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Designing a problem-oriented multi-disciplinary curriculum: integrating human sciences and exact sciences

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Abstract

This paper discusses the design of a curriculum with main focus on human-oriented scientific knowledge and how this can be exploited to develop support for humans by means of advanced devices in the daily environment. The aim was to offer a study path for those students with exact talents with an interest mainly in human functioning and society. The curriculum was designed from a problem-oriented perspective in relation to societal problem areas. From human-oriented disciplines scientific knowledge for human functioning in such problem areas was obtained. Computational modelling for such human processes plays a central role. Elements from Ambient Intelligence, Artificial Intelligence, and Informatics are included for design of support systems.

Keywords: curriculum design, problem-oriented, multidisciplinary, human sciences, exact sciences

1. Introduction

A challenging issue in academic education is how to interest candidate students for further development of their talents in exact sciences. The numbers of students choosing for an exact study are usually very small compared to the numbers welcomed for studies, for example, in Medicine, Psychology or Social Sciences, and this holds even stronger for female students in particular. Among this large group of students a substantial subgroup concerns students whose talents are not in the first place in exact, more formal and technical subjects. However, also a substantial subgroup exists consisting of students with good talents for more exact scientific work, but whose interest is simply not there but on human processes and society. In the current situation, individuals from the latter subgroup do not further develop their talents, which is a pity both for themselves and for society in general. Actions in the past to make more advertising for exact sciences have not brought much change in this situation. The curriculum design presented in this paper took as a point of departure the hypothesis that available curricula in exact sciences are not satisfactory for students with main interest in humans and society. Therefore the question was addressed how an academic curriculum can be designed which is attractive for students with exact talents but with intrinsic interests focused on humans and their functioning in society.

The aim was to develop a 5-year Bachelor (3 years) and Master (2 years) curriculum in which a main focus is on human-directed scientific knowledge (from biomedical, psychological and social sciences, indicated here as human sciences) and how – using elements from exact sciences - this can be exploited to develop scientifically justified support for humans who need this by means of advanced devices (such as smartphones) in the daily environment. The idea was that this will provide a study path which is attractive for those students with an interest in human functioning and society who also have exact talents, and female students in particular.

The curriculum was meant to provide a new, broad multidisciplinary study focussing on human functioning in physical, mental and social respects. Human wellbeing and functioning depends on many factors in their environment. This environment can contribute positive effects (e.g., a working place avoiding RSI, a nice living room), but it can also negative effects (e.g., too high work demands, disturbances during sleep). Insight in interaction between humans and their environment makes it possible to stimulate the positive aspects and limit the

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negative aspects. In this curriculum insights in human functioning are acquired. Moreover it is learnt how these insights can be applied to various practical problems. In this curriculum it is learnt how such problems can be analysed and how solutions can be designed making use of supporting devices so that a more understanding environment is created. This may concern, for example, microphones that can determine whether there is fear or aggression, a wrist belt for elderly that can notice when something may go wrong, or a car that can notice that a driver is drunk or may fall asleep. After this study students may be employed by R&D departments of companies that develop such modern technological devices, and focus on knowledge and models applied in such devices.

The choice was made to design the curriculum from a problem-oriented perspective. Examples of societal problem areas chosen include supporting patients with chronical diseases (e.g., diabetes) or mental problems (e.g., mood disorders), care for elderly persons in their living environment, support for persons in demanding circumstances (e.g., sporters, air traffic controllers). Subjects in human-directed disciplines were identified that provide scientific knowledge for human functioning in such areas, offered by other faculties in biomedical, psychological and social sciences. To create a bridge from these informal, nontechnical bodies of knowledge to the exact domain, specific subjects were developed on computational modelling for such human processes, thereby using formal, computational modelling techniques from Computational Science, Artifical Intelligence and Informatics. Moreover, from the area of Ambient Intelligence, Artificial Intelligence, and Informatics subjects were developed that show how to integrate computational models based on scientific knowledge of human processes with sensoring systems and intervention methods to obtain support in a knowledgeable, human-aware manner, for example through a smartphone.

