Meta-Model Design Technique for Industrial Demand-Driven Curriculum

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산업체 수요중심 커리큘럼을 위한 메타모델 설계 기법

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<Abstract>

The cooperation between universities and IT industry in producing IT manpower of quality is urgently called for to create the effective labor pool of supply and finally balance its supply and demand. Korean Government launched a program where industrial demand-driven curriculums are developed and applied to universities. This paper proposes a design technique of meta-modeling demand-driven curriculums and courses, based on the 3D software space and the software development process. This technique is proven to result in extensibility, flexibility and quality improvement in software design. Therefore, we expect that the proposed technique makes curriculums and courses possible to be continuously improved in many aspects.

Key Words : Meta-modeling, Demand-driven Curriculum, 3D Software Space

Ⅰ. 서론

To solve the imbalance problem between the skill factors demanded by industry and the curriculums of universities, the cooperation between universities and IT industry is urgently called for to create the effective labor pool of supply and finally to balance its supply and demand. To facilitate the cooperation, Korean Government has been focusing on the training program of demand-driven IT works as one of the major policy measures by applying the SCM(Supply Chain Management) model to human resource development[1-5].

This paper suggests a design technique of meta-model of demand-driven curriculums and SI(System Integration) track, as one of five tracks in IT-software field in Korea. The design technique based on meta-model is newly proposed by OMG(Object Management Group) in software modeling and software design. By OMG, MDA(Model-Drive Architecture) standard has already been proposed and

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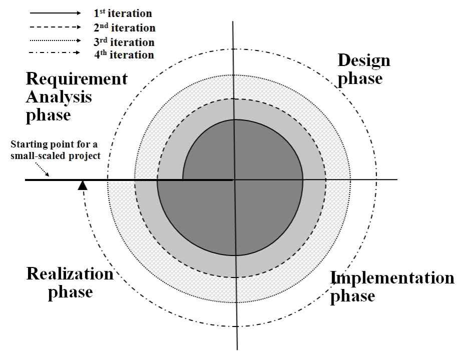
its approach is currently populated worldwide in software design[9-10]. This paper also views different aspects of curriculum and course model by applying the 3D software space in meta-model design technique[12]. The structure of this paper is as follows. Section 2 describes the related works: the concept of the 3D software space and development process of demand-driven curriculums. Section 3 designs the meta-models of demand-driven track curriculums and courses. Section 4 applies the 3D software space to demand-driven curriculum development and proposes a 3D curriculum space. Section5 describes an example of the proposed meta-model and the assessment results obtained by applying the proposed models into real domains. Finally, concluding remarks are described in section 6.

Ⅱ. Mechanism of 3D Software Space

In this section, we describe the concept of the 3D software space, which is a basis for meta-model design of demand-driven curriculums and courses, and the Curriculum Spiral model for demand-driven curriculum development[7, 12].

2.1 Spiral model for curriculum development

Like software development, academic curriculums are to change and evolve over a period of time. Applying the basic concept of the spiral model, which is an evolutionary software process model by Boehm, Curriculum Spiral model for demand-driven curriculum development has been derived[7-8, 11]. Like the original spiral model for software development, a whole curriculum development process is divided into several, time-boxed small-scaled projects, called *iteration stages*. An iteration stage is again subdivided into several activities, called *phases*. The artifacts of each iteration stage contain curriculums, detailed syllabuses, and class materials which can be applied to university programs. Figure 1 depicts the Curriculum Spiral model that performs four iteration stages, each of which contains six *phases*: Preliminary phase, Review phase, Requirement Analysis phase, Design phase, Implementation phase, and Realization phase. We modify existing spiral model[7-8, 11] into Curriculum Spiral Model in this paper.



