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Design-focused Development of a Course Recommender System for Digital Study Planning*

Michaela Ochs[1] [0000-0002-3850-8585], Tobias Hirmer[1] [0000-0002-5281-0342], Katherina Past[2], and Andreas Henrich[1] [0000-0002-5074-3254]

[1] Chair of Media Informatics, University of Bamberg, Germany
{firstname.lastname}@uni-bamberg.de
[2] pastkatherina@gmail.com

Abstract. In recent years, universities have been offering a rising number of courses, creating not only greater flexibility of choice, but simultaneously a more complex decision-making process for students. Therefore, this paper seeks to identify key aspects that should be considered when designing a course recommender system (CRS). To achieve this, the paper introduces the field of course selection as a decision-making process, and a suitable area of application for a recommender system (RS). Through an analysis of students' selection criteria and processes, the paper develops requirements and a prototypical implementation, following the double diamond design process model. The implementation is evaluated via think-aloud user tests in its initial iteration. The results of this study indicate that a multidimensional approach shall be taken to optimize the user experience. As an additional contribution, we identify six guidelines for the design of effective CRS.

Keywords: Study Planning · Course Recommendation · Decision Support · Design-Focused

1 Motivation

When it comes to course access and availability, current study programs offer students a variety of choices that students often fail to take advantage of in an informed and purposeful manner due to the overwhelming complexity. Here, CRS can have significant impact to guide students to make better decisions when choosing appropriate courses in their studies. This paper aims to identify criteria that should be addressed when designing a CRS to enhance its usability.

Therefore, this paper is structured as follows: After introducing the foundations of study planning, decision theory, and recommender systems, as well

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as the state of the art, the paper presents the requirements and characteristics of the study planning process. A prototype is introduced thereafter, which addresses the identified requirements. The paper concludes with a discussion of the findings and presents six guidelines for designing a CRS for study planning.

2 Foundations

2.1 Study Planning

Within the field of European higher education, students face multiple options in the process of planning their individual way through their studies. Students select between different courses that contribute to modules. Modules are thematically specialized and self-contained learning units that are usually taken by students within one semester or more semesters [9]. After completing a module successfully, students get credit points.

Students must complete a specific amount of credits in different groups of modules, which vary depending on the chosen study program. This results in a complex network of connections between modules and courses, making study planning a challenging task. Study planning involves two decision-making processes: first, when to participate in a course or module and second, which course or module to select. Students have to choose from various options in both described decision processes, which makes the process of study planning a use case for the field of decision theory.

2.2 Decision Theory

Decision can be defined as a mental process that consists of judgments, evaluations and choices [16]. A decision is required if a person has to choose between different options or if there is a lag between an actual and an aimed state [16]. Every option leads to a consequence, which occurs with a specific probability. Here, the terms *decision under certainty*, *decision under risk* and *decision under uncertainty* are used [3]. A decision situation can be characterized by different aspects, i. e. if the options are known, if there are dependencies between decisions as well as how often a decision has to be made.

Furthermore, decisions can be classified according to the cognitive load they carry based on Pfister et al. [16]. The least complex is the *routine decision*, which involves automatic and well-established choices between similar options. More complex is the *stereotypical decision*, which involves evaluating options triggered by environmental factors, but with limited flexibility in decision-making. The *reflective decision* corresponds to the third level of complexity, where few preferences exist and personal reflection is required due to new or unfamiliar situations. The most complex is the *constructive decision*, where options may not be known or defined, and personal preferences about the options still need to be developed.

As has become evident, each decision is a process with varying complexity and cognitive load. A model that represents the process of decision-making and its sub-processes is offered by Betsch et al. [3]. First, in the *pre-selectional phase*, one identifies whether a situation requires a decision. Then, the possible options are generated and relevant information about the consequences of the options is retrieved in order to be able to make a decision. Then, the *selectional phase* is triggered if enough information about possible options is available. Using this information, the options are assessed and one of these is selected. Thereby, the complexity of a realization, the feasibility as well as the conformity with personal goals are taken into account. Last, in the *post-selectional phase*, an option is realized and the completion and occurring consequences are monitored.

