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SCA Advice System: Ontology Framework for a Computer Curricula Advice System Based on Student Behavior

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Abstract

This study proposed an SCA advice system. It is an ontology-based recommender that provides advice on appropriate computer curricula based on the behavior of high school students. The three computer curricula at Chiang Mai Rajabhat University include computer science (CS), information technology (IT), and web programming and security (WEB). This study aims to design the ontology framework for an SCA advice system. The system considers three core ontologies: student, computer-curriculum, and advice. After analyzing student behaviors, the behavior types of CS, IT, and WEB were determined to be SB-2, SB-1, and SB-5, respectively. All subjects in these three curricula were analyzed and grouped into seven groups. Their curricula were synthesized in terms of basic skills, basic knowledge, and characteristics. Finally, advice results can be obtained by consolidating the curriculum nature of the CS, IT, and WEB curricula.

Index Terms: Advice system, Education ontology, Recommendation system, Student behavior types

I. INTRODUCTION

Universities offer various types of courses. Although course information is provided on websites, students struggle with finding and selecting courses that meet their expectations. In addition, students do not know what they like or want to do in the future. They should be assisted in finding appropriate courses for their higher education. A recommendation system (RS) [1] assists humans by providing appropriate advice based on certain domains. In the commercial domain, RSs introduce products and services to customers by analyzing their behavior [2,3]. In the health sector, RSs recommend healthcare for individuals, such as in terms of nutrition requirements per day [4], as well as medicine and healthcare methods. In statistics, RSs propose statistical approaches based on multi-criteria rating data [5-10]. In the technology domain, RSs support frameworks that employ online and offline applications [11-14]. In tourism, RSs supply travel information by considering the answers to semantic questions to support personal data interests [15,16]. In academia, RSs are an important tool for academics, such as in managing both online and on-site didactical activities (teaching, learning, and examination) [17,18], measuring learning outcomes, predicting grades, examining how students' academic and courses influence their enrollment patterns, defining student groups and courses at different levels [19], recommending higher education studies [20-22], and recommending suitable courses to students [23,24]. In the career domain, several types of career RSs [25,26] attempt to match relevant careers to users. The RS employs a user profile module that stores user information and personalities and a job-based knowledge module that contains relevant knowledge representing occupations, abilities, and skills to recommend occupations to users.

Most universities have reported an increase in student dropout rates in their annual self-assessments. This is

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believed to be caused by ineffective curriculum management. A root cause for this is the students. Students do not know or understand their characteristics or career preferences. This is because they have no experience with certain courses or knowledge of certain career information.

Accordingly, they cannot select courses that meet their goals. This results in them dropping out of university halfway through their studies. In addition, this results in low grade point averages (GPAs) for students who continue their studies, and those who graduate often do not work in their field of study. Moreover, although computer curricula are diverse, they remain similar in some aspect. Computer curricula include computer science (CS), information technology (IT), web programming (Web), computer engineering (CE), business computers (BC), and computer animation (CA). Many universities have designed their own computer curricula to create strong selling points. Unfortunately, this is a problem for students who lack an understanding of the nature of each curriculum; thus, they may not know which suits them best.

Therefore, finding ways to reduce the dropout rate of students, as well as ensuring that students are enrolled in the curricula that best matches their behavior and nature, is a worthwhile challenge. This study selected and investigated three computer curricula offered at Chiang Mai Rajabhat University: CS, IT, and WEB. Although the core of these three computer curricula are similar, their end careers differ. Students who graduate from CS, IT, and WEB tend to be programmers, analysts/system managers, and web developers, respectively.

We aimed to develop a semantics-based advice system for students planning to study a computer curriculum. We designed the system as an ontology-based framework. It comprises three core ontologies: student, computer-curriculum, and advice. We called this the SCA advice system. The system development process was divided into four main tasks. The first task involved constructing a student behavior test that considers the student ontology and a student-behavior analysis. This task extracted seven types of student behaviors, and the elements of each type were used to design a behavioral test. The second task involved enumerating and interpreting the nature of the three computer curricula (CS, IT, and WEB) in the form of basic skills, basic knowledge, and characteristics. Basic skills refer to the fundamental skills that students require to take certain courses. Basic knowledge refers to knowledge that students should acquire by taking these courses. Characteristics refer to the nature of a student based on the curriculum's requirements. We designed the computer-curriculum ontology to store these curriculum features. The third task involved compiling the student behaviors in the student ontology and the curriculum attributes in the computer curriculum ontology; the advice aspects are maintained in the advice ontology. We constructed the SCA advice system by applying an ontology-based application management (OAM) framework.