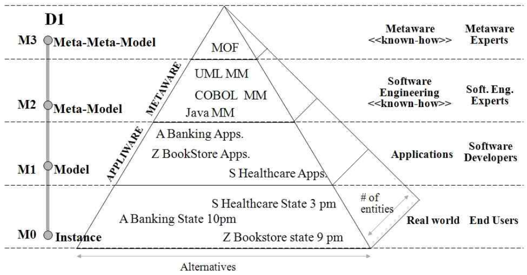
<Figure 1> Spiral model for curriculum development

The *Requirement Analysis phase*, the first phase in iteration stage, feedbacks from industry and universities are gathered, tracks are identified and analyzed, each of which has a demand-driven curriculum for a specialized area while satisfying the guideline of ABET, ACM, and IEEE/CS(Computer Science). In the *Design phase*, track curriculums are identified and designed, along with track goals, a curriculum tree, and preliminary design for demand-driven courses. In the *Implementation phase*, a detailed syllabus and class materials are constructed for each demand-driven course.

The curriculum development process starts from the center of the spiral. Several iteration stages are iterated following the spiral outwards. An iteration stops and resumes according to the needs of curriculum change.

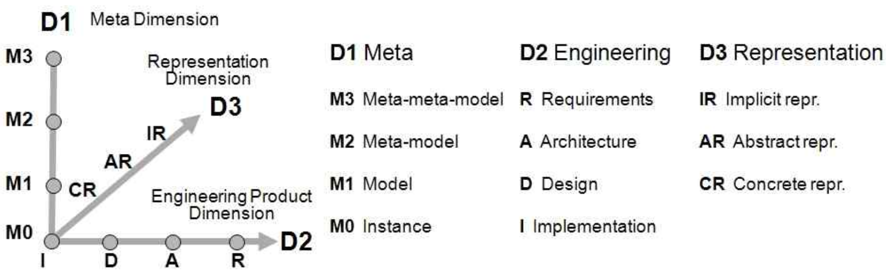
2.2 3D Software Space

The complex nature of software can be represented as a 3D software product space as depicted in Figure 2. Each dimension corresponds to a different kind of abstraction. All dimensions are orthogonal.



<Figure 3 > Meta pyramid and meta-actor pyramid

level (M2) is used to manage the production of software applications. The meta-meta-model level (M3) describes how the meta-models should be described and managed. For instance, the MDA standard proposes to use the Meta Object Facilities (MOF)[14, 17-19].



<Figure 2> 3D Software Space

2.1.1 Meta-Dimension(D1)

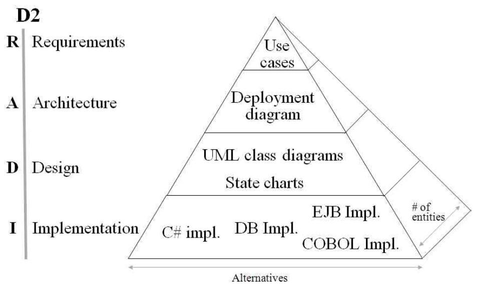
The *meta-pyramid* is depicted in Figure 3. The model level (M1) is the level where regular programs are. Entities at this level depend on the particular application domain considered.

The model level is used to manage the set of all possible real-world situations which are represented at the instance level (M0). *Metaware* by contrast is independent from application domains. The meta-model

2.1.2 Engineering Dimension(D2)

D2 aims at structuring software artifacts following a very basic engineering process. Four levels are distinguished, namely the requirement level (R), the architectural level (A), the design level (D), and the implementation level (I).

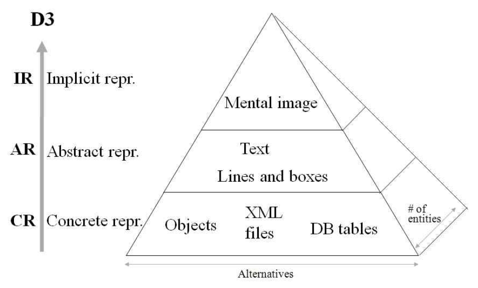
Figure 4 shows the *engineering product pyramid*. The pyramid shows four phases of life cycle and the outputs of each phase as an example.