In a few years time along these lines a problem-oriented multidisciplinary curriculum was successfully developed integrating human sciences with exact sciences, which seems to be unique. For practical reasons the new curriculum was developed as a replacement of an existing curriculum in Artifical Intelligence. The results this far are that the newly developed curriculum has attracted up to this date substantially more (up to a factor 2) students than the original Artificial Intelligence curriculum. Moreover, within a large number of high schools it was investigated how many students (of the prefinal year) would be interested in choosing for such a curriculum in the future. The outcome of this was that 66% had some or much interest to choose for such a curriculum (boys 60%, girls 75%). It was shown to attract much more interests of students than the more traditional curriculum it was replacing.

In this paper, first in Section 2 the overall structure of the designed curriculum is described. In subsequent Sections 3 to 5 the four main streams in the curriculum are discussed in some more detail. Section 6 addresses evaluation and discussion.

2. Overall structure of the curriculum

The aim to design a problem-oriented, multidisciplinary curriculum does not entails only that ingredients from different disciplines are to be incorporated and different social problem areas, but also that these ingredients have to be integrated in a certain way and make them contribute to these societal problem areas. It will be clear that it does not suffice to just include different subjects from a number of disciplines in the curriculum with the idea that students wil integrate and use these subjects by themselves in application areas at hand. To obtain an effective curriculum is a quite challenging aim, and requires much attention on integration, analysis and application with respect to the problem areas.

The four main streams and their main interactions are depicted in Figure 1. The following gives an impression of their approximate relative size in the design of the curriculum: Human Sciences stream (30-35%), Exact Sciences stream (25%), Computational Modelling stream (20-25%), and Integration and Projects stream (20%).

The *Human Sciences* stream and the *Exactc Sciences* stream cover relevant topics from biomedical, psychological sciences, and from ambient intelligence, artifical intelligence, and informatics, respectively. As integration is a crucial element in all this, and the different scientific disciplines used as ingredients are far apart, first of all a stream on *Computational Modelling* was included focussing on integration of human sciences and exact sciences. This stream serves as a strong integration factor as it is here that students learn to take (informally described) topics from *Human Sciences* stream on the one hand and methods and techniques from *Exact Sciences* stream on the other hand and glue them together in a formalised computational (domain) model that is suitable for formal analysis by simulation and by mathematical analysis. Moreover, within the on *Integration and Projects* stream it is learnt how such domain models can be built in in software systems in order to make them human-aware so that they can provide support in a knowledgeable manner. In this *Integration and Projects* involve themselves with analysis of questions and problems in societal application areas and integrate the other ingredients of the curriculum to design and implement solutions. These streams and their interactions are discussed in more detail in subsequent sections.