The remainder of this paper is organized as follows. Section II describes ontology-based technologies. Section III reviews RSs in education. Section IV presents the methods and details for designing the student, computer-curriculum, and advice ontologies, and Section V discusses our findings. Finally, Section VI concludes the paper and presents directions for future research.

II. ONTOLOGY-BASED TECHNOLOGIES

One of the ontology-based technologies currently used is the Web Ontology Language (OWL), which was designed for the semantic web. This web should be human-readable and workable with linked data compared with the scattered messaging of https URLs that point to one another. Data ontology is a key component of creating such a web. We used this technology to build the SCA advice system [27].

Digital twin definition language (DTDL) [28] is a new ontology-based technology used to describe the digital twin models of smart devices, assets, spaces, and environments. It describes the abilities of digital twins that enable new platforms and solutions to leverage the state of each twin. The ontology-based modeling and evolution of digital twins for the assembly workshop has deployed a variant of JSON, called JSON-LD [29]. This is an application of DLDT.

Digital transformation has become increasingly popular. This involves transforming non-digital processes by incorporating computer-based into all aspects of an organization. Ontology-based technology is involved with digital transformation applications. Examples of this include leveraging digital transformation for supply chain resilience [30], identifying the digital transformation of conceptual components required in designing a knowledge model [31], and developing an ontology for business process management [32].

Digital transformation requires data transformation, which includes the development of strategies to access information buried in text. Ontology-based technologies have emerged for data transformation purposes. The most common data transformations involve converting raw data into a clean and usable form, converting data types, removing duplicate data, and enriching data to benefit an organization. During data transformation, analysts determine the structure of the data, map the data, extract the data from the original source, execute the transformation, and store the data in an appropriate database. An ontology-driven framework for data transformation in scientific workflows [33] describes the reduction of integrating heterogeneous data by providing data integration and transformation tools, thereby enabling researchers to focus on "real science," that is, discovering new knowledge through analysis and modeling.

III. RECOMMENDATION SYSTEMS IN EDUCATION

A. Education Recommendation System

Extensive studies on RSs have been conducted in the field of education. The research is classified based on the tasks involved in the target educational process. Concerning before-school preparations, Wu and Wu [34] presented an RS that can recommend a set of courses that students should learn by comparing their learning curves with those of past students. A learning curve is constructed using several grade datasets. For higher education in India [20], a system was proposed that employs content-based filtering techniques to recommend suitable universities to users by calculating similarities between users' preferences and interests. In Australia [21], an education decision support system was proposed that applies a decision tree technique with applicants' data to analyze the user's educational data. The system presents individuals with Australian universities where they can apply.

Concerning during-school recommendations, an RS was developed to help learners succeed in their studies. Oprea [17] introduced a collaborative ontology development methodology for educational systems called "EduOntoFrame." The workflow of the framework comprises the specifications of the ontology purpose, expert domain knowledge conceptualization, personal ontology unification, ontology implementation, and ontology testing. An example of a recommendation is "C++ programming language," which should be studied in object-oriented programming courses.

In the evaluation of student grades, an RS recommends measurements and assessments. Elbadrawy and Karypis [19] introduced a top-n course-ranking RS that employs domain-aware grade prediction. This RS helps advisors recommend courses to students suitable for their degrees and make informed decisions regarding course enrollment to improve learning outcomes. Domain-aware grades are grade datasets that are analyzed using matrix factorization, user-based collaborative filtering, and popularity-based ranking. Students and course groups are defined based on the structures of the grade data and students' academic features.

B. Ontology-Based Recommender in Education

Important attributes regarding RSs in education, both online and on-site [35], include: 1) the student data such as in terms of their sex, age, GPA, gift, skill, special ability, computer literacy, and family information; and 2) university data such as in terms of their faculty, programs, curricula, fees, environment, facilities, and grades (high-low). In education, an ontology-based RS aims to provide guidance based on the attributes most relevant to each student's profile. The system suggests curricula or universities that are appropriate according to the personal information, interests, preferences, and abilities of each student [22,36]. The concept of the system requires student-ontology, course-ontology, and mapping methodologies between the data and ontologies to obtain recommendation results.

Some studies have focused on student ontology, and others have focused on course ontology. Learner ontology, sometimes called an ontological student profile, is popular in knowledge-based construction because the learner's understanding of the domain can be shared and reused. The student profiles, relationships, conditions, and restrictions of the ontology can be reused as a basis for inferring additional student characteristics. Student profiles are provided explicitly by students and divided into three broad information categories: personal, academic, and general [37,38]. Sharma and Ahuja [39] presented an RS that recommended the most appropriate e-learning content for computer science students. It incorporates two ontologies: learner and learning-domain [40,41]. The learner ontology represents information about the learners and their relationship with the learning-domain ontology. The learning-domain ontology describes the target learning concept such that the learning concept is completed and the learning course is mastered.

