Towards high quality exercise classes for Internetworking

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Abstract
There is a lack of scientifically examined exercise classes for the learning process about “Internetworking” which has been successfully introduced in informatics education. Therefore, we examine the relation between knowledge structures and exercise classes within the learning process. Thus, we have defined possible learners’ activities and we have developed a repertoire of exercises in the context of best practice studies. We aimed at getting feedback by introducing these concepts into the learning process at school within an early phase. Therefore, we implemented two studies of feasibility. We have enhanced our theoretical concept with feedback from learners about possibilities and limitations within the learning process.

Keywords
Understanding of informatics systems, exercise classes, Internetworking

INTRODUCTION
Motivation
Our aim is to foster a responsible-minded dealing with Internet applications that requires more than user abilities, because it is necessary to understand the functionality of the Internet. Within this paper we report about results of our research project[1] “Internetworking”. One part of the project is especially concerned with the requirements of informatics in secondary education. Therefore, we develop a theoretical concept described through the Didactic System “Internetworking” (Freischlad & Schubert, 2006). It comprises knowledge networks, exercise classes and learning software. Our theoretical approach was introduced within an informatics course in secondary education. We focus on exercise classes within this paper, because exercises are an important design medium for the learning process. Nevertheless, there is no literature on exercises about Internetworking for introduction into secondary education. Structured exercise classes can be used by teachers and students when they prepare lessons. The structure of the exercise classes enables them to select adequate exercises for learning fundamental concepts, and to deepen important concepts. Furthermore, the context of exercises derived from exercise classes can be varied. Learners were supported through the selection of exercises on different cognitive levels and they can start with simple exercises before they work with highly interconnected exercises. We propose a classification scheme for the development of high quality exercises, i.e., to identify gaps based on these classes. We develop the Didactic System Internetworking within the context of best practice studies. We have to classify exercises, to describe knowledge networks and to develop learning material especially learning software.

Research methodology
We analysed characteristics of informatics systems based on the Internet to identify necessary competences for using Internet applications (Freischlad, 2006) and described our theoretical approach towards knowledge structures and exercise

classes (Freischlad and Schubert, 2006). Additionally, we have started the development of learning software which can be used for practical exercises and experiments. We have developed learning concepts and materials including exercises for the evaluation of our concept in classroom projects based on the theoretical approach. Thus, the evaluation is performed through these classroom projects. For the evaluation we use a knowledge test, a questionnaire for self-assessment of learners, interview with the course teacher, and the experiences and observations made through the lessons. The results of the evaluation of the classroom project are applied for refinement of the Didactic System and learning concepts and materials.

CLASSROOM PROJECTS

The first classroom project was performed with student teachers within the first half-year in 2006. The project lasted for 14 lessons and additionally one lesson for the knowledge test and the questionnaire. Within this project we focused on authentication and confidentiality in the context of e-mail and privacy in the context of the World Wide Web (WWW). In October and November 2006 we started a second classroom project with learners at the age of 18. The course was at its fifth half-year. The project took 13 lessons. In this project 12 lessons were processed by Freischlad and one lesson by a teacher student. The previous knowledge of learners was object-oriented programming, and data structures. In both courses there was no previous knowledge about computer networks and information security out of informatics courses. Therefore we also had to include fundamentals, e.g. the terms client and server.

We discussed the use of computer networks with the example of the school network as an instance of a client-server environment for providing central resources. Learners used a utility to establish a TCP/IP connection to see how these services are implemented based on a logical connection within a computer network. We discussed the terms server and client discerning the program that is waiting for an incoming connection request and the initiating program. To build up a connection to another host it is necessary to address the computer. Learners had to apply their knowledge about IP addresses when they completed a figure with several hosts within connected networks with IP addresses. After they know how to address computers within a network we introduced the term protocol as set of rules for computer-computer interaction. Learners designed an interaction diagram illustrating the retrieval of a web page from a web server. To understand the connection between the domain name known from Uniform Resource Locators (URL) and IP addresses we looked at directory services especially the Domain Name System (DNS). Learners looked up for information from the directory services DNS and “Whois” through a web site. The logical structure of the DNS namespace was analysed when describing the process of domain name resolving. We introduced knowledge about web research subsequent to directory services. Learners applied different search strategies and looked for and applied criteria for web page assessment. They could apply their knowledge about the domain hierarchy. Furthermore they learned how search requests are processed by a search engine. We discussed how this knowledge can influence search strategies. At the end after learners already knew several concepts of Internetworking we looked into the protocol layer model and the functions of the layers. Using an Applet that simulates transmission failures they had to explore services and assign these services to the layers.