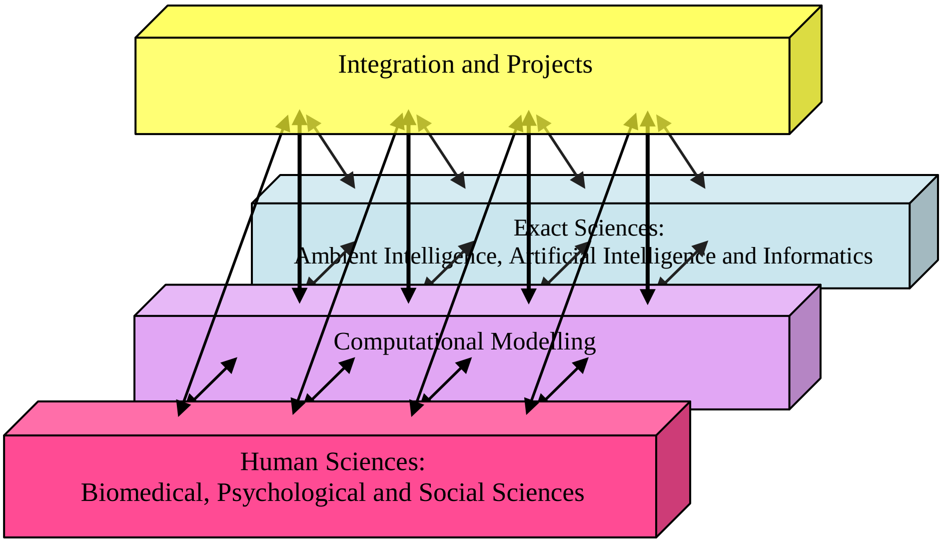

Figure 1. The four main streams in the curriculum and their main interactions

3. Computational modelling stream

Within the designed curriculum the computational modelling stream plays a crucial role in integrating the ingredients from the exact and human sciences. As the curriculum is problem-oriented, specific societal problem areas are a point of departure, as discussed above. These are not just any areas, but are chosen from a specific scope or view, that indicates what is in common for them. As discussed above this demarcation relates to the possibility to provide support to humans by using devices in the humans' environment with scientific knowledge from human sciences built in so that they have a justified understanding of the human processes considered. At the modelling level this view can be translated into a generic, unified type of overall system model, which in (Treur, 2008) was called a *reflective coupled human-environment system*. First a brief sketch is given of this overall modelling perspective. Many applications of support systems in general can be viewed as coupled human-environment systems, where 'coupled' means mutually interacting. For the specific type of systems considered here, however, the coupling also occurs in a reflective form; see also Figure 2.

- On the one hand the coupling takes place as *interaction* between human and environment:
  - the environment gets as input information generated by the human, and
  - the human gets as input information generated by the environment.
- On the other hand coupling at a *reflective level* takes place due to the fact that
  - In specific computational devices the environment has and maintains knowledge about the functioning of the human, the environment and their interaction, and
  - the human has and maintains knowledge about functioning of him or herself, the environment, and their interaction

So, in such a given reflective coupled human-environment system, being coupled does not only concern that the human and its environment interact, but also that they have knowledge, understanding and awareness of each other, themselves and their interaction. This concerns two types of awareness:

- *Human awareness*: awareness *by the human* about the human and environmental processes and their interaction
- *Technological awareness*: awareness *by the environment* about the human and environmental processes and their interaction

By (human and technological) learning, adaptation and development processes for both the human and the environment these types of awareness can also grow over time.

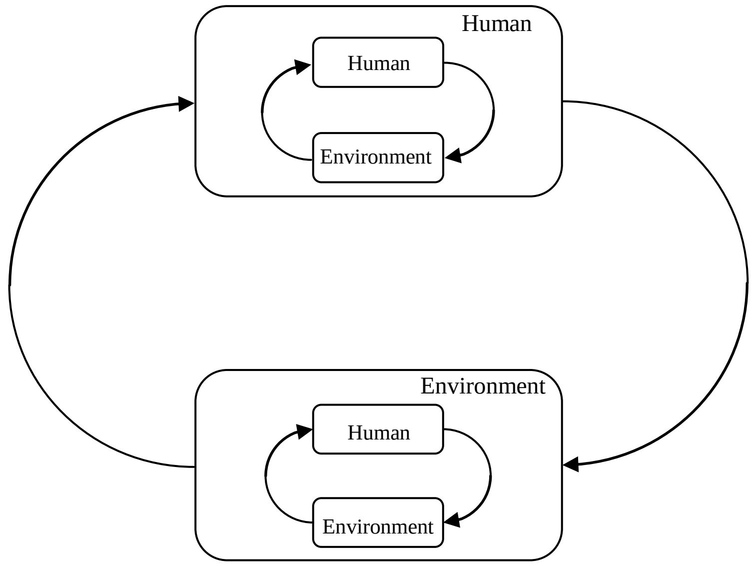

Figure 2. Modelling reflective coupled human-environment systems

In order to realise applications according to the overall unified modelling perspective displayed in Figure 2, a number of more specific ingredients for modelling both natural and artificial processes and their combination are needed:

(1) Computational *domain models* for human processes at physiological, neurological, cognitive, affective and social levels
(2) *Integrative* computational *agent models* for software agents to support humans in their functioning, incorporating domain models with knowledge about human processes and methods for reasoning about them
(3) *Interaction models* for the interaction between software agent models and the environment, including sensor systems to acquire information without having to bother the humans