Course ontology or ontology-based recommended courses are designed to collect information about course qualifications and recommended courses that meet the different needs of learners [24,42]. With an ontology, curriculum data enrichment is an input for teachers to reflect on and use as a training medium in classrooms. In addition, an ontology-based curriculum RS exists that guides adaptive learning by introducing courses for learning and practicing skills to increase the competitiveness of future jobs [43].

C. Ontology-Based Application Management Framework

The OAM framework [11,44] is a semantics-based knowledge management approach. Semantics-based knowledge management is a method of organizing and linking explicit and tacit knowledge to specialized knowledge or ontologies in information systems or computer programs. An ontology is stored as a structure of specialized knowledge developed by knowledge engineers and domain experts. The OAM architecture comprises three layers. The first layer is an ontology development tool or core engine. The second layer is a database ontology mapping tool. The third layer comprises ontology applications such as RSs and semantic searches.

IV. METHODS AND RESULTS

A. Overall Framework

The overall framework of the SCA advice system is structured in two processes. The first step involves identifying the characteristics of each student. To this end, we introduced a seven student-behavior (7-SB) test. The 7-SB test is a tool for judging students' behavioral categories based on the 7-SB types. To conduct the test, students log into a platform, fill out their profile information, and complete the 7-SB test. The system then analyses and determines the student's behavioral type. The second process involves recommending the computer curriculum that best matches the students' behavior. Because the system comprises semantics-based knowledge of three domains, the main components of the system are the student, computer-curriculum, and advice ontologies. Fig. 1 illustrates the framework.

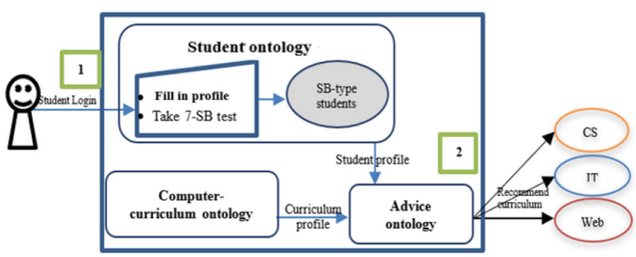

Fig. 1. Overall framework of the SCA advice system

B. Student Ontology and SB-Types for CS, IT, and WEB

In education, the student domain is a key element in ontology-based recommendations. A student ontology was used to store student profiles. Our preliminary study on student ontology [45] highlighted the problem of students selecting their majors in the computer science field. Because the target university offers three similar computer curricula (CS, IT, and WEB), students interested in the computer science field struggled with deciding which curriculum to select. Therefore, we extracted the characteristic groups of the students for each curriculum. We [45] illustrated the processes of extracting learner characteristics and revealed seven groups of learner characteristics for CS, IT, and WEB students. The extraction process began with synthesizing human behaviors from four classical theories: Myers-Briggs type indicator (MBTI), Enneagram, Holland's six personality types, and multiple intelligences (MIs). By matching synonymous keywords relevant to the behavior of learners from these four theories, nine special groups of learner characteristics were synthesized. Each group contained several attributes that represented the behavior of the learners in that group.

The next step involved confirming whether the nine synthesized learner characteristic groups represented the learners' actual behavior. The tests were constructed and assessed using the objective consistency of items, exploratory factor analysis (EFA), and confirmatory factor analysis (CFA). The analyses were performed on a test group of 400 students. Guffaz et al. [36] reported only seven characteristic learner groups. These are the 7-SB types (Fig. 2). Moreover, a measurement tool for assessing the behavior type was constructed (the 7-SB test).