Learners know different search strategies and are able to consciously apply them. They have understood the fundamental principle of Internet applications, i.e., the client-server model. They developed an abstract description of the terms client and

server for themselves after looking at the uses of computer networks and how programs interact within networks. Furthermore, they have learned the abstract concept of protocol layers and could assign functions to protocol layers after practical exercises with the applet about the protocol layers. Therefore, they know an important concept for structuring knowledge about Internetworking. But just some of the learners have understood the physical structure of the Internet. One cognitive obstacle was the approach by connecting the physical structure and the knowledge about the composition of IP addresses of network and host identifier. Besides, learners have not gotten a clear understanding how IP addresses were assigned. A question of a learner was how it is possible within private networks with Internet access to decide which addresses were assigned to computers. To answer this question we have to consider the distinction between private and public addresses within the learning process.

CLASSIFICATION OF EXERCISES

Classification strategy

We started by analysing the structure of textbooks comprising knowledge about Internetworking. There are no such books for secondary education. Therefore we used those for higher education to derive classification criteria. We identified five international standard textbooks (Comer, 1999; Kurose & Ross, 2001; Meinel & Sack, 2004; Peterson & Davie, 2003; Tanenbaum, 1996). These books are structured by protocol layers which constitute a representative informatics model. Kurose and Ross structure their book beginning with the Application Layer, passing through the layers top-down while the other authors follow a bottom-up approach. The reason for this top-down approach is to adequately consider the meaning of the Application Layer, especially topics like the client-server concept. Another reason is that starting with applications has a motivating effect for learners. Peterson and Davie call their structuring “systems approach”. They look at thoroughgoing concepts independently from the Internet layer model, because it is not possible to assign these concepts to one layer. They explain that the Internet layer model is useful for structuring some but not all concepts. And they recommend an end-to-end perspective, e.g., considering client and server interaction when looking at the network. The fact that these textbooks were written for higher education implies three difficulties:

- The educational aim is to qualify students to design computer networks instead of fostering understanding of informatics systems as contribution to general education.
- The cognitive abilities of learners in secondary education were not adequately addressed.
- The scope of the content is too large.

Kurose and Ross recommend structuring an entire course in higher education by protocol layers. Nevertheless they indicate the possibility to use the introductory chapter as basis for a short course although it is not structured by protocol layers, but it is a complete overview about computer networks and the Internet. Therefore, it is not necessary to structure the course by the Internet layer model to understand processes in computer networks. Moreover, there are basic concepts which cannot be assigned to one layer. Although the Internet layer model is an approach to structure the complexity of computer networks. For the classification we choose the end-to-end perspective. As a result of the analysis of the textbooks about basic concepts, protocol layers, applications and services we have got a substantial list of items. To find those classes that are adequate for informatics education, we apply the following criteria:

1. The items must be fundamental (Schwill, 1997).

2. It is possible to prepare theoretical and practical exercises for secondary education.

We have identified five major classes. We discern “Applications” with their characteristics, their uses, and their specific realisation as distributed systems in the Internet. The other classes are designed to foster understanding of the functionality of these applications. The second item is “Protocols”, i.e., a set of rules for computer-computer interaction in networks. It also comprises Internet security because Internet specific security mechanisms were implemented through protocols. Identification of hosts within a network is realised through “Addressing”. Furthermore, this class includes directory services that support information about an address. The description of what is going on while data has left one end-system and before it reaches the targeted end-system is described by the class “Data Transfer”. The last class “Architecture” is composed of models and informatics systems which are essential for the architecture of the Internet. In Figure 1 the five major classes and assigned subclasses are shown. We don’t claim that this tree is complete. We have classified 77 exercises which were introduced within our classroom projects. The classification is shown with the number of assigned exercises in parentheses.

