive	5
data logging	3
variety of methods; fun	3
explanation; teacher-centred	3
higher-order thinking	3
application of science	2
activity based learning	2
summary notes	2

Table 3.7: Proposed methods for teaching science in secondary school— overall percentages

The following topics were mentioned only once or twice:

> data analysis, develop their personal interests in science related areas, guest speakers, have a plan; well planned lessons, integrated approach; cross curricular, regular tests, Science, Technology and Society, using stories, role play, drama, worksheets, workbooks, forensic science, problem solving, reading science books, report writing.

A breakdown by group of the responses to Question 2b is given in Table 3.8.

Methods mentioned in the responses	Total	Students	Teachers	Teacher educators	Scientists
practical experiments; active learning, experiments	57.8	49.1	59.5	71.4	60.0
ICT, virtual labs, multimedia	45.7	39.6	48.6	57.1	40.0
PowerPoint presentations	17.9	18.9	28.4	0.0	0.0
demonstrations, models	16.8	13.2	14.9	28.6	20.0
discussion or debate; brainstorming; interactive learning; thinking	15.0	7.5	23.0	9.5	12.0
group work; peer teaching; cooperative learning	14.5	3.8	23.0	23.8	4.0
enquiry based or investigative approach; discovery learning	13.3	3.8	24.3	4.8	8.0
everyday life; real world applications; concrete/relevant examples	11.0	1.9	13.5	14.3	20.0
field trips	9.8	7.5	8.1	19.0	12.0
trips, seminars etc., competitions	9.8	7.5	8.1	19.0	12.0
project work	8.1	5.7	12.2	4.8	4.0
quizzes, questionnaires, Q&A, games, crosswords	8.1	3.8	14.9	4.8	0.0
hands-on activities	5.2	5.7	8.1	0.0	0.0
interactive	4.6	1.9	2.7	14.3	8.0
data logging	3.5	3.8	4.1	0.0	4.0
variety of methods; fun	3.5	1.9	6.8	0.0	0.0
explanation; teacher-centred	2.9	5.7	2.7	0.0	0.0
higher-order thinking	2.9	3.8	2.7	0.0	4.0
application of science	2.3	0.0	4.1	0.0	4.0
activity based learning	1.7	1.9	1.4	4.8	0.0
summary notes	1.7	5.7	0.0	0.0	0.0

Table 3.8: Methods proposed for secondary school science — percentages by group.

It appears that the word ‘contexts’ in Question 1(b) and the word ‘methods’ in Question 2(b) were interpreted similarly by many respondents. Considering the brevity of the questions this is hardly surprising. Practical work was the predominant ‘method’ suggested by respondents (over 58%). Below are sample responses:

> “Lots of experiments. Practical work, investigations, brainstorming, discussions.” (Respondent 35, teacher)
>
> “Group work, discussions, ICT, quizzes, use of interesting handouts, experiments for everybody, VLE apps, powerpoint presentations, use of models.” (Respondent 4, teacher)
>
> “Pre-assessment using formative learning method. Discovery approach followed by new language. Hands-on experiments, much discussion and questioning.” (Respondent 109, teacher)
>
> “All available teaching tools should be focussed on developing pupil insight (mathematical modelling, laboratory experiment, demonstrations, computerised simulations and animations, applets, internet searches etc.” (Respondent 116, scientist)
>
> “A more hands-on approach e.g. More experiments. Getting students to think for themselves.” (Respondent 102, student)

"Practical work - more resources (time, technicians etc.) Essential to make the most of out of this. Coursework B of Junior Cert. Encourages enquiring minds. Time - if teachers had more time and weren't constrained by getting a syllabus covered, there would be greater opportunities for students to explore their own ideas . Use of ICT - powerpoint, clips from youtube or animations. Demonstrations." (Respondent 17, teacher)

Question 3(a) asked respondents what **skills** should be developed in science classes in order to help pupils to become educated. The overall responses are summarised in Table 3.9.

Skills mentioned in the responses	% of total
ability to enquire	30
self reliant, thinking logically, critical thinking	26
laboratory skills, instrumentation	22
practical work, experiments	16
problem solving	15
data analysis	14
independent learner, skilful, confident	11
planning, organisation, time management	9
write report, present findings, keep records	9
basic maths, drawing and interpreting graphs	8
ICT, multimedia	8
communications skills, presentation skills	6
group work, team work	6
scientific method	5
able to discuss; interactive, analytical skills	5
(oral) language skills, literacy	4
fun, variety, enjoyment, motivation	3
creativity, inventiveness, think outside the box	3
able to apply knowledge	2
curiosity	2

Table 3.9: Skills to be developed in science education

The following topics were mentioned only once or twice:

active learning, hands-on, electronics, electricity, passion for science education.