2.3 Recommender Systems

In general, recommender systems (RS) act on the basis of various data sources, which are usually stored in a model and used to generate future recommendations. RS can be classified into different types of approaches based on their method of selecting elements [1]:

- *Collaborative approaches* use user profiles to filter elements based on similarity of ratings. In neighborhood-based collaborative filtering, both an item-based as well as a user-based approach can be used.
- *Content-based approaches* use element properties and previously rated data to generate recommendations.
- *Knowledge-based approaches* rely on element specifications rather than user-element ratings, and can be constraint-based or case-based. Constraint-based approaches use user-specified attributes of elements to find matching elements. In case-based approaches, the user specifies an element, based on which similar elements are then searched.
- *Hybrid methods* combine the aforementioned approaches.

Due to its complexity, the process of study planning is an interesting field for a RS to support student decisions. In particular, the process of course selection is already a popular use case for RS.

3 State of the Art

Course recommender systems (CRS) for higher education institutions can be characterized by individual conditions that influence their selection and use. Factors such as grades, career prospects, and social considerations can affect the recommendation of university courses [12]. In this specialized research field, Ma et al. [10–12] provide related papers with an explicit focus on the user experience. Initially, patterns in students' course selection were analyzed and based on this, a framework with a matching course recommendation algorithm was envisioned and qualitatively evaluated [12]. The two subsequent papers [10, 11] focused on the design and evaluation of an interactive CRS. Here, recommendation technologies were combined with an interactive user interface to combine flexible course scheduling and user control [10, 11].

4 Method

This work is guided by the double diamond design process model, which structures the design process of service products [4]. The framework comprises the four phases *Discover*, *Define*, *Develop* and *Deliver* – the first and second of which are commonly referred to as *research phase* and the third and fourth as *design phase* [4]. The double diamond design process model is user-centered and encourages iterative thinking, revision and solutions – which corresponds to the design-focused aspects of this research. It underlies and guides this contribution as visualized in Fig. 1. In the research phase, students' course selection behav-

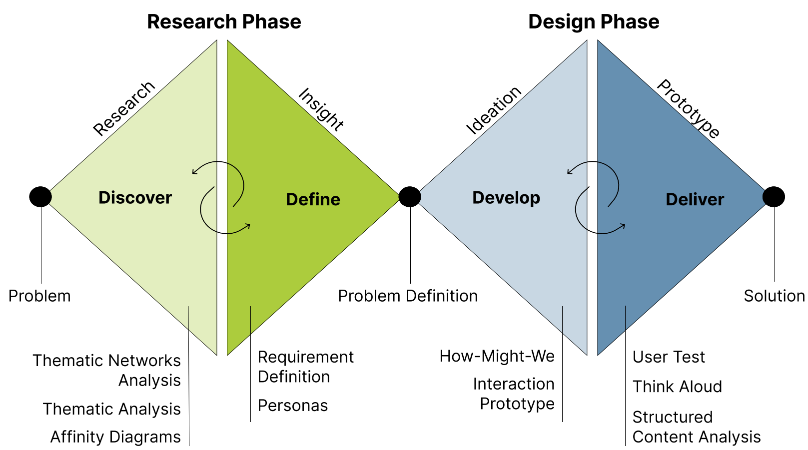

Fig. 1. Methodical Structure According to the Double Diamond Decision Process Model (Adapted from [4])

ior was discovered in a qualitative, explorative study, which resulted in a list of requirements for a CRS (cf. Chapter 5). For this purpose, previously collected interviews [7] have been re-examined in a complementary secondary analysis [6]. *Thematic analysis* allowed to extract attitudinal and behavioral data [18] based on which *thematic networks* [2] and *affinity diagrams* [15] were further used to structure the results of the previous analysis [18] in order to derive and define requirements. Following this research phase, a prototypical CRS was designed and tested in the design phase. For this purpose, the *How-Might-We-Method* was employed to translate requirements into questions in order to generate solution ideas [8], which were realized by iterative *interaction prototyping* [14]. The resulting prototype was tested and evaluated in a semi-structured *user test* with the *concurrent think aloud method* [5] and the users' answers were then analyzed via the method of *structured content analysis* [13]. Next, Chapter 5 describes the results of the research phase and then Chapter 6 introduces the concept and design of the course recommender prototype.