These ingredients can be obtained from areas such as Computational Science, Artifical Intelligence, Ambient Intelligence, and Informatics. In the curriculum such ingredients are included in the exact sciences stream, and in the computational modelling stream students learn how to use and integrate these elements with domain knowledge as included in the human sciences stream (see Section 4). Examples of methods and techniques covered include: qualitative, logical, quantitative, numerical and hybrid dynamical modeling; recursive modelling and model-based reasoning in software agent models using domain models; methods for analysis, assessment and intervention action generation. Given the specific motivations and backgrounds of the students aimed to enrolling in this curriculum, much work was needed to develop course material in such a form in order that it fits well to these motivations and backgrounds. For example, much available literature on computational modelling is presented in a rather technical form, with examples often taken from engineering and physical sciences (Shiflet and Shiflet, 2006). Such methods and techniques have been focused more on the human perspective. Moreover, the integration of domain models within (software) agent models is an area still underdevelopment, and developing course material for this has gone hand in hand with research. The same applies to the topic of model abstraction. More specifically, the following courses have been developed and are included in the computational modelling stream:

- *Introduction to Modelling and Simulation*
  This course addresses dynamical (domain) modelling of human processes, using elements of numerical, logical and hybrid computational modelling as, for example described in (Ashby, 1952; Beer, 1995a, Port and van Gelder, 1995; Busemeyer and Diederich, 2010; Shiflet and Shiflet, 2006; Bosse, Jonker, Meij, and Treur, 2007; Miller and Page, 2007).

- *Integrative Modelling*
  This course addresses integration of domain models in agent models for supporting software agents. Here elements from computational modelling and agent modelling are combined; see, for example, (Bosse, Hoogendoorn, Klein, and Treur, 2011; Bosse, Hoogendoorn, Klein, Lambalgen, Maanen, and Treur, 2011).
- *Comparative modelling*
  In this course relations between models are addressed, according to three dimensions of abstraction and interlevel relations as discussed in (Bosse, Hoogendoorn, Klein, and Treur, 2010; Treur, 2011). The three abstraction dimensions addressed are the process abstraction dimension (e.g., Sharpanskykh and Treur, 2012a; 2012b; Treur, 2011), the temporal abstraction dimension (e.g., Bosse, Jonker, Meij, Sharpanskykh, and Treur, 2009) and the agent cluster abstraction dimension (e.g., Bosse, Gerritsen, Hoogendoorn, Jaffry, and Treur, 2011; Bosse, Jaffry, Siddiqui, and Treur, 2012; Sharpanskykh, and Treur, 2011).
- *Behaviour Dynamics*
  This course addresses in more depth from a dynamical systems perspective dynamics of the behaviour of social networks and social agent systems and their analysis and validation. See, for example, (Beer, 1995b; Bosse, Hoogendoorn, Klein, Treur, Wal, and Wissen, 2012; Treur, 2012a; 2012b).
- *Model-Based Intelligent Environments*
  This course continues integrative modelling to more realistic overall intelligent environments.

4. The human sciences and exact sciences streams

As mentioned in Section 3 above in the curriculum ingredients are used from the exact sciences stream and in particular from areas such as Artifical Intelligence (e.g., modelling knowledge and reasoning), Ambient Intelligence (e.g., interaction with humans using sensor systems), and Informatics (e.g., human-computer interaction). More specifically the exact sciences stream contributes courses such as:

- Logic and Sets, Intelligent Systems, Machine Learning, Evolutionary Computing (Artificial Intelligence)
- Pervasive Computing, Lab Human Ambience (Ambient Intelligence)
- Problem Solving, Introduction to Programming, Databases, Human-Computer Interaction, Multimedia authoring, Web Technology (Informatics)

For the human sciences stream a large number of options is available from the existing curricula in human sciences such as Biomedical and Health Sciences, Psychology, Social Sciences. Such courses may addres more fundamental aspects of human processes, but also focus on limitations or shortcomings in functioning, for example due to specific disorders. Examples of course for this stream are:

- Medical Physiology, Behaviour and Health (e.g., Widmaier, Raff, Strang, 2004)
- Introduction to Psychology and its Methods, Anxiety and mood disorders, Empirical methods (e.g., Gleitman, Fridlund, Reisberg, 2004; Ashcraft, 2005; Nolen-Hoeksema, 2005)
- Social Psychology, Text Analysis (e.g., Smith and Mackie, 1999)

Within the curriculum in a number of cases choices can be made by students for subjects or profiles they prefer. In this way they can create a specialisation, for example, in themes such as mental health, sports, crime, elderly.