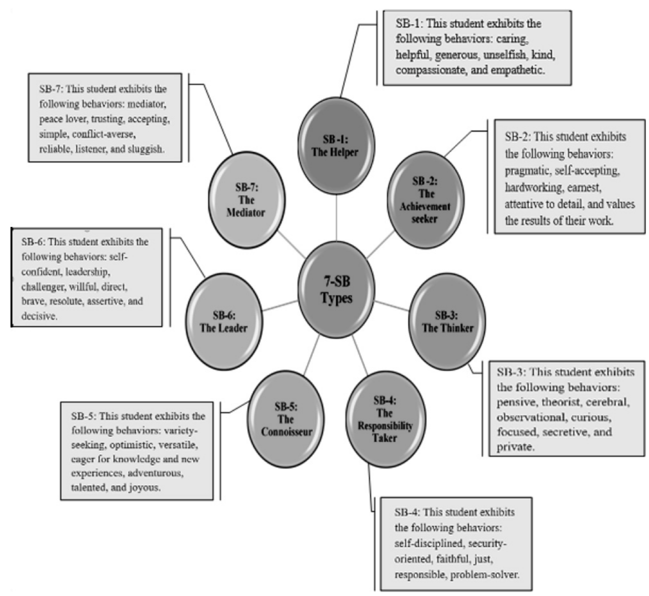

Fig. 2. 7-SB types

After we obtained the 7-SB types, we analyzed student behavior types for students in three similar computer curricula to obtain the behavior types of students in CS, IT, and WEB. The sample consisted of third- and fourth-year students with a GPA of more than 2.75. They were selected and considered representative students of their curriculum. Participants were asked to complete the 7-SB test. The behavioral attributes of each type in the 7-SB test involved a 1-6 rating scale to indicate the level of concordance of the students' behavior, where 1 means the least concordant and 6 means the most concordant. The most concordant type (1^{st}) was the type with the largest number of students, who rated it as six (6). The second-most concordant type (2^{nd}) was the type with the largest number of students, who rated this type as five (5). The results show that SB-2 and SB-1 are the 1^{st} and 2^{nd} concordant type of CS; SB-1 and SB-2, the 1^{st} and 2^{nd} concordant type of IT; and SB-5 and SB-2, the 1^{st} and 2^{nd} concordant type of WEB, as shown in Table 1.

We designed and created a student ontology to analyze and store student profiles. The student ontology consists of five

Table 1. The most and second-most concordant behavior types were third- and fourth-year CS, IT, and WEB students

Major	CS		IT		WEB	
No. of samples	57		72		23	
The most and second-most behavior types	1^{st}	2^{nd}	1^{st}	2^{nd}	1^{st}	2^{nd}
	SB-2	SB-1	SB-1	SB-2	SB-5	SB-2

concepts: the student profile, 7-SB type, level of concordance, 7-SB test, and test results. The relationships of the concepts are is-a, part-of (p/o), and attribute-of (a/o). Fig. 3 shows the architecture of the student ontology, and Fig. 4 details the architecture.

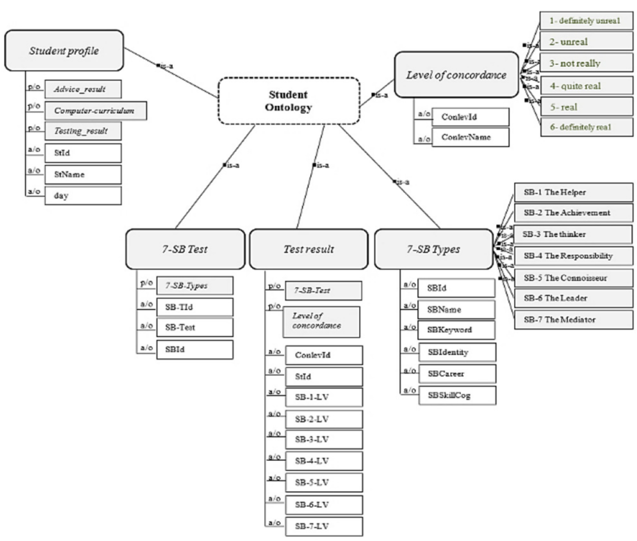

Fig. 3. Architecture of the student ontology.

C. Computer-Curriculum Ontology

To determine the student characteristics for which this curriculum is suitable, we analyzed the characteristics of the three curricula. We identified 15 compulsory subjects and 32 elective subjects, 15 compulsory subjects and 39 elective subjects, and 15 compulsory subjects and 34 elective subjects for the CS, IT, and WEB, respectively. We analyzed all 55 subjects of the three curricula and determined that some subjects served as the basis for all three curricula, some were shared between two curricula, and a few were specific to one curriculum. Therefore, we divided the patients into seven groups (Table 2). We synthesized the students' basic skills, basic knowledge, and characteristics suitable for taking the subjects in each group. We call these three elements the "curriculum nature." Basic skills are the fundamental skills that students should possess to take a subject. Basic knowledge refers to the knowledge that students should prepare to