5 Requirements

This chapter presents the findings of the exploratory study on students' course selection process within the research phase. The requirements presented are based on two thematic networks identified in the analysis: *course selection criteria* and *course selection process*.

Table 1 shows eight criteria that are relevant for selecting courses that have been derived from the first theme: *(1.1) course features* relate to a course's credits, teaching and examination methods, difficulty and the information if it is mandatory or elective; Furthermore, *(1.2) module context* is relevant because students want to know which courses they need to complete modules and which courses may offer similar content; The *(1.3)* course *organizer* and their expectations are also considered by students in their course selection decisions; Further, *(1.4) time constraints* such as the semester in which the course is offered, conflicting courses and suitable days of the week determine students' decisions as well as further *(1.5) organizational constraints* such as the cycle of courses, course capacity or the course form, i. e. online, hybrid, or in-class; Further criteria are *(1.6) social constraints and recommendations* such as other students' selections or course ratings as well as their recommendations; Lastly, *(1.7) individual interests and goals* such as the credits to be taken, prerequisites for later courses, focus of study and career goals as well as *(1.8) individual prerequisites and study history*, i. e. prior knowledge or failed courses are also relevant criteria.

Table 1. List of Course Selection Criteria Which Shall Be Considered (Random Order)

Number	Criteria
1.1	Course Features
1.2	Module Context
1.3	Organizer
1.4	Time Constraints
1.5	Organizational Constraints
1.6	Social Constraints and Recommendations
1.7	Individual Interests and Goals
1.8	Individual Prerequisites and Study History

Table 2 shows seven criteria related to the semester and study planning process and the difficulties students are facing that have been derived from the second thematic network: Following the previous criteria, students want to be *(2.1) considering course selection criteria while planning*. They also consider *(2.2) getting assistance and support* in the form of official help or older students' knowledge to be relevant. Further, students are interested in *(2.3) doing short-term (single semester) and long-term (several semesters) study planning* in a flexible way while being able to save their plans. Another important criteria is *(2.4) considering semester workload* among all their subjects and for each semester. They also want to *(2.5) know and consider individual and relevant options and prerequisites* regarding courses and modules in a personal, helpful, efficient, and accessible way. They also strive for *(2.6) having less complexity when planning* and *(2.7) identifying time conflicting courses.*

Table 2. List of Requirements Regarding the Semester and Study Planning Process

Number	Criteria
2.1	Considering Course Selection Criteria while Planning
2.2	Getting Assistance and Support
2.3	Doing Short-Term and Long-Term Study Planning
2.4	Considering Semester Workload
2.5	Knowing and Considering Individual and Relevant Options and Prerequisites
2.6	Having Less Complexity when Planning
2.7	Identifying Time Conflicting Courses

Based on the secondary analysis of the interview transcripts in terms of semester and study planning as a decision problem, seven further requirements for a CRS have been identified as shown in Table 3: A central requirement for the decision-making process is *(3.1) staying informed about short- and long-term consequences of course selections* as well as students *(3.2) making decisions under risk, not insecurity.* Further, students shall be *(3.3) knowing all options* they have and shall be *(3.4) faced with a given set of options* when making course decisions. A further requirement regarding the decision process is *(3.5) being supported during the multilevel course selection process.* What is also considered to be beneficial is *(3.6) being supported with individual and social decisions.* Lastly, it is desirable for students to be *(3.7) supported during all phases of the decision process within semester and study planning.* These requirements show that students need a holistic, simplified and supportive process design within the CRS. Lastly, Pu et al.'s guidelines for designing effective RS [17] have also been considered in the design of this paper's implementation and evaluation.

6 Design and Evaluation of CRS

This section describes the realization of the requirements that have been described in the previous section, comprising the generation of recommendations, decision process support and visual design. For each of these subsections, the realization of the prototype is described as well as the insights gained from its evaluation in user tests, which represents the first iteration of the double diamond design process model as introduced in Chapter 4. In order to conclude this section, a short impression of the overall feedback on the prototype is given.