Skills mentioned in the responses	% of total (*n*=173)	Students (*n*=53)	Teachers(*n*=74)	Teacher educators (*n*=21)	Scientists(*n*=25)
ability to enquire	30.1	17.0	37.8	38.1	28.0
self reliant, thinking logically, critical thinking	26.0	17.0	25.7	33.3	40.0
laboratory skills, instrumentation	22.0	24.5	20.3	28.6	16.0
practical work, experiments	16.2	5.7	28.4	9.5	8.0
problem solving	15.0	5.7	21.6	19.0	12.0
data analysis	13.9	1.9	23.0	14.3	12.0
independent learner, skilful, confident	11.0	11.3	16.2	4.8	0.0
planning, organisation, time management	8.7	3.8	10.8	23.8	0.0
write report, present findings, keep records	8.7	5.7	8.1	23.8	4.0
basic maths, drawing and interpreting graphs	8.1	3.8	10.8	9.5	8.0
ICT, multimedia	7.5	5.7	6.8	19.0	4.0
communications skills, presentation skills	6.4	5.7	5.4	14.3	4.0
group work, team work	6.4	1.9	8.1	9.5	8.0
scientific method	5.2	1.9	6.8	9.5	4.0
able to discuss; interactive, analytical skills	4.6	3.8	6.8	0.0	4.0
(oral) language skills, literacy	4.0	1.9	2.7	9.5	8.0
fun, variety, enjoyment, motivation	2.9	1.9	1.4	4.8	8.0
creativity, inventiveness, think outside the box	2.9	0.0	2.7	9.5	4.0
able to apply knowledge	2.3	1.9	2.7	0.0	4.0
curiosity	2.3	0.0	2.7	4.8	4.0

Table 3.10: Skills to be developed in science education — percentages by group.

The responses indicate that teachers, teacher educators and scientists prioritised higher order skills (critical thinking, ability to enquire) while students saw practical skills as more important.

Below are examples of responses:

> “Ability to think logically - to plan an investigation and carry out an investigation, write a scientific report, analyse data, question data, and use scientific equipment.” (Respondent 34, teacher)
>
> “Practical skills, communication skills - oral and written. Presentation skills, computer literacy, capacity for critical analysis.” (Respondent 4, teacher)
>
> “Confident practical work. Initiative (not to be afraid of being wrong - allow student to test their theories). Understanding and ability to apply this knowledge.” (Respondent 13, teacher)

> "Critical thinking. Learning that to ask the right question provides the correct answer.. (Respondent 153, teacher educator)
>
> "Higher order thinking and decision making. Structured thinking (logic). Manual dexterity. Application of the scientific method." (Respondent 149, teacher educator)

Some such as the following were quite comprehensive:

> "Problem solving , critical thinking , logic, reasoning, scientific method and approaches, communication, language, enquiry , research , investigative, observation, and laboratory skills, (e.g. Using measurements instruments and experimental apparatus) recording skills, planning and design skills." Respondent 65, student)

Question 3 (b) asked what **attitudes** should be developed in pupils in order to help them to become scientifically educated. The responses are summarised in Table 3.11.

Attitudes mentioned in the responses	% of total
positive attitude, motivation, interest, fun	43
questioning, curious, inquisitive	35
logical thinking, reflection, open minded	17
everyday applications; how things work	9
problem solving	6
awareness of the world around them	4
work with others	4
patience	4
scientific method	3
mathematical ability	3
careful, precise	3
sense of wonder; care for environment	2
assessment, tests	2
analyse data	1
independent learner/thinker	1
use laboratory equipment/instruments	1
confidence	0.6

Table 3.11: Attitudes to be developed in science education — overall percentages

The responses to this question were generally shorter that the answers to the other questions. The attitudes most frequently mentioned were:

1. positive attitude, motivation, interest, fun
2. questioning, curious, inquisitive
3. logical thinking, reflection, open minded

