Junior College Utrecht: Challenging talented secondary school students to study science

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At JCU science and mathematics are taught to talented upper secondary school students in an academic research environment, while it also provides a laboratory for innovation in school science

In many countries special programmes for talented science students have run for decades, including masterclasses (Adamczyk and Willson, 2004), enrichment projects (Taber and Riga, 2006) and special science high schools (e.g. Ngoi and Vondracek, 2004). In the Netherlands such programmes are very recent and so far only one specialised science-enriched secondary school has been established, the Junior College Utrecht (JCU). The JCU has an approach that is unique in several respects. In this article, the institutional, educational, curriculum and outreach aspects of this approach are explained and experiences during its first two years are evaluated.

In 2003, Utrecht University decided to start a project for motivated and gifted secondary students with a science and technology orientation. The idea was based on the belief that current curricula and teaching conditions do not provide sufficient challenges to students with above average ability and interest in science and mathematics. These students are often bored by regular classes and their talents are not challenged by the lessons, which may result in underachievement (Peterson and Colangelo, 1996). They may lose interest in further studies in science and technology or develop study habits that do not fit with the requirements of higher education in this field. Schools feel that they are not able to meet the needs of these students because of current curriculum requirements and the lack of time and opportunities for teachers to offer challenging individual alternatives to bright students.

ABSTRACT

The Junior College Utrecht (JCU), an initiative of Utrecht University and 26 secondary schools, was established in 2004. It has a dual purpose: to offer a challenging science education to talented 17–18 year-old (grades 11 and 12) students in an academic environment; to create a laboratory for innovation in science curricula and teaching/learning. Talented and science-motivated students are selected first by the partner schools and then through intake interviews. For two years they follow the JCU curriculum for mathematics, physics, chemistry and biology for two days a week at the university campus while taking other subjects at their respective schools during the remaining three days. This article describes the unique approach of the JCU and reflects on experiences during its first two years.

The JCU project is intended to benefit both students and the schools they come from. Therefore the project has a dual purpose:

- To offer a challenging science education to talented students from partner schools (grades 11 and 12, ages 17–18) in an academic research environment.
- To create a laboratory for innovation in the science curricula and science teaching of the JCU partner schools.

The university started negotiations with schools in the region to set up a gifted and talented (GAT) education programme involving cooperation between the university and the schools. As a maximum of 50 per cent of the Dutch upper secondary education consists of science subjects, it was agreed that participating students would be at the JCU for two

days a week, the remaining days being reserved for non-science subjects and JCU assignments. The JCU started in August 2004.

Junior College Utrecht

The JCU is a partnership between Utrecht University and 26 partner schools. This cooperation is a specific elaboration of one of the school innovation strategies that Watter and Dietzmann (2003) termed '*cluster groups – cooperation between schools in a region to provide a central facility and specialism*'. Its administrative board consists of representatives from the university and from the partner schools. The partner schools provide students, teachers and a part of the funding. The university provides staff, teachers, housing, laboratory facilities and funding. The JCU also receives indirect funding from the Dutch Ministry of Education through a scheme for national science curriculum reform. The institutional flow chart is depicted in Figure 1. Below we give some details about the students, the teachers, the staff and facilities and the funding.

The students

The first JCU cohort of 23 students was admitted in 2004 and completed their examinations in 2006 (the 2006 cohort). The 2007 cohort and the recently started 2008 cohort each consist of about 50 students from 26 partner schools. The selection procedure starts with the 'JCU Open Day' organised in April for interested grade 10 (age 15–16 (UK year 11) students and their parents. Here the prospective students can obtain a fairly comprehensive impression of what attending JCU involves. Students who want to apply can indicate their interest to their own school. In this respect there is also self-selection, both in terms of ability and motivation. Each partner school is allowed to nominate up to four candidates. As JCU students will miss the non-science lessons that are scheduled on JCU days, the schools only recommend students who are good in all subjects and not just in science. Typically about 75 nominations are received for 50 places.