<Figure 4> D2: Engineering product pyramid

2.1.3 Representation Dimension(D3)

It is important to recognize that a single piece of information can be represented in many different ways ranging from implicit representations to very concrete ones. Figure 5 depicts the *representation pyramid* Though there is a continuum of abstraction levels, only three levels are named for the sake of simplicity: implicit representation (IR), abstract representation (AR) and concrete representation (CR).



<Figure 5> D3: Representation pyramid

Ⅲ. Meta-models of Demand-Driven Curriculum and Courses

We design meta-models of both demand-driven track curriculums and demand-driven courses. These meta-models are the core artifacts which are used to build the 3D space in the next section.

3.1 Meta-model of Demand-driven Track Curriculums

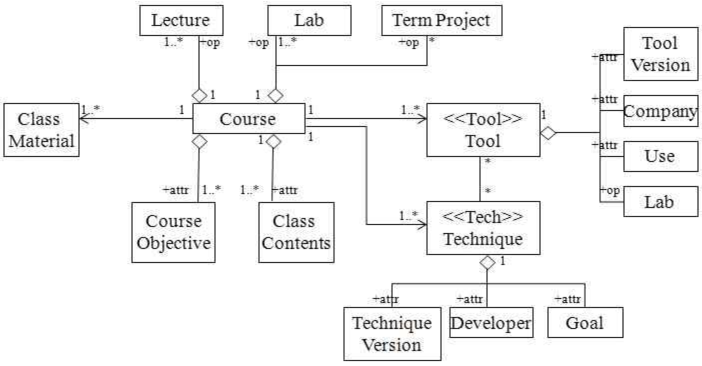
Figure 6 depicts a meta-model of total demand-driven curriculums defined by using UML(Unified Modeling Language) class diagrams[9-10, 15-16, 19-20]. Each element consisting Track Curriculum is represented with each class of UML. Also metal-model describe how to related with elements such as Track Curriculm, Track, Course, and so on.

As a result of Korean Government-leading surveys from universities and IT industry, IT-software field is divided into 5 tracks, which are SI(System Integration) track, SD(Software Development) track, MM(MultiMedia and game software) track, EM(EMbedded system software) track, and BI(Business Information) track. Track includes Curriculum Tree, Course Syllabus, and Detailed Syllabus. Course is classified into Fundamental Course, Prerequisite Course, and Demand-driven Course. Classified courses are described in the form of Prerequisite relationships in Curriculum Tree.

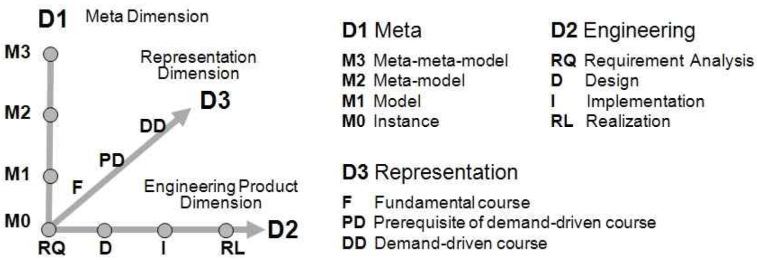
Real model is developed based on Meta-model. Example of real model is Figure 11 and Figure 13.

3.2 Meta-model of Demand-driven Courses

We define a meta-model of demand-driven courses of each track by using UML class diagrams. As shown in Figure 7, each Course consists of Course Objective,