Concepts	Relationship	Relationship details	
		Name	Description
Student profile	part-of	*Computer-curriculum* *Testing_result* *Advice_result*	It is the concept in Computer-curriculum ontology It is the concept in Student ontology It is the concept in Advice Ontology
	attribute-of	StId StName Day	Student ID Student name Login date
7-SB Types	IS-A	SB-1: The helper SB-2: The achievement seeker SB-3: The thinker SB-4: The responsibility taker SB-5: The connoisseur SB-6: The Leader SB-7: The Mediator	Seven types of student behavior
	attribute-of	SBId SBName SBKeyword SBIdentity SBCareer SBSkillCog	ID of the particular behavior type (ex. SB-1) name of the particular behavior type (ex. The helper) keyword of the particular behavior type identity description of the particular behavior type proper career of the particular behavior type skills and cognitive found in the particular behavior type
Level of concordance	IS-A	1- definitely unreal 2- unreal 3- not really 4- quite real 5- real 6- definitely real	Six level of concordances between each question in the test and the actual behavior of the test taker
	attribute-of	ConlevId ConlevName	Concordance level ID (ex. 1) Concordance level name (ex. definitely unreal)
7-SB Test	part-of	*7-SB Types*	It is the concept in Student ontology
	attribute-of	SB-TId SB-Test SBId	Question no. in 7-SB test Question sentence in 7-SB test This question indicates which SBId.
Test result	part-of	*7-SB Types* *Level of concordance*	It is the concept in Student ontology It is the concept in Student ontology
	attribute-of	StId SB-1-LV SB-2-LV SB-3-LV SB-4-LV SB-5-LV SB-6-LV SB-7-LV	Student code Student's concordance level of question no.1 in 7-SB test Student's concordance level of question no.2 in 7-SB test Student's concordance level of question no.3 in 7-SB test Student's concordance level of question no.4 in 7-SB test Student's concordance level of question no.5 in 7-SB test Student's concordance level of question no.6 in 7-SB test Student's concordance level of question no.7 in 7-SB test

Fig. 4. Details of the student ontology.

take a subject. The characteristics are the nature of the student based on the subject's requirements.

The computer-curriculum ontology was designed to store the curriculum characteristics of the seven subject groups. It comprises seven concepts: Computer-curriculum, Subject _group, Subject, Subject_type, Computer_science, Information_technology, and Web_programming. The relationships between the concepts are is-a, part-of (p/o), and attribute-of (a/o).

Fig. 5 illustrates the architecture of the computer curriculum ontology, and Fig. 6 details the ontology.

Table 2. Seven subject groups and the number of subjects in the group for the CS, IT and WEB curricula

Subject group	No. of subjects	Description
CS_IT_WEB_group	15	Common subjects for CS, IT and WEB curricula
CS_IT_group	6	Common subjects for CS and IT curricula
CS_WEB_group	7	Common subjects for CS and WEB curricula
IT_WEB_group	5	Common subjects for IT and WEB curricula
CS_group	5	Subjects for CS curriculum
IT_group	10	Subjects for IT curriculum
WEB_group	7	Subjects for WEB curriculum

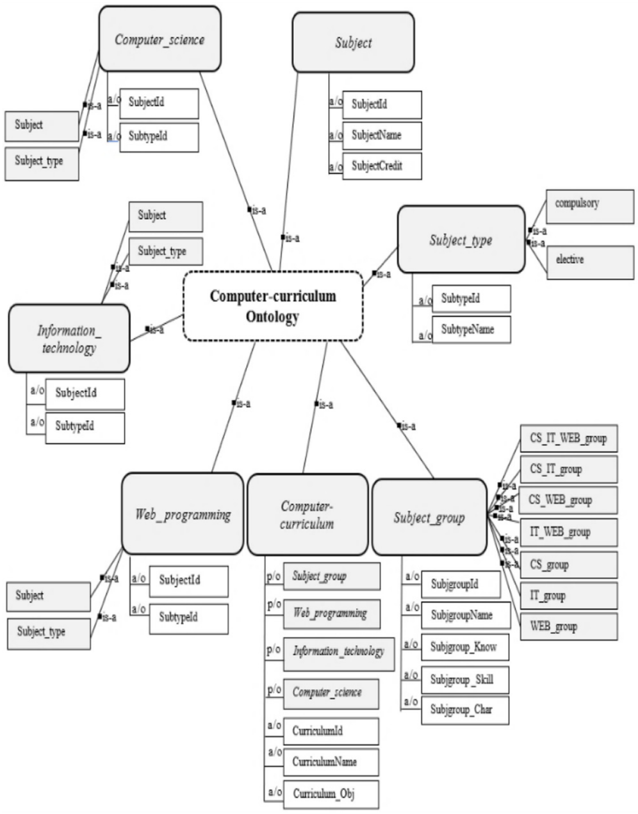

Fig. 5. Architecture of the computer-curriculum ontology.