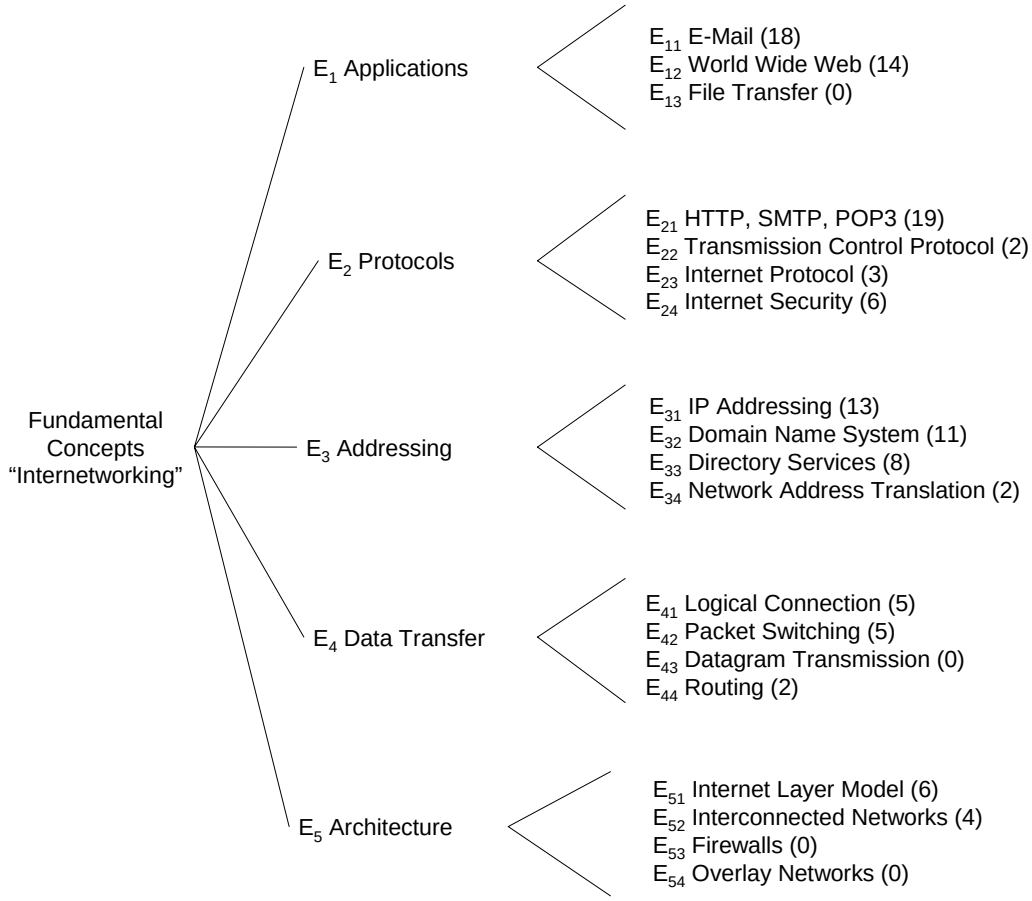

Figure 1: Exercise classes derived from textbooks.

Besides fundamental concepts of “Internetworking” we have identified necessary knowledge which is not just characteristic for the Internet. We concentrate on contents about “Internetworking” within our classroom projects and developing the didactic system. Looking at the structure of informatics concepts we defined necessary previous knowledge particularly in the fields of computer networks and

information security. Therefore, we defined two major classes to structure previous knowledge. Basic knowledge about “Computer Networks” is necessary to understand the Internet as network that is build up through connecting networks. The Internet inherits uses of computer networks like central resources and fundamental concepts like the client-server model. The second major class is “Information Security”. The requirements and mechanisms and typical applications were not just used for the Internet even though its importance is raised through worldwide networked informatics systems. Figure 2 illustrates the structure of necessary previous knowledge.