<Figure 7> Meta-model of demand-driven course



<Figure 8> 3D curriculum space

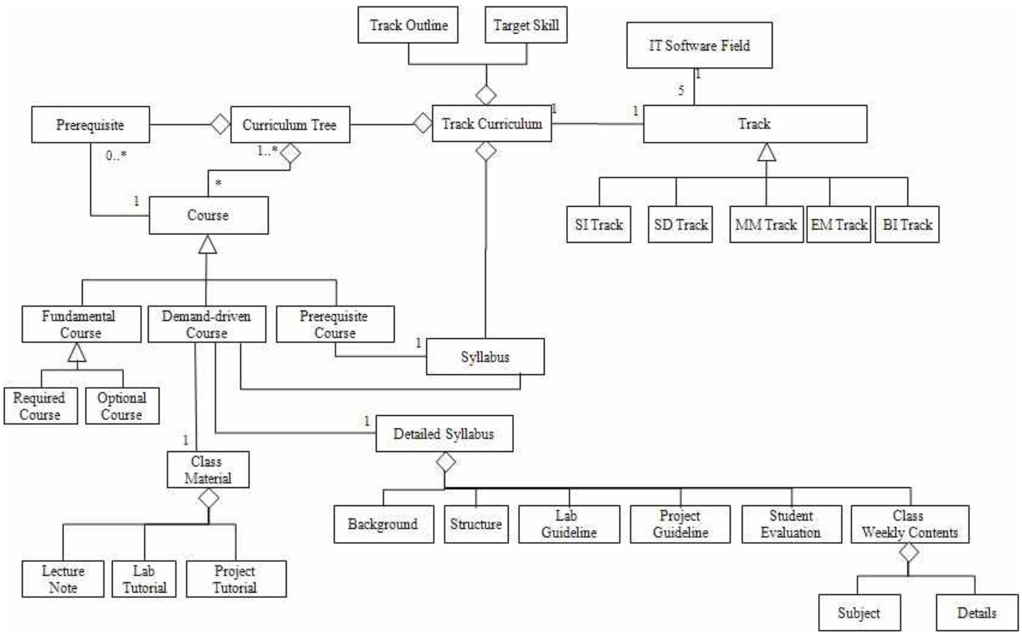
Class Contents, Lecture, Lab, and Term Project. Class Material and Tool are developed for each Course. The role name of Lecture, Lab, and Term Project is represented with ‘op’(abbreviation of ‘Operation’). This means that they become the operations of “Course” class. Each course should be operated with one or more lecture, lab, and term project.

Ⅳ. 3D Curriculum Space

In this section, we apply the concept of the 3D software space to demand-driven curriculum development[12]. The nature of curriculum can be represented as a 3D curriculum space as depicted in Figure 8. Like the 3D software space in 2.1, each dimension corresponds to a different kind of abstraction.

4.1 Model Architecture based on D1 Space

D1 constitutes the core of Korean Government-leading policy about IT university education. As in the original software D1 Space, four levels are distinguished: instances, models, meta-models and meta-meta models. As shown in Figure 9, curriculums and courses are at the model level (M1), Meta-models described in section 3 are mapped into the M2 level. Tracks and courses adopted and realized in universities correspond to the instance level (M0). The meta-meta level (M3) is included for the sake of completeness.



<Figure 6> Meta-model of demand-driven curriculum

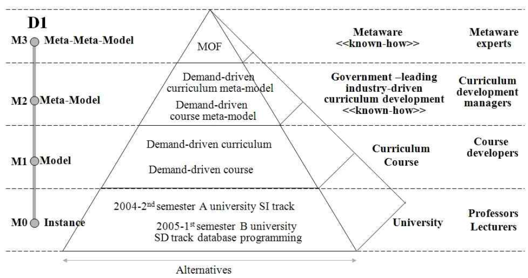
To describe the various levels in the meta pyramid, actors at each level are described, depicted in Figure 9. The goal of the actors working at a level is to help the actors at the lower level.

At the highest level of the pyramid (M3), *Metaware experts* can be anyone who triggers and support the curriculum development process in many aspects. They could be governmental administrators or officials in the area of university education.