Concepts	Relationship	Relationship details	
		Name	Description
Computer-curriculum	Part-of	*Subject_Groups* *Computer_science* *Information_technology* *Web_programming*	They are concepts in Computer-curriculum ontology
	Attribute-of	CurriculumId CurriculumName CurriculumObj	Computer curriculum ID Computer curriculum name Computer curriculum objective
Subject_groups	IS-A	CS_IT_WEB_group CS_IT_group CS_WEB_group IT_WEB_group CS_group IT_group WEB_group	Seven subject groups
	Attribute-of	SubgrId SubgrName SubgrKnow SubgrSkill SubgrChar	Subject group ID Subject group name Basic knowledge of this particular subject group Basic skills of this particular subject group Basic characteristics of this particular subject group
Subject	Attribute-of	SubjectId SubjectName	Subject ID Subject Name
Subject_type	IS-A	compulsory elective	Two types of subjects
	Attribute-of	SubtypeId SubtypeName	Subject type ID Subject type name
Computer_ science	Part-of	*Subject* *Subject_type*	They are concepts in Computer-curriculum ontology
	Attribute-of	SubjectId SubtypeId	Subject ID of the subject in CS curriculum Subject type ID of this particular subject.
Information_ technology	Part-of	*Subject* *Subject_type*	They are concepts in Computer-curriculum ontology
	Attribute-of	SubjectId SubtypeId	Subject ID of the subject in IT curriculum Subject type ID of this particular subject.
Web_ programming	Part-of	*Subject* *Subject_type*	They are concepts in Computer-curriculum ontology
	Attribute-of	SubjectId SubtypeId	Subject ID of the subject in WEB curriculum Subject type ID of this particular subject.

Fig. 6. Details of the computer-curriculum ontology.

D. Advice Ontology

We constructed the advice ontology from advice_CS, advice_CS, and the curriculum nature of CS, IT, and WEB. This was achieved by performing an intersection operation among the curriculum nature of the subject groups in which the particular curriculum was composed. For example, the curriculum nature of CS is the intersection of the curriculum nature that appears in CS_group, CS_IT_group, CS_WEB_ group, and CS_IT_ WEB_group, and this is called advice_CS. The IT curriculum nature is the intersection of the curriculum nature that appears in IT_group, IT_ WEB_group, and CS_IT_WEB_group, and this is called advice_IT. The curriculum nature of WEB is the intersection of the curriculum nature that appears in WEB_group, CS_WEB_group, IT_WEB_group, and CS_IT_WEB_ group, and this is called advice_WEB.

Recalling the analysis of SB type for the students in CS, IT, and WEB, the SB-2 type is the main behavior type of CS students. Therefore, students who completed the 7-SB test and received the SB-2 type receive the recommendation that they should enroll in the CS curriculum. The system then provides the student with advice on CS. Table III shows three SB types, CS, IT, and WEB, and their corresponding advice.

Table 3. SB types and their corresponding advice

SB-type	Advice	The intersection of "curriculum nature" (basic skill, basic knowledge, and student characteristics) of these subject groups			
SB-2	advice_CS	CS_group	CS_IT_group	CS_WEB_group	CS_IT_WEB_group
SB-1	advice_IT	IT_group	CS_IT_group	IT_WEB_group	CS_IT_WEB_group
SB-5	advice_WEB	WEB_group	CS_WEB_group	IT_WEB_group	CS_IT_WEB_group

We designed the advice ontology to store advice_CS, advice_IT, and advice_WEB. This consists of *advice* concepts. Fig. 7 illustrates the architecture of this ontology, and Fig. 8 presents its details.

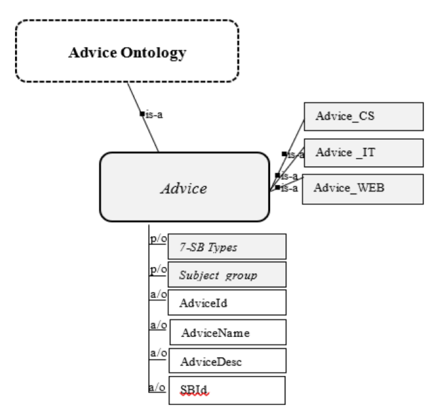

Fig. 7. Architecture of the advice ontology.