5. Integration and projects

The Integration and Projects stream aims at integrating the different elements and streams in the curriculum, mostly in the form of project activities. A starting point for this stream is the integrative first year the course Introduction Lifestyle Informatics, in which students design their first application. Later in the first year and in the second year there are integrative projects in which the knowledge from the other streams obtained this far is integrated. In the third year the Bachelor study ends with a larger integrative project. Similarly in the fifth year the two year master study ends in a larger integrative project of about half a year fulltime. In the fourth year, which is the first year of the two year master program, the integrative course Human Ambience Innovation aims at getting an overview of the field, on the basis of the following three dimensions (see also Figure 3):

- The modelling and implementation methods and techniques used
- The domain knowledge from human sciences used

The societal application area in which a problem is addressed Each application can be mapped or projected on each of these axes, thus providing a triple characterising it. As a simple example, an application to support a depressed person through Internet and mobile phone, exploiting some causal model of how a depression can develop can be characterised as a triple

<causal modelling and mobile Internet; psychological knowledge about depression; mental healthcare>

As another example, if a person's social network is addressed in an application to avoid becoming socially isolated, for which a dynamical system model and Twitter are used, then the application can be characterised as:

< numerical dynamical system modelling and Twitter; knowledge about social networks; mental healthcare>

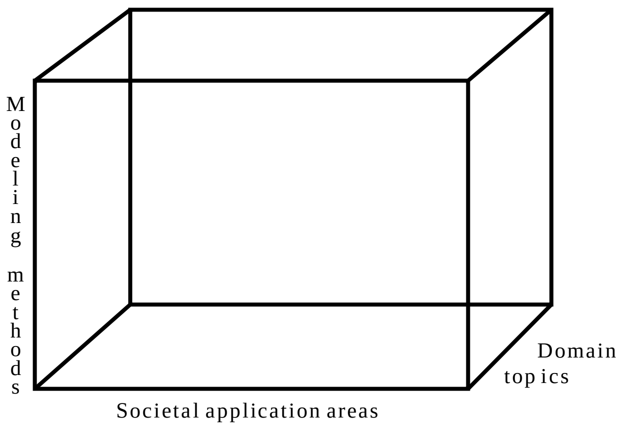

Figure 3. Three dimensional space for justified applications

6. Evaluation and discussion

Curriculum design for higher education is not a well-developed area; for an impression of different perspectives and meanings, see (Fraser and Bosanquet, 2006; Mäkinen and Annala, 2010). Curricula can be developed for existing scientific disiplines; specific case studies have been reported in different domains, for example, for automotive engineering and history in (Shay, 2011; Mears, Omar, and Kurfess, 2011). However, curricula can also be designed for newly developing disciplines or multidisciplinary areas, such as sustainability science (e.g., Michelcic et al., 2003). As both the scientific area and the curriculum are developing, this provides an extra level of challenge. The current paper reports a curriculum design for such a multidisciplinary area. The curriculum as presented above was designed in a coherent manner according to a welldefined view, and was meant to contribute a serious innovation in the landscape of academic curicula. Indeed, it does not look like the more common or traditional curricula. A question that can easily come up is whether this curriculum actually has an academic character. It seems clear that when it is compared to any of the monodisciplinary ingredients it has less depth. However, the academic value is in the integration of the different scientific ingredients. It that sense more depth is achieved, even for different monodisciplinary ingredients. For example, software systems are designed in a manner that is justified by knowledge from human sciences, which has more depth than software systems that are only tested with users on whether they appreciate the system. As another example, knowledge on human sciences is not only acquired in informal forms, but also in more depth in formalised forms based on computational models. In that sense students in this curriculum achieve more depth than, say, psychology students.