Attitudes mentioned in the responses	% of total (*n*=173)	Students (*n*=53)	Teachers(*n*=74)	Teacher educators (*n*=21)	Scientists(*n*=25)
positive attitude, motivation, interest, fun	42.8	64.2	33.8	38.1	28.0
questioning, curious, inquisitive	35.3	7.5	52.7	38.1	40.0
logical thinking, reflection, open minded	17.3	15.1	17.6	28.6	12.0
everyday applications; how things work	9.2	5.7	9.5	14.3	12.0
problem solving	5.8	3.8	5.4	9.5	8.0
awareness of the world around them	4.0	0.0	6.8	0.0	8.0
work with others	4.0	1.9	2.7	9.5	8.0
patience	4.0	7.5	1.4	4.8	4.0
scientific method	2.9	0.0	2.7	9.5	4.0
mathematical ability	2.9	0.0	2.7	9.5	4.0
careful, precise	2.9	1.9	1.4	14.3	0.0
sense of wonder; care for environment	1.7	1.9	2.7	0.0	0.0
assessment, tests	1.7	5.7	0.0	0.0	0.0
analyse data	1.2	0.0	2.7	0.0	0.0
independent learner/thinker	1.2	0.0	2.7	0.0	0.0
use laboratory equipment/instruments	1.2	0.0	1.4	0.0	4.0
confidence	0.6	0.0	1.4	0.0	0.0

Table 3.11: Attitudes to be developed in science education — percentages by group.

In general the respondents recommended that teachers should try to make science more **enjoyable**, engaging and responsive to students' questions. When students see the relevance of science to everyday life they are more likely to be interested in it and to enjoy it. Successful investigations in which students progress from raising a question about something they have observed to researching, hypothesising, experimenting and drawing conclusions are very motivating for them. Investigations that are too difficult for students can lead to frustration and can foster negative attitudes to science. For this reason **careful judgement i**s required on the part of the teacher in allowing, selecting or suggesting investigations.

While making science enjoyable was seen as important by many respondents, and especially by students, the majority of responses indicated that students are likely to have positive attitudes to science when they are facilitated in understanding scientific principles, asking questions and generally becoming independent learners.

Here are some examples of responses:

> “An enthusiastic attitude helps you understand the topics better.” (Respondent 70, student)
>
> “A sense of discipline and need for precise , thorough work to achieve accurate results should be developed. Creativity, enterprise, innovation must be encouraged and nurtured. Curiosity and intrigue in how the world works. A positive attitude towards the relevance and need for the science. An appreciation of the natural world around us.” (Respondent 65, student)
>
> “Positive thinking towards science classes. Students with a sense of belonging to the scientific community, create enthusiasm.” (Respondent 6, teacher)
>
> “Positive thinking and appreciation of the world all around them. Seeing the links which make the world a wonderful place.” (Respondent 3, teacher)
>
> “Attitude to challenge rather than accept concepts / definitions etc! A positive attitude to teamwork in order to hear other pupils thoughts, view and opinions and to challenge and appreciate their various perspectives on different scientific concepts.” (Respondent 153, teacher educator)
>
> “That science is interesting and fun. That science is useful and applicable in our daily lives.” (Respondent 163, teacher educator)
>
> “Respect for the scientific method. Value of logical and critical thinking. Value for understanding material (as distinct from rote memory.” (Respondent 116, scientist)
>
> “Curiosity, self-satisfaction with discovery, appreciation of nature and the wonders of the world.” (Respondent 128, scientist)

In summary, while respondents favoured more enjoyable science lessons they also valued higher-order learning involving questioning, investigating, looking for evidence and understanding.

Appendices

Summary of responses to Question 1 a

1. Aims and context of science education.

(a) What do you see as the main reasons for teaching science subjects in school?

Reasons mentioned in the responses	% of Total	% Students	% Teachers	% Teacher Educators	% Scientists
to understand the world; how things work; why things are as they are	43	47	39	48	40
to learn basics of science	18	25	20	14	4.0
preparation career in science	17	13	14	29	24
to develop an enquiring mind; to learn to question things; develop curiosity	16	6	26	19	4.0
preparation for life	12	6	19	4.8	8.0
preparation for work; economy	12	11	8	24	12
develop and interest in science	12	13	7	19	16
learn to think logically, to analyse	11	2	23	5	0
preparation for science courses in college	10	13	9	14	4
understanding	10	2	20	5	0
preparation for technological future	7	4	5	24	4
understand the working of the human body/ health	5	9	5	0	0
general knowledge	5	6	5	0	8
problem solving	4	0	8	0	4
to be able to discover new things; to be creative	3	0	7	0	4
to learn to apply their learning	3	2	5	0	0
learn to observe	3	0	5	0	4
understand the place of science in society/the significance of science	3	0	4	0	8
develop awareness of global issues	2	0	4	0	4
to develop a love of learning; lifelong learning	2	0	4	5	0
develop a sense of wonder/appreciation	2	2	1.4	10	0
develop or expand their knowledge	2	2	1.4	0	4
learn practical skills	2	0.0	1.4	10	0
learn to discuss/communicate	1.2	0.0	2.7	0	0
to learn to inquire	1.2	0.0	0.0	10	0
develop intellectually	0.6	0.0	1.4	0	0
knowledge of historical development of ideas	0.6	0.0	1.4	0	0
to pass examinations	0.6	1.9	0.0	0	0