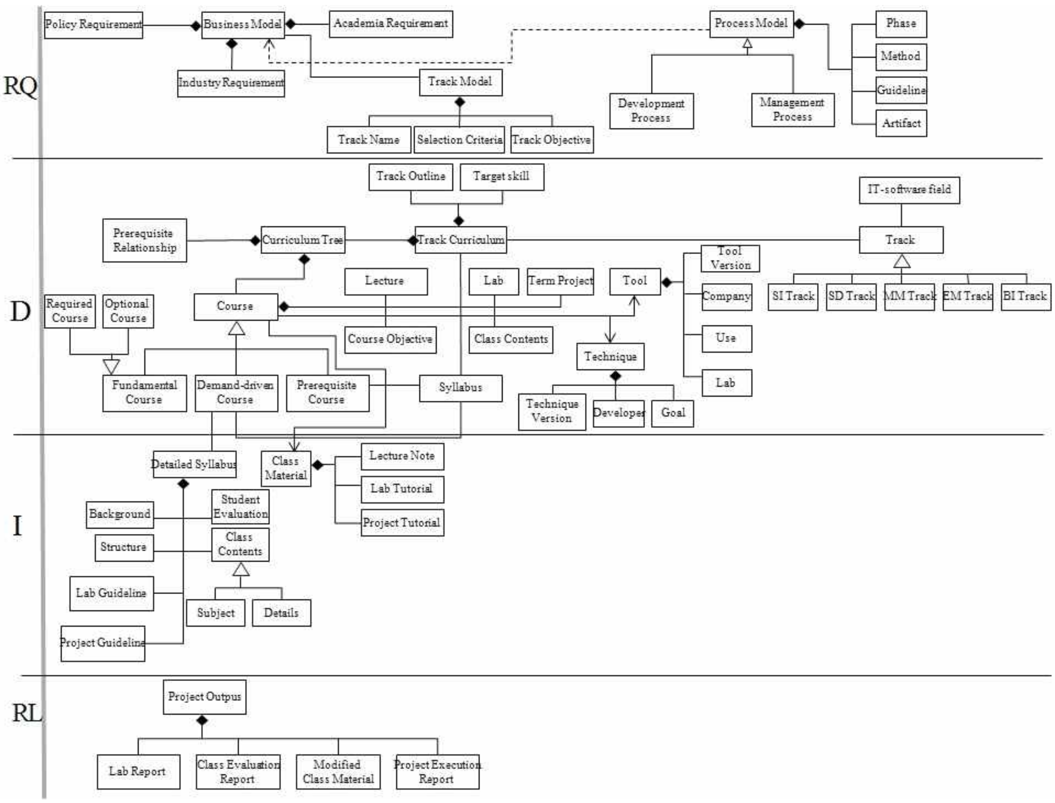
At the next level (M2), *Curriculum development managers* coordinate all phases of curriculum lifecycle. Curriculum development manager plans overall process, collects ideas, suggestions, and information from the rest of the participants and finalizes track decision and curriculum design.

Course developers are developers of curriculums and courses (M1). They develop all artifacts for curriculums and courses, such as track goals, syllabuses, curriculum trees and course materials.

At the instance level (M0), *Professors* develop the proper curriculums and courses according to the state of their departmental environments. *Lecturers* lecture courses using artifacts.