Table 3. List of Requirements Regarding the Decision Problem and Process

Number	Criteria
3.1	Staying Informed About Short- and Long-Term Consequences of Course Selections
3.2	Making Decisions under Risk, not Insecurity
3.3	Knowing all Options
3.4	Being Faced with Given Set of Options
3.5	Being Supported during the Multilevel Course Selection Process
3.6	Being Supported with Individual and Social Decisions
3.7	Being Supported during all Phases of the Decision Process within Semester and Study Planning

6.1 Generation of Recommendations

Based on the requirements that have been introduced, a knowledge-based as well as a collaborative recommendation approach were selected for the algorithmic realization of the CRS.

Responding to the requirements of personal recommendations (cf. requirements 2.5, 3.4) and support during the entire (multilevel) course selection and planning process (cf. requirements 2.6, 3.5, 3.7), the knowledge-based recommendation approach was chosen. It can fulfill these requirements by adapting to specific student needs based on user specifications and also supports transparency [17]. Users can observe item composition and revise recommendations, leading to control and trust in the system. The interaction process of students with the knowledge-based CRS was designed according to the interaction model of constraint-based recommendation systems [1] and the students' multilevel selection and decision support (cf. requirements 3.5, 3.7): The system takes in user specifications and recommends options (courses) accordingly. Users can then choose to either accept the recommended courses or modify their specifications.

Within the knowledge-based system, user input is incorporated via a search-based system. Here, students are asked questions about their course preferences [1], which is efficient and also responds to requirements by Pu [17]. Within the context of the search-based system, users are asked for the semester they are going to plan and their personal interests as keywords. They are further asked for courses they are interested in and that they want to take in higher semesters. This helps to fulfill requirement 3.1, which specifies that students want to be informed of short- and long-term consequences of their decisions. Based on their input, students may be notified that they have the prerequisites for these courses.

Apart from the knowledge-based approach, the collaborative approach was found to be helpful, as it addresses students' wish for multi-source recommendations, i. e. by students with the same or a higher semester count or students within the same degree program (cf. requirements 1.6, 2.2). These recommendations can be provided via course ratings in the context of the collaborative approach. Since using subjective ratings may negatively impact the relationship between students and teachers, only indirect ratings (*taken* = *recommended* and *not taken = not recommended*) were used. In order to circumvent cold-start issues, the rating modalities were adjusted so that they could be automatically derived from process-generated data that already exist in related systems. The cold start problem for new items was addressed by adding a banner with new courses to the interface of the course selection process that students have to close. With respect to the collaborative recommendation approach, an item-based approach was chosen over the user-based approach [1] since students do not always remain constant within their interests and evaluations. However, the recommendations may further be made more precise through preliminary filtering of the users according to their study program. The selected collaborative method also fulfills requirement 17 [17], which states that the recommendations should be diverse since it does not only consider the features and user behavior, but also takes into account the preferences of other users [19].

In the context of the generation of recommendations via this knowledge-based and collaborative approach, the main problems identified during the user tests were problems with the representation of the recommendation approaches. The understanding of how the recommendations are generated on the basis of the knowledge-based procedure was largely present. Nevertheless, the users struggled to differentiate between the two methods due to the unclear designation of the course recommendations based on the collaborative approach. The users wished a more precise formulation, in particular with respect to the similarity between the students. Therefore, the wording was adjusted and the recommendation procedure has been extended, so that the users can adjust the way in which the students should be similar to them, i. e. focus of study, degree program and faculty. Within the context of the knowledge-based recommendations, more specifically the customizable specifications for course recommendations (Fig. 2), the wording was adjusted or specified further according to the user tests and additional explanations were provided (e. g. distinction between prior knowledge and prerequisites). It was also suggested that the visual implementation of the interest input should be further developed, which was also fixed in the prototype.

6.2 Visual Design

This section will briefly discuss how certain requirements were considered in the visual design of the prototype. The main navigation includes items for semester and study planning with corresponding functionalities (cf. requirement 2.3). The comprehensibility and accuracy of the recommendations (14 and 19 in [17]) are met by providing precise titles (Fig. 3 - A) and the possibility of customization (Fig. 3 - B). In addition, relevant information that properly describes the course is displayed for each recommendation item (20 in [17]; cf. requirement 1.1; Fig. 3 - C). Clicking on one item displays more detailed information about the course.