Concepts	Relationship	Relationship details	
		Name	Description
Advice	Part-of	*7-SB Types* *Subject_Groups*	It is the concept in student ontology It is the concept in computer-curriculum ontology
	IS-A	Advice_CS Advice_IT Advice_WEB	Three kinds of curriculum advice
	Attribute-of	AdviceId AdviceName AdviceDesc SBId	Advice ID Advice Name Advice result which summarized basic skill and knowledge the learner should have, as well as characteristic the learner should be. ID of the behavior type (ex. SB-1) from *7-SB Types*

Fig. 8. Details of the advice ontology.

E. Assessment of the SCA Advice System

First, we assessed the behavioral type of a target group. The target group of the SCA advice system was high school students about to enter the university system. According to the principles of adolescent behavior, high school students and first-year bachelor's students belong to the same group. Therefore, we conducted SB-type tests on first-year students who had just entered their curriculum. Table 4 lists the number of students in each curriculum and the SB-type results**.** These are the same as the SB types for CS, IT, and WEB.

Table 4. The most and second-most concordant behavior type of first-year CS, IT, and WEB students

Curriculum	CS		IT		WEB	
No. of sample	25		36		10	
The correct SB type	1st	2nd	1st	2nd	1st	2nd
	SB-2	SB-1	SB-1	SB-2	SB-5	SB-2
The SB test result of target group	1st	2nd	1st	2nd	1st	2nd
	SB-2	SB-1	SB-1	SB-2	SB-5	SB-2

Then, experts performed a conformance assessment of the nature of the CS, IT, and WEB curricula. Fig. 9 summarizes the results.

Advice	advice_CS	advice_IT	advice_WEB
SB-type / Curriculum nature	SB-2: The achievement seeker (towards success, pragmatic, self-accepting, hardworking, earnest, always self-development, attentive to detail and follow-up, the results of the work is important)	SB-1: The helper (caring, helping, generous, unselfish, kind, compassionate, principle of others benefits rather than him/herself, openly feelings)	SB-5: The connoisseur (variety-seeking, optimistic, versatile, always quest for knowledge and new experience, favor adventurous and risk, talent, joyous and lives planner.)
Basic skill	1. Computer skill	1. Adhoc problem-solving skill 2. Flowcharts/algorithms skill	1. Skill in reading and summarizing the main concepts 2. Software design and website development skill 3. Flowcharts/algorithms skill 4. Mathematical / logical skill
Common basic skill	1. Skills in comparing, analyzing, distinguishing, and applying data 2. Operating system and internet skills 3. Programming skill 4. Search skill 5. Communication skill 6. Presentation skill		
Basic knowledge	1. Flowcharts, symbols, and algorithm 2. Computer laws and ethics. 3. Mathematical logic, sets, and graphs.	1. Flowcharts, symbols, and algorithms 2. Computer laws and ethics 3. Technology multimedia	1. Principle of the algorithm 2. Information technology system 3. Information security 4. Mathematical logic, sets, and graphs
Common basic knowledge	1. Principles knowledge of information, computer components, database system, operating system, and the internet system. 2. Programming in one or more computer languages.		
Characteristic	A principled person who thinks, analyzes, and solves problems in a systematic way. A person who plans and works in a step-by-step manner, A person who dares to face problems, and dare to decide A person who is logical and rational	A person who has the art of designing and presenting information A disciplined and prudent person who has leadership, vision, and ability to work as a team A person who likes to explore and experiment	A principled person who thinks, analyzes, and solves problems in a systematic way. A person who plans and works in a step-by-step manner, A person who is diligent in practicing web development. A person who is passionate about challenging and creating new things.
Common characteristic	A diligent and patient person who always practice in programming, study, and search for new information and knowledge A creative person who likes to initiate, observe, and remember.		

Fig. 9. Summary of advice results from the conformance assessment.

V. DISCUSSION

We developed the SCA advice system as a semantics-based knowledge system. We constructed three ontologies: student, computer-curriculum, and advice.

We designed the architecture of the student ontology to store student profiles. In this study, the stored profiles consisted of one type of 7-SBs, which were determined from the results of the 7-SB test. The 7-SB types [36] were extracted by synthesizing human behavior from four classical theories and assessing the behavior types of 400 high school students. The behavioral characteristics of the 400 students were collected voluntarily. During data collection, we followed the research ethics guidelines. The 400 high-school students under the supervision of trainee teachers at Chiang Mai Rajabhat University. They informed of the research policy, and underwent only personality tests. Personal information such as their identification number, first name, last name, address, and any other identifying information was not recorded. The personality test results were analyzed and grouped into behavioral groups. Participants agreed to provide their personality test results.