<Figure 9> Model architecture of demand-driven curriculums and courses in D1



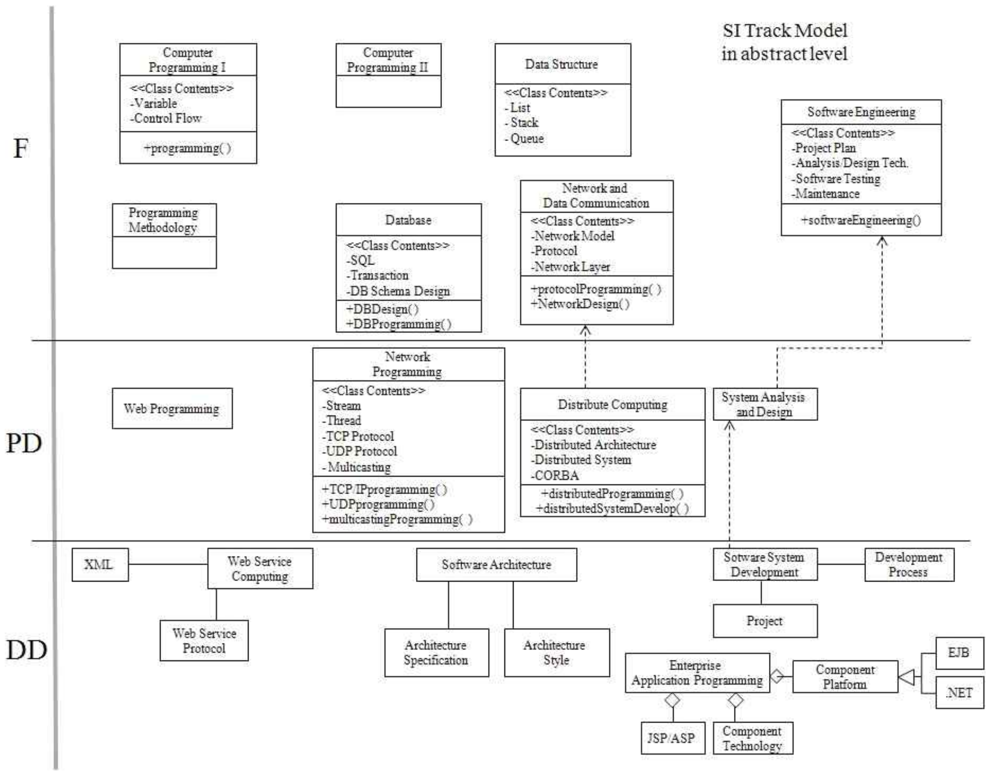
<Figure 10> Engineering pyramid : meta-model of curriculum development artifacts in D2

4.2 Model based on D2 Space

We propose models of demand-driven curriculums and courses by reflecting engineering pyramid in D2 space. D2 aims at structuring artifacts of demand-driven curriculums following the curriculum developing process in 2.2. Four levels are distinguished, namely the requirement analysis level (RQ), the design level (D), the implementation level (I), and the realization level (RL). D2 helps to make the distinction between requirement descriptions, design documents, implementation artifacts, and realization feedbacks. Figure 10 describes a meta-model of outputs, which shows four phases of life cycle and the outputs of each phase.

4.3 Model based on D3 Space

There are many different ways to represent a given entity ranging from very abstract representations to concrete ones. The D3 curriculum space is to represent the degree of abstractions for all artifacts from software life cycle, and is applied to curriculum development in this paper. Figure 11 depicts the degree of abstraction for courses of SI track. Courses of each track are divided into 3 layers: Fundamental



<Figure 11> Representation pyramid : meta-model of course description in D3

course (F), Prerequisite course of demand-driven course (PD), and Demand-driven course (DD). Fundamental courses are regarded as traditional computer science courses, Prerequisite courses are the direct prerequisites of Demand-driven courses, which deal with the skills most urgently needed by IT industry in Korea.

Ⅴ. Experiments and Assessment

For the purpose of proving feasibility of the approach proposed in this paper, this section describes a case study for the model derived by applying meta-model, and its assessment.

5.1 Case Study

The artifacts by applying the meta-model of demand-driven curriculum are tracks, curriculums, demand-driven courses, detailed syllabuses, and class materials.

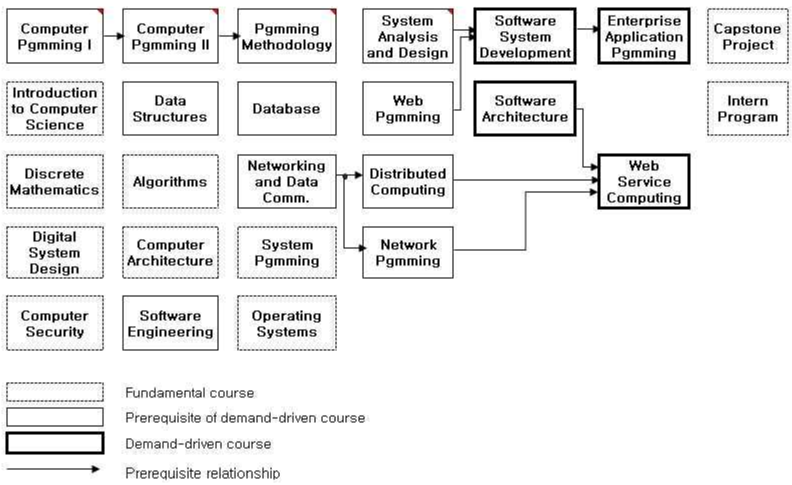
Referencing the previous work and analyzing industrial and academic needs, the five tracks are identified for IT-Software field and a curriculum and 4 demand-driven courses are designed for each track[6-7].