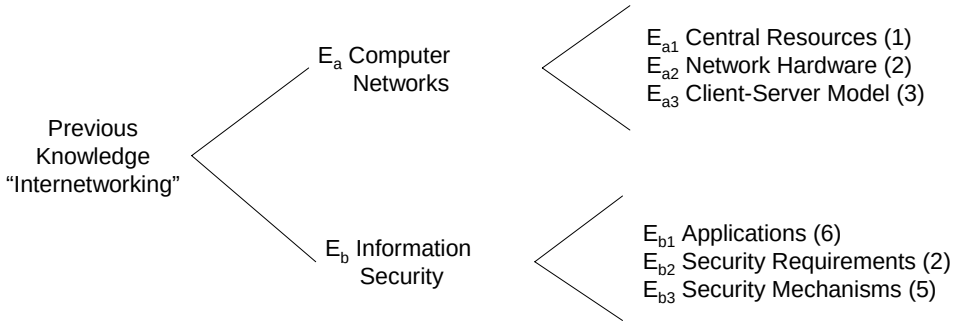

Figure 2: Structure of required previous knowledge for “Internetworking”.

Classification problems

Assigning exercises to exercise classes (EC) as they were described above we face the problem that there are networked exercises, i.e., to work on this exercise knowledge and abilities of different classes are necessary. The following exercise is an example:

> “Explain the possibility of analysing the source code of an e-mail to detect fraud.”

This exercise was deliberately created to connect knowledge about e-mail application (EC_{11}), directory services (EC_{33}), and lacking of authentication during e-mail transfer (EC_{24}). The proceeding starts with analysing the source code, specifying IP addresses of mail servers which were used for the transfer, and looking up for information about these addresses provided by the directory service “Whois”.

Another problem occurs when exercises contain a more abstract concept. The following exercise is an example:

> “Make your choice whether the following statement is true or wrong: A protocol is used to store the processing between two programs.”

We defined the major class “Protocols” that contains three classes for concrete protocols. The exercise aims at a more abstract understanding for the term protocol. We assigned this exercise to EC_{21}, EC_{22}, and EC_{23}. Furthermore, the analysis of textbooks about computer networks shows that this literature does not cover the entire scope of knowledge and abilities using the Internet. Information retrieval on the WWW and assessment of web pages are not covered in one of these books. We assigned these exercises to the corresponding Internet application (e.g. EC_{11}).

LEARNER'S CLASSROOM ACTIVITIES

Didactic functions and exercise attributes

The usage of exercises in classroom has different didactic functions. They were used for setting up awareness or as introductory example, for learning by getting through new material, for practising new knowledge, and for examinations (Brinda, 2004). For an adequate usage we are in need of exercises with different characteristics. Therefore we have analysed exercises according to the criteria context, style, cognitive level, and interconnectedness.

The context has to be motivating for learners. But it is also possible that the context distracts from the core of the exercise, i.e., the intended learning objective. We discern three levels of abstraction of the context:

1. Very illustrative or familiar context, e.g., "Alice wants to send an e-mail to Bob",
2. Informatics system, e.g., "Find information about the domain uni-siegen.de using a website for accessing the directory service 'Whois'",
3. Informatics model, e.g., "Explain the processing of Simple Mail Transfer Protocol (SMTP) by means of the state diagram", or "Create an interaction diagram for illustrating the client-server model by the example Hypertext Transfer Protocol (HTTP)".

The style describes the way to solve the exercise and how the solution has to be represented. We particularly have to discern practical and theoretical exercises. They have to be introduced balanced out in the learning process. We distinguish eight styles in Table 1.