Given the way in which it deviates substantially from known curricula, the innovation process to get a curriculum as described above implemented is certainly not straightforward. Although a first aim was to add this as a completely new curriculum to the spectrum of already available curricula, after some time it turned out that the chances to get such a curriculum realised were considered politically much higher when it was replacing an existing curriculum. At this point the decision was made to implement this curriculum for the first three years as replacing the existing bachelor study Artificial Intelligence (including adopting a new name for this Bachelor: Lifestyle Informatics), and for the fourth and fifth year as a specific profile (called Human Ambience) within the existing master study Artificial Intelligence. Both studies are organised by the Department of Computer Science of the Faculty of Exact Sciences in cooperation with different faculties for human sciences.

In the initial phase of this whole process, in spring 2007 by a professional organisation an investigation was conducted to estimate the appreciation of such a study by candidate students. This study focused on high school students of the prefinal year of several schools in the Netherlands with 1104 respondents; see (Hamstra, 2007). This is a group of students that after their next year could choose for this curriculum. After a brief description of the curriculum (which was a Dutch variant of the third paragraph included in Section 1 above), they gave an answer on the question: *In how far do you find this bachelor interesting, after reading the description?* Some of the results are depicted in Figure 4. It turned out that a majority (63%) of these students would find such a study interesting, varying from a bit interesting (34%) to interesting (24%) and very interesting (5%). From the opposite side, only 31% of them would find the study not interesting. One of the more specific positive outcomes was that in a significant manner the female student were the most positive ones. For example, from them only 25% would find the study not interesting, whereas for the male students this percentage was 39%.

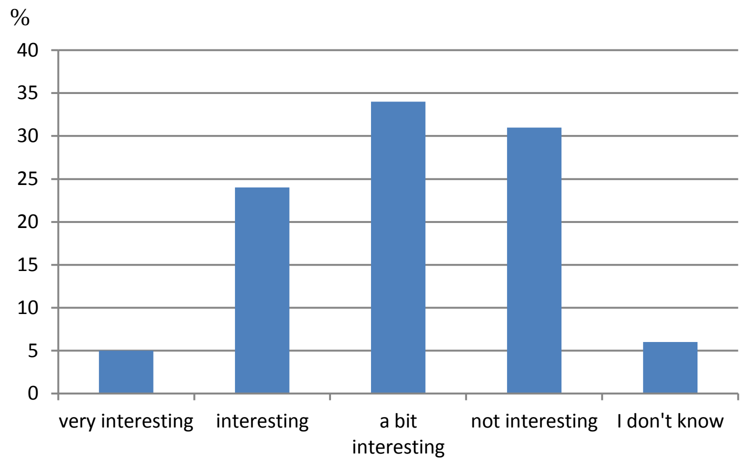

Figure 4. Interests in the curriculum for 1104 students in the prefinal year of the high school

In the mean time the study is functional for about three years. In these years the numbers of students attracted by the new Lifestyle Informatics bachelor study (up to between 40 and 50 new students per year) were about double the numbers that were attracted by the Artificial Intelligence bachelor it was replacing. It has become one of the most popular bachelor studies within the Faculty of Exact Sciences, and certainly compared to those organised by the Department of Computer Science. The percentages of students who successfully continue the study after the first and second year are high.

About the question 'Should I try this at home?', the following can be said. On the one hand, be aware of some of the difficulties in implementing this, both for the contents and politically. In the paper they have been pointed out from time to time. On the other hand, also be aware of the great opportunities such a curriculum offers in attracting new types of students; for example, groups of students become possible that almost have an even balance between male and female students, which is quite exceptional in an exact academic context. As put forward in this paper, the integration through computational modelling is a crucial factor in order to obtain coherency in the curriculum. From the experiences described above, a first advice would be to address that area very seriously. In contact with the author it may be possible to get dedicated course materials that have been developed already.

In (Treur, 2007) a description is included of the designed curriculum in much more detail, and including, for example, how it relates to the Dublin descriptors (cf. Joint Quality Initiative Group, 2004).

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