A selection committee conducts interviews with all candidates to judge breadth of giftedness, personal skills (e.g. cooperation skills, autonomy, self-discipline) and motivation (applicants are requested to write a motivation letter). Typical questions asked during the interview are: '*What would the JCU mean for you?*' and '*What can you contribute to the JCU?*' A final selection is made based on marks, a ranking of the aspects just mentioned, and the desire to form a varied group in terms of student interests, gender balance, ethnicity and representation from different partner schools.

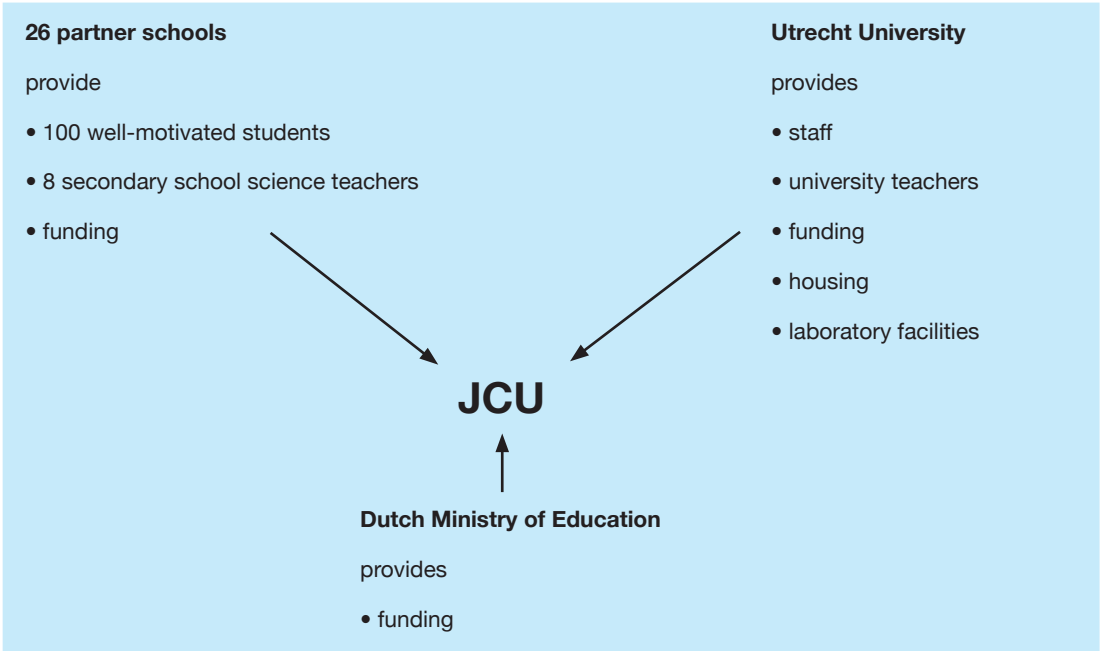

Figure 1 The institutional embedding of JCU.

Staffing

JCU employs teachers from partner schools to teach the secondary school science. The teachers selected all have a solid background in their own subject (MSc minimum), a continuing interest in research and education in their discipline, and a high level of dedication.

The (senior) university lecturers involved are not employed by JCU, but work in the Faculty of Science, Geology or Medicine. They offer a small part of their time (10 to 50 hours on a year) for teaching JCU students. They are recommended on the basis of their teaching skills, interest in younger students and their subject specialisation.

The principal of the JCU comes from the university administration and arrived with a wide network of university contacts. The Utrecht Centre for Science and Mathematics Education supplied a curriculum coordinator who organises the science curriculum, university involvement in the curriculum and outreach to partner schools.

Finance

The recurrent budget is made up as follows. The partner schools pay a contribution for membership of the network and a per-student contribution. This covers the salaries of the secondary school teachers involved in the JCU. The Board of the university provides classrooms and laboratory facilities and it funds the principal, the curriculum coordinator and secretarial support. The costs of laboratories, laboratory personnel and lecturers' time are absorbed mainly by the budgets of the Faculty of Science.

JCU curriculum development is supported by additional project funding from the Ministry of Education to give the JCU teachers extra time to develop innovative teaching materials and to develop enrichment modules for the JCU in cooperation with university staff.