Style	**Explanation**
Observation	Practical activities and results were documented.
Experiment	Learners have to define a hypothesis, plan a strategy to test it, and document their observations.
Description	A procedure, a process, a sequence, or a term is described. The answer is a text, just items, a figure, or a cloze has to be filled.
Assignment	An assignment represents the assignment of statements and terms into one or two dimensional structures such as tables or a figure has to be completed.
Decision	A typical representation is a multiple choice question, where it is possible to distinguish exercises by statements which must be assigned to true or false or correct answers to a given question have to be selected.
Reasoning	The learner has to argue conclusively.
Diagram	Diagram is a figure which is created with a formal syntax. An exercise is assigned to this type in case that a diagram must be created or completed.
Calculation	We assign this style whenever a calculation must be performed.

Table 1: Styles of exercises.

For assessment of the degree of difficulty we discern two criteria. First the cognitive level is described with a scale from easy to hard. Easy exercises are, e.g., questions about basic knowledge. Medium exercises are, e.g., are exercises which aim at confusion. And hard exercises are about abstract concepts. Secondly, we consider the interconnectedness of knowledge fields within one exercise. The range is from low to middle to high.

Exercises about Internetworking

When we assigned the exercises to exercise styles we found several difficulties. We assigned an exercise to the style that is the most important if more than one process step is necessary for solving an exercise. Thus, there are exercises that are composed of a description and on the basis of this result performing an assignment:

> "Describe the structure of the school network by a graphic and allocate the terms server, client, and switch."

The learner has to create the graphic before it is possible to allocate the terms client, server, and switch. This exercise is assigned to exercise style "Description", because this is the more important step. Within other exercises an analysis must be performed before creating a diagram or giving a textual answer. Within the following exercise the observations of an activity must be presented by a diagram. This exercise is given the style "Observation":

> "Retrieve the web page using the Hypertext Transfer Protocol (HTTP) and document your performance with an interaction diagram!"

When parts of a problem were solved within interconnected exercises, we assigned more than one style:

> "Find out the IP addresses of the following domain names and assign the addresses to network classes."

This exercise is assigned to "Observation" and "Assignment". Within Table 1 the number of assigned exercises of each major class is displayed.

Exercise Style / Exercise Class	Observation	Experiment	Description	Assignment	Decision	Reasoning	Diagram	Calculation
EC_1	8	2	11	2	1	4	5	0
EC_2	5	0	11	3	1	5	4	0
EC_3	4	0	9	6	0	4	4	6
EC_4	3	0	0	1	0	5	1	0
EC_5	1	1	1	6	0	3	0	3
EC_a	1	1	2	1	1	0	0	0
EC_b	4	0	1	1	0	1	0	0

Table 1: Number of exercises assigned to exercise classes and styles.

In Table 2 the level of difficulty depending on the assignment to exercise classes is shown. The teacher has to consider the cognitive level which is adequate for the learners. Most of the analysed exercises were assigned to the medial cognitive level. Just those exercises of class 4 and 5 are mostly rated as hard. This rating is confirmed by the questionnaire which was filled out by learners of the second classroom project. Out of 18 participants 13 learners denoted the overall level of difficulty as adequate. Within the self-assessment the understanding of the protocol layer model (part of EC_5) was ranked worst. Seven learners stated that they have not really or not at all understood the way protocols with different functionality were organised in this model. This is because we had no exercise on easy cognitive level

within the area of protocol layers (EC_5), and just one exercise with high interconnectedness.

	Cognitive level			Interconnectedness		
	Easy	**Middle**	**Hard**	**Low**	**Middle**	**High**
EC_1	10	17	5	19	10	3
EC_2	9	10	7	10	12	4
EC_3	6	12	8	12	8	6
EC_4	1	3	5	1	5	3
EC_5	0	2	8	4	5	1

Table 2: Number of exercises assigned to exercise classes and levels of difficulty.