We conducted an EFA and CFA and confirmed 7-SB types: SB-1 (the helper), SB-2 (the achievement seeker), SB-3 (the thinker), SB-4 (the responsibility taker), SB-5 (the connoisseur), SB-6 (the leader), and SB-7 (the mediator). We then analyzed the student behavior types for three similar computer courses. The analysis revealed that SB-2, SB-1, and SB-5 were behavior types specific to CS, IT, and WEB students, respectively.

The architecture of the computer curriculum ontology was constructed to represent the curriculum nature of the students belonging to a curriculum. To obtain the curriculum nature of these three curricula, we analyzed 55 subjects from these three curricula and grouped them into seven subject groups: CS_IT_WEB_group, CS_IT_group, CS_WEB_group, IT_WEB_group, CS_group, IT_group, and WEB_group. The curriculum nature of the seven subject groups were synthesized and stored in the computer-curriculum ontology.

We constructed an advice ontology to store the advice results of the curriculum nature for CS, IT, and WEB and called them advice_CS, advice_IT, and advice_WEB, respectively. The results presented the curriculum nature that students should have or exhibit. Moreover, experts assessed the advice results for conformance.

The SB-2-type behavior matched the basic characteristics obtained from advice_CS. SB-2-type students are achievement seekers who are likely to be successful, pragmatic, self-accepting, hardworking, earnest, self-developed, attentive to detail, likely to follow-up, and value the results of their work. They are principled people who think, analyze, and solve problems in a systematic manner, plan and work in a step-by-step manner, and face problems and make decisions in a logical manner. SB-2 is the correct type for CS students. In addition, advice_CS provided the skills and knowledge that CS students should possess, such as in terms of computer skills, flowcharts, symbols, algorithms, logic, sets, graphs, and computer laws and ethics. Advice_IT revealed SB-1. SB-1-type students are helpers who are caring, helpful, generous, unselfish, kind, compassionate, conscious of others' benefits rather than their own, and open to their feelings. The SB-1-type behavior matches the basic characteristics of IT students, based on the results obtained from advice_IT, in that IT students exhibit a vocation for art in designing and presenting information. They are disciplined, prudent, team players, explorers, and willing to experiment. In addition, advice_IT provides the skills and knowledge that IT students should possess, for example, ad hoc problem-solving, flowchart/algorithm, and technology multimedia skills, as well as knowledge of computer laws and ethics.

Finally, advice_WEB was matched with SB-5-type students. SB-5-type students are connoisseurs. They are variety-seeking, optimistic, versatile, in search of knowledge and new experiences, in favor of adventure and risks, talented, joyous, and life planners. This type is appropriate for the basic characteristics of WEB students, based on advice_WEB. They are passionate about challenges and creating new things. Basic skills for WEB students include reading and summarizing, software design and website development, flowchart and algorithm, and mathematical and logical skills. In terms of basic knowledge, WEB students should learn about algorithms, IT systems, and information security.

VI. CONCLUSIONS AND FUTURE RESEARCH

The SCA advice system is an ontology-based RS that suggests an appropriate computer curriculum based on the personal information of high school students. This study investigates three similar computer curricula: CS, IT, and WEB. Because the SCA advice system was developed as a semantics-based knowledge system, three ontologies were designed: the student, computer-curriculum, and advice ontologies. This study presents the methodologies used to design the three ontologies.

The student ontology was designed to store student profiles. To obtain the correct student profile, the SB types were extracted for the CS, IT, and WEB curricula. This began with synthesizing human behaviors from four classical theories and then assessing the SB type of 400 high school students. The EFA and CFA results confirmed 7-SB types for target students. Next, the behavioral types of students in three similar computer curricula were analyzed. We determined that SB-2, SB-1, and SB-5 were specific behavior types for CS, IT, and WEB students, respectively. The architecture of the student ontology was designed. It contains five concepts: student profile, 7-SB type, level of concordance, the 7-SB Test, and test results.

The curriculum nature captures the basic skills, basic knowledge, and characteristics of learners belonging to a curriculum. The architecture of the computer-curriculum ontology involved seven concepts: Computer-curriculum, Subject_group, Subject, Subject_type, Computer_science, Information_technology, and Web_programming.

The architecture of the advice ontology includes advice concepts called advice_CS, advice_IT, and advice_WEB. The results presented the curriculum nature that students should have.

In the future, we plan to extend the scope of the SCA advice system to other curricula at Chiang Mai Rajabhat University. We hope that our SCA advice system will be widely applied and that it assists high school students in selecting an appropriate curriculum for their higher education.

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