The JCU curriculum

JCU students have to fulfil the requirements of the regular Dutch pre-university stream curriculum (Dutch acronym VWO), which is typically taken by the top 20 per cent of the population of 16–18 year-olds. VWO has four streams, two of which are science streams. At the JCU we have opted to combine the two science streams. Therefore, JCU provides the full science and mathematics curricula for grades 11 and 12 (comparable to years 12 and 13 in the UK). In contrast to UK A-level students, the Dutch VWO students are also examined in subjects (including the Dutch and English languages) that are common to all VWO streams. For further information about the Dutch school system see the Internet link at the end of this article.

The JCU students spend two days a week at the university campus to take the science/maths component of the secondary curriculum plus enrichment and they spend three days a week at their own secondary school to take their non-science courses (Table 1). Biology and chemistry are scheduled on Monday and physics and mathematics on Tuesday. Now and then the normal timetable is changed for interdisciplinary projects or investigations. In the final year the regular timetable is changed for teaching modules that go beyond the secondary curriculum. As timetables in the partner schools cannot be adapted to the few students that go to JCU, this schedule implies that the students miss the Monday and Tuesday lessons for non-science subjects. They are expected to make up for this in their own time (selection criterion).

The JCU curriculum has four characteristics that make it different from science curricula in regular secondary schools. These are summarised in Table 2 and described below.

Table 1 The JCU weekly timetable

Students follow lessons	*at JCU*		*at their regular schools*		
	Monday	*Tuesday*	*Wednesday*	*Thursday*	*Friday*
about	biology chemistry	physics mathematics	non-science subjects		
taught by	secondary teachers and university lecturers		regular teachers in the partner schools		

Table 2 The four main JCU curriculum characteristics.

JCU curriculum characteristics

Accelerated	*Comprehensive*	*Curricular coherence*	*Enriched*
• Syllabus topics taught in 60% of regular time • Students find out details themselves	More profound understanding by • lab work in University labs • excursions e.g. to CERN	Coherence between the science subjects by • doing investigations • modelling • project work, e.g. GPS	Academic topics by • guest lectures • modules e.g. – HIV/AIDS – nanoscience – molecular biology
Topics from syllabuses		***Topics beyond syllabuses***	

Accelerated pace

Teaching the topics from the national VWO syllabuses for biology, physics, chemistry and mathematics is completed in about 70 per cent of the time needed by regular schools. Thus, about five months are available to study a range of extra topics and to carry out some research projects. We have learnt through experience that we must avoid becoming a high-pressured 'prep' school that only differs from regular schools in its fast pace. We adopted the 'compacting and enriching model' of Reis and Renzulli (1992) with enrichment right from the start rather than postponed to the second year.

Comprehensive

In spite of the accelerated pace, the curriculum is taught in a more comprehensive and profound way than at regular Dutch schools, because of the academic environment at the JCU. Much of the lesson time is spent doing lab work in university laboratory facilities. Moreover, excursions take place to university research groups as well as to other research institutes such as CERN in Geneva (Figure 2).

Regular VWO students have to carry out a research project of 80 hours in their schools. In grade 12, the JCU students do an extended project

Figure 2 JCU's first batch of students in front of the old CERN bubble chamber. The CERN visit was the climax of their first year.

Moving in three dimensions

A topic for JCU pre-thesis offered by: Research group 'Physics of Human Perception'

'We have recently acquired apparatus that can measure the movements of a person in three dimensions very precisely and with high time resolution. Research questions could be: How accurately can somebody move his finger along a virtual straight line? How is this done when the hand is visible or when the eyes are closed? Does it work better in two dimensions on a table top than in free space? And are there differences between moving vertically and horizontally? Other issues suggested by the students themselves can also be investigated.'

of 120 hours, called the 'JCU thesis'. In grade 11 the thesis is prepared by doing a 'pre-thesis' of 60 hours. Unlike at regular schools, these projects are done in a university research environment. University researchers from the Faculties of Science, Geology and Medicine are asked to give suggestions for topics for the (pre-)thesis. In the past two years, many attractive investigations have been proposed, such as that in the panel below. In teams of three, the students choose one of the projects. The projects are supervised by (senior) researchers from Utrecht University.