Summary of responses to Question 1 b

1. Aims and context of science education.

(b) In what contexts do you think that science lessons should be taught to pupils in order to encourage them to take an interest in additional science-related educational activities?

Contexts mentioned in the responses	% of Total	% Students	% Teachers	% Teacher Educators	% Scientists
practical experiments	46	58	28	67	52
everyday life; real life situations; relevant	31	8	45	43	28
application of science	14	6	16	14	24
hands-on activities	14	13	18	10	8
enquiry based or investigative approach; discovery based	12	2	22	10	8
ICT, internet, use PowerPoint presentations, multimedia	11	9	11	24	4
develop their personal interests in science related areas, more fun	8	6	5	14	12
discussion or debate, interactive	6	2	8	10	4
Science, Technology and Society	6	4	7	5	8
demonstrations	5	11	1	0	4
activity based learning, variety	3	2	5	5	0
trips, seminars etc.	3	4	3	0	4
project work	3	2	3	10	0
variety	3	4	4	0	0
show career opportunities	2	0	5	0	0
fun	2	4	1	0	4
group work	2	0	4	0	4
science competitions (e.g. Young Scientist, SciFest)	2	4	1.4	5	0
cross-curricular approach or integrated approach	1.7	0	4.1	0	0
current affairs	1.7	0	2.7	0	4
demonstrations	1.7	0	1.4	10	0
local context	1.7	0	4.1	0	0
problem solving	1.7	2	1.4	0	4
theory as well as practical	1.7	0	2.7	0	4
continuous assessment	0.6	0	1.4	0	0
constructivist approach	0.6	0	1.4	0	0
develop curiosity	0.6	0	1.4	0	0
hobbies	0.6	0	1.4	0	0
have a plan; well planned lessons	0.6	2	0.0	0	0
regular tests	0.6	2	0.0	0	0
use visual aids	0.6	2	0.0	0	0
writing - it is better remembered	0.6	2	0.0	0	0

Summary of responses to Question 2 a

2. Subject content and themes of science education

(a) Please list scientific themes (topics) that you think should be taught in science lessons to pupils by the end of their compulsory education

Themes mentioned in the responses	% of Total	% Students	% Teachers	% Teacher Educators	% Scientists
human body, physiology, nutrition	49	51	53	57	28
general science	25	17	15	71	32
basic chemistry	24	23	35	10	8
general biology	22	32	24	5	8
general physics	17	11	27	10	8
electricity/ electronics	14	21	16	0	8
environmental issues; environmental science	14	8	19	19	8
everyday life and application of science	10	6	12	5	16
industrial chemistry	8	2	12	10	8
astronomy; space science	7	0	14	5	4
basic biochemistry; biotechnology; molecular biology	6	4	8	5	8
ecology	5	4	8	5	0
microbiology, biotechnology, genetic engineering...	5	2	9	0	0
chemistry	3	2	0	10	12
graphing	3	9	1	0	0
modern physics	3	0	5	5	4
fuels; renewable energy; energy conservation	3	6	0	0	8
practical applications	3	0	3	0	12
mathematical skills	2.3	0	3	0	8
scientific method	2.3	0	5	0	0
agriculture	1.7	4	1	0	0
geology	1.7	0	3	0	4
industrial or engineering application of science (hydraulics, electronics...)	1.7	0	3	0	4
logical thinking	1.7	2	3	0	0
medical / biomedical	1.7	0	3	5	0
wiring a plug	1.7	6	0	0	0
data analysis	1.2	0	3	0	0
forensics	1.2	0	3	0	0
how buildings are constructed	0.6	2	0	0	0
laboratory instrumentation	0.6	0	1	0	0
pharmaceutical industry	0.6	0	1	0	0
scientists	0.6	2	0	0	0

Summary of responses to Question 2 b

2. Subject content and themes of science education

(b) Please list methods you feel are useful for teaching science subjects in secondary school?