Based on user testing, the prototype was improved by adding information about course type, room, and module affiliation (Fig. 3 - D | E | F). The course selection criteria was made more visible in the extended course information and aspects that were unclear were made clearer, such as a reference to a compulsory course (Fig. 3 - G) and the warning above the timetable (Fig. 3 - H). The list of

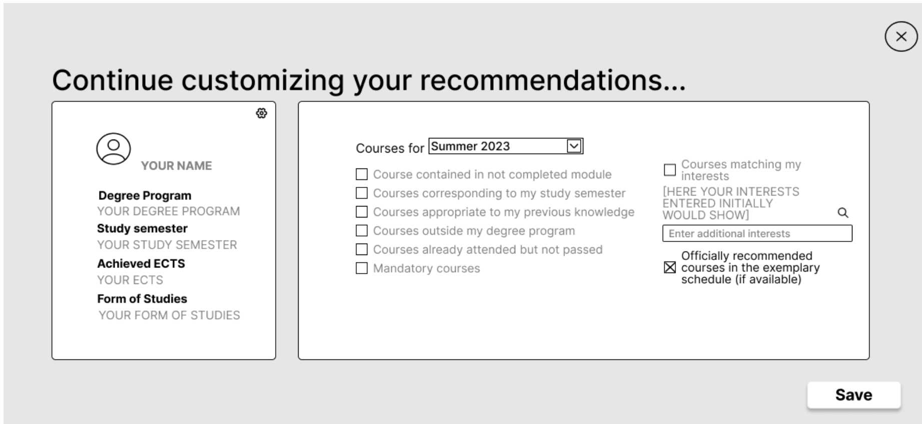

Fig. 2. Customization of Course Recommendations

recommendations generated from the knowledge-based procedure was adjusted by adding a clearer scroll button and improving the icons, including adding a hover function for the "Study Later" and "Hide Course" icons (Fig. 3 - I).

6.3 Decision Process Support

In order to address the multi-level decision support in semester and study planning (cf. requirements 3.5 and 3.7), a workflow was integrated into the prototype according to the aforementioned interaction model of constraint-based recommendation systems. The semester planning process – as entry of this workflow – begins with collecting the users' specifications. Next, a list of recommended courses is generated based on these specifications (Fig. 3 - A1). The specifications can also be modified by the user afterwards (Fig. 3 - B). The adjustable specifications include relevant course and user specifications that address multiple requirements (cf. requirements 1.1, 1.2, 1.5 - 1.8, and 2.5; Fig. 2). Additionally, based on the collaborative approach, another list of courses is generated and displayed to the user (Fig. 3 - A2). In both lists, certain courses can be hidden (Fig. 3 - I left), moved to a later semester (Fig. 3 - I right) or added to favorites (Fig. 3 - J). The list of favorites can be sorted according to specific course selection criteria (cf. Chapter 5) in accordance with requirement 3.5 (Fig. 3 - K). From the list of favorites, courses can then be scheduled into the timetable (Fig. 3 - L). In case of discrepancies, e.g. in the form of overlaps, differences from own goals or missing prerequisites, a hint is displayed to the user (Fig. 3 - H).

The linking of semester and study planning is enabled by moving courses to later semesters. In the study planning overview, it is then possible to schedule these courses into one of the following semesters. As in the semester planning overview (Fig. 3), a course list based on the collaborative approach is provided. Altogether, this process-oriented approach aims to simplify the planning process and reduce complexity (cf. requirement 2.6).