For the thesis project, the students have more freedom to define their research aims and methods of investigation than in the pre-thesis. They also can choose their own topic, provided that it connects to some Utrecht University research group. Table 3 gives some examples of 2006 JCU thesis titles and Figure 3 shows two students at work on their project.

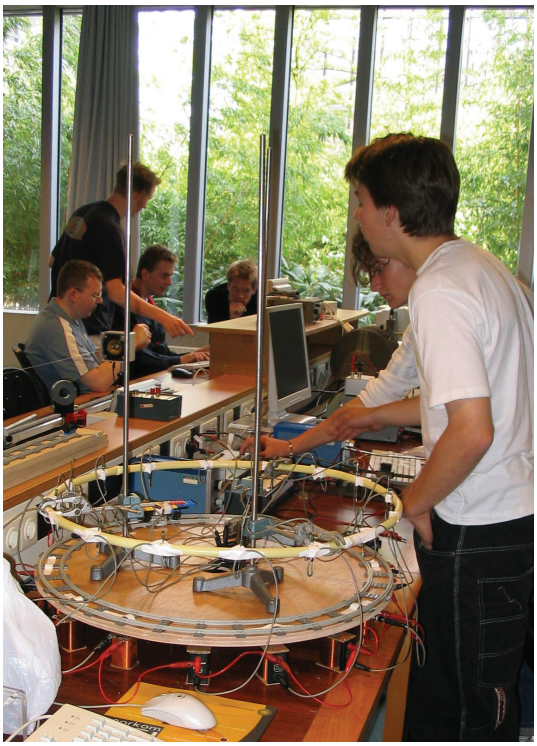

Figure 3 In their first research project Mark and Karel designed a magnetically propelled train with controllable speed. Through successive stages the design became simpler and yet more powerful in terms of control.

Focus on coherence of sciences

All JCU-students study the full science and mathematics curricula. Dropping biology or a part of physics is not an option, although it is possible in the regular system. The JCU has the option to offer interdisciplinary topics. For example, a project on

Table 3 Some titles of 2006 JCU theses. Full reports (in Dutch) can be found on www.jcu.uu.nl

Title of JCU thesis	*Domain*
The North Sea as a cesspool	Chemistry/biology
El Niño, the problem child	Meteorology/oceanography
Reflection as a means for perfection	Physics/solar cell technology
In the future travel by boat rather than by train!	Engineering/transportation technology

Table 4 Some topics in the enriched part of the curriculum.

Titles of some interdisciplinary projects (11th grade)	*Titles of JCU university modules (12th grade)*
Molecular biology (biology and chemistry)	Modellng
Equilibria (chemistry and mathematics)	Astrophysics
Human perception (physics and biology)	HIV/AIDS
Global Positoning System (physics and mathematics)	Nanoscience

Global Positioning Systems (GPS) is taught jointly through physics and mathematics. And biophysical topics are studied in a project involving physics and biology. Many enrichment modules also have an interdisciplinary character (Table 4).

Enrichment programme

We have spent much effort finding out how to introduce intellectual enrichment in a broad sense (a synthesis of wisdom, intelligence, creativity **<OK?>**; Sternberg, 2003). In the grade 11 classes, teaching topics beyond the syllabuses can take the form of a seminar or a lecture (e.g. about relativity) or of an excursion to a university lab (e.g. the Utrecht Van de Graaff accelerator). In the grade 12 classes, university specialists teach modules that elaborate issues related to current research.

The dissemination model

One of the main aims of the JCU is to be a laboratory for innovation in science curricula and science teaching and learning. This fits in with the science and mathematics reforms that are taking place in Dutch secondary education. A main objective of the reform is to update the curriculum content to take account of recent trends in scientific research and to narrow the gap between secondary and university education. For example, a new integrated science subject is to be introduced into senior secondary education: 'Advanced Science, Mathematics and Technology'. At the JCU, new modules that fit into the reform plans are developed and tried out. New curriculum materials and teaching methods will be disseminated to partner schools and to other secondary schools. By disseminating, the JCU hopes to generate a new enthusiasm in the science and mathematics departments in secondary schools. For this, a dissemination model has been developed consisting of three phases (Figure 4). **<Figure 4>**

In the first phase, university and secondary teachers develop new lesson series that are taught at the JCU. Experiences are evaluated. The 'university modules' are examples of these. In the second phase, the lesson series are revised, adapted to the regular VWO-students and school circumstances. Then, they are made available to partner schools. They test (parts of) the material in their classes and evaluation studies are carried out. In the third phase, a final revision will be carried out and then the lesson materials will be made available to all secondary schools.