The five tracks identified are SI(System Integration)

1. Track outline
   System Integration track has a main goal in training practical skills required in SI company which develop general business application programs.
2. Target skill
   - Programming skill for web applications
   - Knowledge and application of software modeling
   - Understanding of software development process
3. Curriculum tree
4. Syllabuses of demand-driven courses

Course title	Web Service Computing
Prerequisite skill	Distributed computing
Course objective	- Understanding of Service-based Architecture and Necessity of Web Service - Understanding of XML Schema - Understanding of standard skill related to Web Service
Class method	Lecture, Lab, HW, Team Project, Test
Class contents	- Introduction to Web Service - XML, XML Schema - Web Service Basic Profile(SOAP, WSDL, UDDI) - Web Service support structure on NET Platform - Web Service support structure on Java Platform - Web Service Security, Business Process, Quality, Interoperability

<Figure 12> Partial track curriculum for System Integration track



<Figure 13> Curriculum tree for System Integration track

track, SD(Software Development) track, MM (MultiMedia and game software) track, EM(EMbedded system software) track, and BI(Business Information) track.

Figure 12 shows a track curriculum for SI track as an artifact from the Design phase. Through the preceding Requirement Analysis phase, outline and target skill for a track are defined to satisfy industrial and academic needs, and a curriculum is designed accordingly.

Figure 13 shows a curriculum tree for System Integration track, resulting from modeling. Arrows

<Table 1> Track preference in each technology (%)

Technology \ Track		SI	SD	EM	MM	BI	Etc.
S/W	System	31.03	34.48	11.81	2.59	15.00	5.43
	Application package	33.33	35.16	10.91	4.62	12.47	4.25
	Embedded	13.00	22.42	41.65	6.73	14.35	1.85
	Development tool	27.40	34.73	15.00	7.77	13.15	2.37
Subtotal		29.12	33.42	15.57	5.01	13.48	3.88
Computer-related service	SI	34.48	26.51	8.49	6.51	17.73	6.40
	DB	18.57	25.00	6.43	8.57	34.29	7.14
	Information security	21.11	51.11	14.44	2.22	7.78	3.33
Subtotal		32.21	28.58	8.87	6.27	17.99	6.18
Digital contents	Game	7.50	16.25	7.19	59.69	6.25	3.75
	Image · animation	22.00	16.00	2.00	17.00	10.00	33.00
	Contents solution	29.32	23.41	13.41	13.86	15.45	5.45
	Other contents	22.86	30.00	7.50	11.43	18.57	9.64
Subtotal		20.96	22.37	9.21	26.40	13.16	8.42
Information and communication service	Communication business	31.42	24.06	14.16	5.81	17.26	7.29
	Broadcasting service	26.58	24.74	11.32	7.11	22.11	8.16
Subtotal		30.28	24.22	13.49	6.11	18.40	7.49
Information and communication equipment	Communication equipment	18.53	32.06	20.88	3.24	13.24	12.06
	Communication terminal	13.54	35.83	26.46	7.92	8.33	7.92
	Information equipment	25.12	28.98	17.20	5.42	18.81	5.55
	Broadcasting equipment	17.27	20.91	48.18	0.45	11.36	1.82
	Parts	23.95	28.42	18.29	3.29	16.97	9.08
Subtotal		21.74	29.68	21.53	4.69	15.58	7.24
Educational service	Education	7.33	9.83	26.50	35.00	19.00	2.33
Total		27.02	29.18	15.19	7.56	15.45	5.95

between courses represent direct prerequisite relationships. Squares with dotted lines represent fundamental classes, squares with thick solid lines represent demand-driven courses, and squares with thin solid lines represent prerequisites of demand-driven courses. Artifacts from the Implementation phase include detailed syllabuses and class materials. Class materials include lecture notes, lab tutorials, and project tutorials.