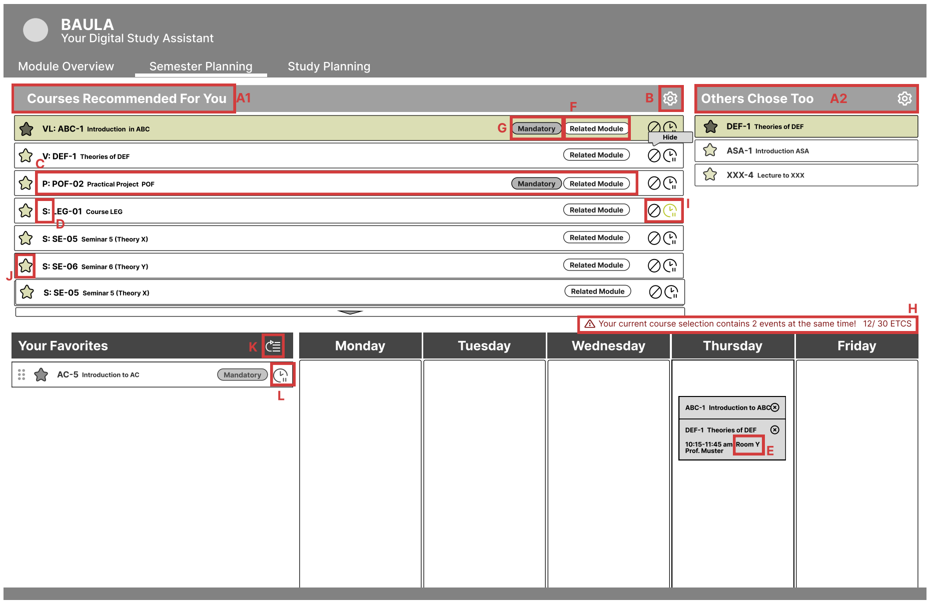

Fig. 3. Semester Planning Page of the CRS

The overall recommendation system and procedures were rated as helpful in the user test ($n = 6$). Students mentioned that the planning process is easier and more comprehensible and that such a system would motivate them to more detailed planning, while creating a more secure feeling when planning. In addition, the step-by-step process support and the selection criteria were evaluated as useful. It was also found that individual planning steps (e. g. course prioritization) were used according to one's personal needs – as they should be.

7 Discussion

Based on the previous findings, supported by the user evaluation, this research suggests six guidelines for designing a CRS:

- *The short-term and long-term course selection criteria used in practice should be included in the recommendation generation*, which can help to better match the recommendations to the needs of the user, which might lead to a higher satisfaction and usage rate of the application.
- *The CRS should not only provide course recommendations, but should also accompany the entire planning and decision-making process.* Thereby, the effectiveness and efficiency of the system may be improved, maximizing the benefits for students.
- *The potential (negative) consequences of selecting a recommendation should be made accessible to students*, which can encourage an informed decision, prevent an insufficient user experience and strengthen the trust in the system.

- *The (additional) effort of the use of the recommendation system should be kept as low as possible and be proportional to its use*, which particularly refers to the retrieval of specifications and the terminology used. Efficiency, familiarity and comprehensibility can increase the value for the students.
- *Adaptation to different students and their needs should be possible within the CRS*, so it can help realize individual and self-paced study progress.
- *The visible course information within the CRS is to be carefully sorted and presented according to its relevance*, whereby students get a quick overview of the most important course features.´

With regard to these findings, a major limitation is that they have been elicited in a specific University context and cannot be fully generalized. A second limitation is that although the thematic analysis was carried out transparently, the reliability of the results could further be improved using inter-rater reliability and triangulation. Further limitations are related to the prototype, i. e. the *How-Might-We method* is prone to fluctuating results, and the prototyping tool used for user tests has limitations – which have been considered in the user tests. Lastly, not all specified requirements were considered in the CRS as they relate to organizational aspects. Also, some of the evaluation results will remain open for further iteration.

8 Conclusion

This work has identified criteria for designing a user-oriented CRS. In the context of the decision-making process of study planning, the central criteria and the course selection process have been analyzed and transformed into requirements for a CRS, which was implemented prototypically and evaluated in a user test. As has been shown, a user-centered CRS shall include multidimensional criteria which can be condensed into six guidelines. Thereby, this research contributes to filling the research gap within the user-centered design of CRS. It is also an extension to the previously more algorithmically driven design of course recommendation algorithms. Moreover, it shows how a user-centered design can be developed and tested from an application context of RS, similar to Ma et al. [10–12]. Further steps are a second iteration regarding the double diamond model, as well as the selection of a recommendation algorithm for this specific context.

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