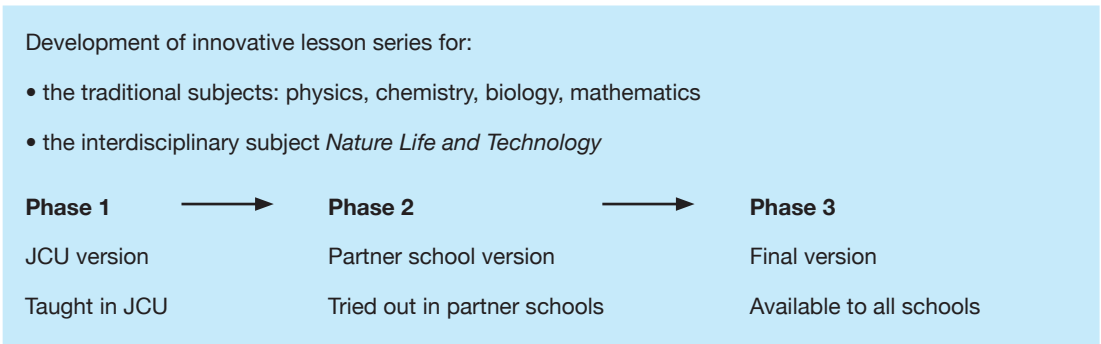

Figure 4 The JCU dissemination model.

Reflection on two years of JCU implementation

The first cohort of students turned out to be able students with many interests, talents, and hobbies. In the national TV broadcast at the opening of the JCU in 2004, students talked confidently about how they hoped that learning at the JCU would be different, go much deeper into the subject matter and allow them to pursue their own interests and research. At the time, their statements were only based on trial lessons during the Open Day. The advertising had clearly worked, but would the execution of the programme live up to that?

Secondary education in a research environment

A considerable amount of lesson time is spent on learning in a research environment: laboratory work, projects, and excursions. Of course the laboratory should emphasise real research rather than cookbook exercises. However, research on laboratory teaching (Hodson, 1993; Hofstein and Lunetta, 2004) has raised many questions about the efficiency and outcomes of laboratory teaching methods. Evaluations at various times during the first two years of the programme have shown consistently that JCU students value their learning experience in the labs very highly in all subjects and that they derive a lot of confidence from it.

JCU students' progress

All 23 first cohort students passed the national examination with medium to high marks. Now, 19 students are at university; the other four took a gap year, e.g. by studying Spanish in Spain. Eighteen students enrolled in a science or science-related study; one opted for economics. Eight opted for Utrecht University, while 11 went to another university including six who opted for engineering, which is not offered at Utrecht University. All 48 second cohort students have passed their grade 11 exams.

Evaluation data

The JCU experiences of students, teachers and partner schools have been evaluated. All groups were very positive about the JCU and its curriculum, although many suggestions for further improvements were given.

The students enjoy the open and stimulating atmosphere in the JCU. The accelerated and enriched JCU curriculum has appeared to be feasible for them. The students report that they have become more interested in the sciences, in particular because of challenging open assignments and investigations.

A student's reflection on her first-year experiences in the JCU

'Right now, the nicest things to look back on are the normal sorts of things that didn't go quite as you expected them to. Like how I finally understood all about DNA after we had been working on DNA as a topic and isolating our own DNA. And I'd had no idea what I was doing all day. So in some way the practical helped me to understand what I couldn't understand before. It didn't actually matter how it was explained to me; it was only after the practical that I really understood what was going on.'

The secondary school JCU teachers find teaching in the JCU quite challenging. They have found that implementing the JCU curriculum is feasible; however, it is complicated because of, for example, the complex organisation involved (e.g. using university facilities in different buildings) and cooperation with university staff. They have been inspired to change their teaching in their own schools and to inform their school colleagues about their experiences. They have also presented their experiences at conferences for secondary school teachers.