5.2 Assessment

Korean Government has designed and driven the innovation of undergraduate curriculums to meet increasing industrial demand. A research made surveys on industrial preferences for the five tracks. About 2, 000 Korean companies were surveyed (about 1, 000 IT companies and about 1, 000 non-IT companies)[1]. The result shows demand preferences for human resources in each track. Out of five tracks, SD and SI stand out in demand pressure from the industry. Table 1 shows preferences of the tracks in each technology.

Korean Government selected 39 universities from all over the country for the first project year, 2004 and 71 universities for the next year, 2005. Each university in the program selected one or more tracks and adopted the suggested track curriculums.

Table 2 ~ Table 5 show survey results from lecturers and students at universities which participated in the program in 2004[13]. 96.8% of lecturers and 82% of students are found to be positive to the effect of SCM Project on college education. 79% of students are found to be satisfied with demand-driven courses. 81.5% of students answered positively for the lab and project based demand-driven courses to be effective in the real IT field.

<Table 2> Lecturer survey: Effects of the SCM project on IT college education

Evaluation Index	very unsatisfactory(1) ~ very satisfactory(5)					No Answer	total
	1	2	3	4	5		
Number Answered	0	0	2	1	60	0	63
Percentage	0%	0%	3.2%	1.6%	95.2%	0%	100%

<Table 3> Student survey 1: Effects of the SCM project on IT college education

Evaluation Index	very unsatisfactory(1) ~ very satisfactory(5)					No Idea	No Answer	total
	1	2	3	4	5			
Number Answered	12	29	120	106	724	2	19	1012
Percentage	1.2%	2.9%	11.9%	10.5%	71.5%	0.2%	1.9%	100%

<Table 4> Student survey 2: Class evaluation

Evaluation Index	very unsatisfactory(1) ~ very satisfactory(5)					No Idea	No Answer	total
	1	2	3	4	5			
Number Answered	4	22	178	448	358	3	7	1020
Percentage	0.4%	2.2%	17.5%	43.9%	35.1%	0.3%	0.7%	100%

<Table 5> Student survey 3: Lab/team project evaluation

Evaluation Index	very unsatisfactory(1) ~ very satisfactory(5)					No Idea	No Answer	total
	1	2	3	4	5			
Number Answered	3	16	160	481	350	3	7	1020
Percentage	0.3%	1.6%	15.7%	47.2%	34.3%	0.3%	0.7%	100%

Ⅵ. Concluding Remarks

Korean Government launched a program where demand-driven curriculums are developed and applied to universities. Five specialized areas in the IT-software field, called tracks, have been identified to reflect the demand from IT industry.

This paper suggests a design technique of meta-modeling demand-driven curriculums and courses based on the concept of the 3D software space. As well, the Spiral model for software development by Boehm is applied to the curriculum development process. The concepts of 3D software space are well-proven engineering techniques to produce high-quality and low cost software products. The meta-modeling technique using these concepts is proven to result in extendibility, flexibility and quality improvement in software design. Applying the concepts and the technique to curriculum development, we propose the 3D curriculum space. We architected, layered, and abstracted demand-driven curriculums. Because our approach describes the artifacts and the process of curriculums and course design by applying the 3D software space, we expect that curriculums and courses can be designed and represented in multidimensional aspects.

Furthermore, the modification or refinement of curriculums and courses can be achieved with flexibility and extensibility, and the quality of curriculums and courses can be improved continuously and incrementally. However, current research has limitations such as statistical significance test, quantitative assessment, and so on. We will develop an assessment model to verify our proposed technique.

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