Methods mentioned in the responses	% of Total	% Students	% Teachers	% Teacher Educators	% Scientists
practical experiments; active learning, experiments	58	49	59	71	60
ICT, virtual labs, multimedia	46	40	49	57	40
PowerPoint presentations	18	19	28	0	0
demonstrations, models	17	13	15	29	20
discussion or debate; brainstorming; interactive learning; thinking	15	8	23	10	12
group work; peer teaching; cooperative learning	14	4	23	24	4
enquiry based or investigative approach; discovery learning	13	4	24	5	8
everyday life; real world applications; concrete or relevant examples	11	2	14	14	20
field trips	10	8	8	19	12
trips, seminars etc., competitions	10	8	8	19	12
project work	8	6	12	5	4
quizzes, questionnaires, Q&A, games, crosswords	8	4	15	5	0
hands-on activities	5	6	8	0	0
interactive	5	2	3	14	8
data logging	3	4	4	0	4
variety of methods; fun	3	2	7	0	0
explanation; teacher-centred	3	6	3	0	0
higher-order thinking	3	4	3	0	4
application of science	2	0	4	0	4
activity based learning	2	2	1	5	0
summary notes	2	6	0	0	0
data analysis	1.2	0	1	0	4
develop their personal interests in science related areas	1.2	2	0	5	0
guest speakers	1.2	0	3	0	0
have a plan; well planned lessons	1.2	2	1	0	0
integrated approach; cross curricular	1.2	2	0	5	0
regular tests	1.2	2	1	0	0
Science, Technology and Society	1.2	2	1	0	0
using stories, role play, drama	1.2	0	3	0	0
worksheets, workbooks	1.2	4	0	0	0
forensic science	0.6	0	1	0	0
problem solving	0.6	0	1	0	0
reading science books	0.6	2	0	0	0
report writing	0.6	0	1	0	0

Summary of responses to Question 3 a

3. Skills and attitudes.

(a) What skills do you think should be developed in science classes in order to help pupils to become educated?

Skills mentioned in the responses	% of Total	% Students	% Teachers	% Teacher Educators	% Scientists
ability to enquire	30	17	38	38	28
self reliant, thinking logically, critical thinking	26	17	26	33	40
laboratory skills, instrumentation	22	25	20	29	16
practical work, experiments	16	6	28	10	8
problem solving	15	6	22	19	12
data analysis	14	2	23	14	12
independent learner, skilful, confident	11	11	16	5	0
planning, organisation, time management	9	4	11	24	0
write report, present findings, keep records	9	6	8	24	4
basic maths, drawing and interpreting graphs	8	4	11	10	8
ICT, multimedia	8	6	7	19	4
communications skills, presentation skills	6	6	5	14	4
group work, team work	6	2	8	10	8
scientific method	5	2	7	10	4
able to discuss; interactive, analytical skills	5	4	7	0	4
(oral) language skills, literacy	4	2	3	10	8
fun, variety, enjoyment, motivation	3	2	1	5	8
creativity, inventiveness, think outside the box	3	0	3	10	4
able to apply knowledge	2	2	3	0	4
curiosity	2	0	3	5	4
active learning	1	2	1	0	0
hands-on	1	0	3	0	0
electronics, electricity	0.6	0	1	0	0
passion for sc ed	0.6	2	0	0	0

Summary of responses to Question 3 b

3. Skills and attitudes.

(b) What attitudes do you think should be developed in pupils in order to help them to become scientifically educated?

Attitudes mentioned in the responses	% of Total	% Students	% Teachers	% Educators	% Scientists
interest, fun, motivation, positive attitude	43	64	34	38	28
curious, inquisitive, questioning	35	8	53	38	40
logical thinking, reflection, open minded	17	15	18	29	12
everyday applications; how things work	9	6	9	14	12
problem solving	6	4	5	10	8
awareness of the world around them	4	0	7	0	8
work with others	4	2	3	10	8
patience	4	8	1	5	4
scientific method	3	0	3	10	4
mathematical ability	3	0	3	10	4
careful, precise	3	2	1	14	0
sense of wonder; care for environment	2	2	3	0	0
assessment, tests	2	6	0	0	0
analyse data	1	0	3	0	0
independent learner/thinker	1	0	3	0	0
use laboratory equipment/instruments	1	0	1	0	4
confidence	0.6	0	1	0	0