The JCU partner schools have various motives for participating in the JCU, ranging from giving their students more opportunities for learning to promoting curriculum innovations in the school and being in closer contact with university research. When the participation in JCU started, the science teachers at partner schools had mixed feelings because they would lose the better students in their classes. Having heard about their experiences in the JCU, they realised that they could never offer them what JCU does. Moreover, they see some competition among their fourth-form classes as students strive to be selected for the JCU. So the support of the JCU in the partner schools has been growing, with science teachers taking part in the curriculum innovation activities.

At the time of writing (early spring 2007), new schools are applying for partnership in the JCU. We have to consider how we are going to cope with that.

Challenges

Students who are used to being the best in their class are in for a slight shock when they are grouped with equals. On the one hand they are no longer the best;

on the other hand, they are challenged by meeting peers who are equally interested in and motivated by science. Furthermore, the fast pace and intensive school days create tension. For most students this tension is quite productive but some need frequent reassurance during the first half-year.

Surprisingly, being out of their school for two days a week is not a problem socially. Students report that they can maintain their old friendships at school as well as work on new friendships at the Junior College. JCU students have proved to be able to cope with the timetable problems in their regular schools very well. They can miss 30 per cent or even 50 per cent of a non-science subject, as they are the better students and do not need all lessons. Moreover, the pace and pressure at JCU is so high that students find the non-science lessons at their own school easy. Logistically, students meet problems in their home schools, for example with tests for non-science subjects scheduled on JCU days, or with excursions. Communication often goes wrong, for example assignments or test dates announced during a missed lesson are not properly transmitted. To help overcome this, each partner school has assigned a mentor for the JCU students who assists with straightening out these kinds of problems.

The typical drop-out rate in the first two years of operation was about 10 per cent and in such cases students were reabsorbed into their school of origin. Withdrawals have been due to a student being selected for a national sports team, to the high demands and to inability to adapt old working habits. So attention is now paid to adopting a proper study attitude and this year the drop-out rate was reduced to 5 per cent.

Apart from being much more demanding academically and in terms of homework, most students also have to travel further to the JCU. Travel times are usually at least half an hour longer each way than to their regular school.

JCU was originally set up as a project for three years. However, because of the positive evaluation by students, partner schools and Utrecht University, it has recently been decided that JCU will continue on a permanent basis. Contribution to the science curriculum reforms will be a main focus of the activities. JCU should not become a static institution, but be a dynamic enterprise of teachers, students, universities and schools.

Conclusions and discussion

The JCU programme has been very successful in a number of ways. It has provided unique learning conditions and outcomes for the students involved. These students no longer complain about being bored or a lack of challenges. They sometimes complain about having to work hard but they also experience the benefit of their additional efforts. For the students' home schools, the challenge was to organise the teaching of the non-science subjects in three days. For the university it has been a challenge to develop innovative curriculum materials and teaching methods. The costs for the university are substantial and could probably only be absorbed by a university with a large Faculty of Science.

JCU now has 100 students. It will stay at this number of students, although more schools apply for membership. Ways have to be developed to challenge the gifted and talented students at their regular schools. Therefore, the real challenge lying ahead is the transfer of knowledge and experiences to teachers in secondary schools. For this, JCU adapts enrichment teaching materials for use in partner schools. From 2007 onwards a new curriculum is to be introduced that will provide teachers with more freedom to teach additional topics to senior secondary students. Moreover, the new integrated science subject 'Advanced Science, Mathematics and Technology' will be introduced in addition to the regular subjects of mathematics, physics, biology and chemistry. This interdisciplinary science course offers the opportunity to deal with new developments in science and technology in an advanced way, in close cooperation with higher education. Hopefully JCU will prove to be an excellent laboratory to experiment with new curriculum materials and teaching methods.

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Websites

Junior College Utrecht (in Dutch): www.jcu.uu.nl

University College Utrecht: www.ucu.uu.nl

Information about the Dutch school system: http://www.minocw.nl/documenten/eurydice_en.pdf

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