Exercises with variable interconnectedness are necessary because of the usage of exercises with different didactic functions throughout the learning process. The connection of knowledge about more than one concept within one exercise can be increased through the learning process. The interconnection can serve two purposes. First, in case of an abstract concept, it is connected to a concept which is more easily accessible. The following exercise gives an example:

> "Describe on the basis of the figure how authentication with SMTP-AUTH (Simple Mail Transfer Protocol Authentication) is performed during sending an e-mail."

This exercise is assigned to EC_{21} and EC_{24}, because authentication will be examined with the example SMTP, but SMTP is not just the context. Another purpose of interconnection of concepts within one exercise is that particularly in real-life situations often problems occur which cannot be solved with knowledge about one concept, e.g.:

> "Explain why the domain name is inapplicable to build up a connection to another computer."

This exercise is assigned to classes EC_{32}, EC_{42}, and EC_{44}, because it is necessary to understand the logical structure build up by the DNS namespaces and how switching and routing is working.

CONCLUSIONS

Within this article we have shown how it is possible to evaluate exercises used in the learning process. This is necessary for the development of high quality classes. For this purpose we consider exercise classes, exercise styles, and the cognitive level which comprises the level of abstraction and of interconnectedness. By means of the classification we identified focal points and gaps in the learning process concerning the covering of exercise classes. There is a high amount of exercises for EC_{11} (E-Mail) and EC_{21} (HTTP, SMTP, POP3). Besides, there are classes with less or even no exercises. Considering exercises in the context of the learning process we found that the exercise style "Description" was used very often. Other styles were rarely used, e.g., "Experiment" and "Diagram". But the exercise style "Experiment" supports the development of strategies for creating knowledge, because learners start from defining a hypothesis and end up testing their assumptions. The exercise style "Diagram" is an important representation of informatics concepts for illustration and for discussion about informatics systems. Furthermore, we found a concentration of the exercise style "Assignment" when we analysed exercises that were assigned to EC_5. And we found that there is a lack of

easy exercises assigned to EC_5 analysing the interrelation between exercise classes and the cognitive level.

The identified exercise styles are necessary to enable learners using different approaches to a subject matter. Therefore, teachers have to consider exercise styles when they are preparing the lessons, i.e., when they are selecting or creating exercises. We had to analyse whether these styles where appropriate for preparation of lessons and for this subject matter. Further exercise styles have to be used for creating exercises particularly about IP addressing and the Internet layer model. Additionally, we described with the exercise classes a broader domain than we introduced into informatics courses, e.g. datagram transmission. Therefore, we have to enhance our approach with further exercises, because

- We recognized flaws and gaps concerning exercise styles and levels of difficulty,
- We identified exercise classes, which were not used or which were not adequately represented within our best practice studies yet.

For further development of the Didactic System “Internetworking” we will implement another classroom project within the first half-year 2007 with teacher students for eight weeks, i.e. 24 lessons. Existing exercises will be used, and further exercises have to be created. We will start with the client-server model, the structure of the school network and the Internet and IP addressing within the first week. We have to enhance the material with exercises about interconnected networks (EC_{52}). Within the second week we introduce exercises about HTTP and the Domain Name System followed by learning about information research on the World Wide Web (EC_{12}). It comprises searching strategies, knowledge about how a search engine works and about web page assessment. We will develop further exercises of EC_{51} (Internet layer model) which we will use within the fourth week. As we have already stated it is necessary to develop exercises which were on a lower level of abstraction and those which were more interconnected. Exercises out of EC_{11} and EC_{24} about e-mail and Internet security, especially about authentication and confidentiality, will be used from the fifth until the seventh week. New exercises will be developed for EC_{34}, EC_{42}, EC_{43} and EC_{44} about network address translation (NAT), packet switching, datagram transmission, and routing.

Furthermore, students are developing learning software at the Universität Siegen. This software particularly enables teachers and learners to integrate experimental exercises into the learning process. The software allows learners to simulate computer networks and their interconnection to an internet and to use and manipulate applications and services within this environment.

NOTES

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Biographies

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