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A Method to Solve PBL Issues and to Improve Project Management Competencies of Students

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It is generally accepted that Project-Based Learning (PBL) is very valuable in preparing students to become working members of society. However, some issues have been recognized with PBL such as: (1) some students lack an active attitude or ride on the coattails of their teammates in their PBL team work; (2) a range of achievement levels among project teams; (3) spending most of their time to discuss the objective and the goal; and (4) not well managed as a project. Integrated Scheduling Method (IScM) and the associated tool called Deliverables Dependency Matrix (DDM) have been proposed to create a highly feasible project schedule for a product development. It was noticed that they might have the potential to resolve these PBL issues because the schedule creation is a core part of project management and includes most of all factors to manage PBL as a project. Two trials of the application with Modified-IScM (M-IScM) and DDM to PBL courses have been conducted. The first trial was intended to evaluate if M-IScM and DDM could resolve the PBL issues. A lecture prior to the second PBL with some findings from the first trial was given to students to improve their project management competencies. As a result, it was confirmed that M-IScM and DDM had the potential to resolve the PBL issues and revealed that PBL had two internal project types, the Goal Search Project and the Goal Oriented Project with the associated work processes and methods. Furthermore, the Goal Oriented Project could be divided into the Development Project and the Value Creation Project. Understanding and utilizing these project types will improve the competencies of students regarding project management to produce a good outcome in PBL, and help develop the leadership and fundamental skills to be a capable business person .

Keywords: project management, project-based learning, work breakdown structure, scheduling

Introduction

It is generally accepted that Project-Based Learning (PBL) is very valuable in preparing students to become working members of society through the experience of resolving the social problems and themes presented by companies. Studies about PBL have been conducted from various aspects such as aiming at

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improving thinking, action, and teamwork of students on a proposed management model and evaluating their progress (Ioi, 2014), expanding the PBL scope of the collaboration to industry, local government, and universities globally (Furukawa, Hasegawa, Mano, Yamazaki, & Inoue, 2014; Pavlov, Nikitina, & Ilyinsky, 2017), and establishing the whole course structure in undergraduate and graduate schools, in which technical courses and PBL courses spiral up interdependently (Inoue, Hasegawa, Mano, Furukawa, Yamazaki, & Khantachawana, 2015).

The following common PBL issues, however, have been pointed out and some studies have been conducted.

(1) Some students lack an active attitude to the PBL team work, or ride on the coattails of their teammates in their PBL team work (Iwata, 2014; Johnston, 2005).

(2) It is sometimes difficult for a team leader to form a good team and to unify the team.

(3) It is difficult to fairly evaluate the grade of individual student (Bil & Dorrington, 2017; Matsuura, 2007).

The following issues are often observed in PBL courses.

(4) The achievement levels among project teams vary.

(5) The final deliverables are developed at the last minutes of the project, since students tend to spend most of their time to discuss the objective, the goal, or to create a new idea.

(6) Project management in the PBL project is not done well because the actual work has a higher priority than the project management work such as creation of a Work Breakdown Structure (WBS), a project schedule, and a project control with them.

Though the P and B in PBL stand for Project Based, PBL has not been studied well from a project management perspective. This paper studies PBL from a project management perspective.

Project management can be basically thought of as a methodology to implement the target deliverables within the planned QCD (Quality, Cost, and Delivery) by creating the project schedule, monitoring the gaps between the project plan and the actual performance, and controlling the project activities. The project schedule can be thought of as a core part of the project management because it contains most of the project management factors such as the roles and responsibilities of the project members, a scope management, an integration management, WBS creation, an assessment of work difficulty and uncertainty, a risk management, a quality management, a resource plan, a financial plan, and various conditions or restrictions unique to the project. It is important for students to view PBL as a project and to learn how to manage it with project management.

Integrated Scheduling Method (IScM) using the project management tool called Deliverables Dependency Matrix (DDM) has been proposed to create a highly feasible project schedule for a new product development and the relevant paper revealed the effectiveness of IScM and DDM for product development in a matrix organization (Yokemura, 2016). The paper pointed out the possibility to resolve the PBL issues noted above by applying IScM and DDM to PBL. The reasons are that the work on IScM and DDM can clarify the roles and responsibilities of project members which can strengthen a sense of responsibility among them, can make a feasible project schedule which can make students feel able to complete the assigned work by the due date, and as a result, the team can make a quality outcome by using project management deliverables and techniques.

The study has been conducted in two PBLs. The slightly modified IScM called Modified-IScM for PBL and DDM were applied to the first PBL to evaluate the effectiveness against the PBL issues. The first trial revealed the internal project structure in PBL which may improve the competencies of students for project

management to manage PBL as a project, and those findings were applied to the second PBL to see their effectiveness. The objectives of this paper are as follows.

(1) To evaluate the feasibility to resolve PBL issues as a result of the trial.

(2) To look for valuable findings to improve the productivity and competencies of students in PBL.

This paper studied PBL from the project management perspective. It revealed that the internal structure of PBL could be categorized into project types in the first half and in the latter half of PBL and there are suitable work processes and methods for the respective projects.

Students with these competencies are expected to select the project type and to take an appropriate work process and method to smoothly execute PBL. These competencies can develop the leadership competency of students to actively lead a project, and the fundamental project management skills needed to be a capable business person.

Overview of WBS, M-IscM, and DDM

Basics of WBS

WBS is the foundation of the project scope, the job assignment, and the project schedule creation in project management. WBS is briefly depicted below to facilitate the understanding of this paper. WBS is a hierarchical structure which includes the decomposed elements to extract all activities to produce the final outcome or the final deliverables. Deliverables include something measureable, tangible, and verifiable, and normally are expressed with an adjective + noun (Haugan, 2002, Chapter 2). In general, the project consists of deliverables and the work to produce the deliverables. Therefore, there are two directions to perform the decomposition, one from the deliverables side and the other from the work side. The first decomposition from the deliverables side is suitable for the project in which the final deliverables can be clearly defined such as a product development and a system development. This decomposition is called the physical decomposition and the decomposed element is called the deliverable in this paper. The deliverable is produced by several activities called the task. The second decomposition from the work side is suitable for the project in which the final outcome cannot be clearly defined such as holding events, offering services, and producing some results. This decomposition is called the logical decomposition and the decomposed element is called the logical element or the task in this paper. The task consists of several activities and can produce the deliverable. Figure 1 summarizes what mentioned above.

For example, WBS of the project, “making a sandwich”, can be constructed using both ways of decomposition. WBS of this project can be decomposed to “Preparation of materials”, “Preparation for cooking”, and “Finishing” by the logical decomposition. The physical decomposition can decompose this project to “Bread” and “Ingredients”. The second layer of WBS may have the physical elements and the logical elements such as software development and training. The decomposition is required to follow the 100% rule that the lower elements include everything in the upper element and the rule that the lower elements satisfy MECE (Mutually Exclusive and Collectively Exhaustive).

In the previous example, “Preparation of materials” in the logically decomposed WBS, can be constructed with the activities such as “Buy eggs”, “Buy bread”, and other activities. “Bread” in the physical decomposition can be constructed with the activities such as “Buy bread”, “Cut crust of a slice of bread”, and other activities. The project schedule is normally created by connecting those activities based on the dependency and the duration of activities (Department of Defense, 2010; NASA, 2010a; 2010b).

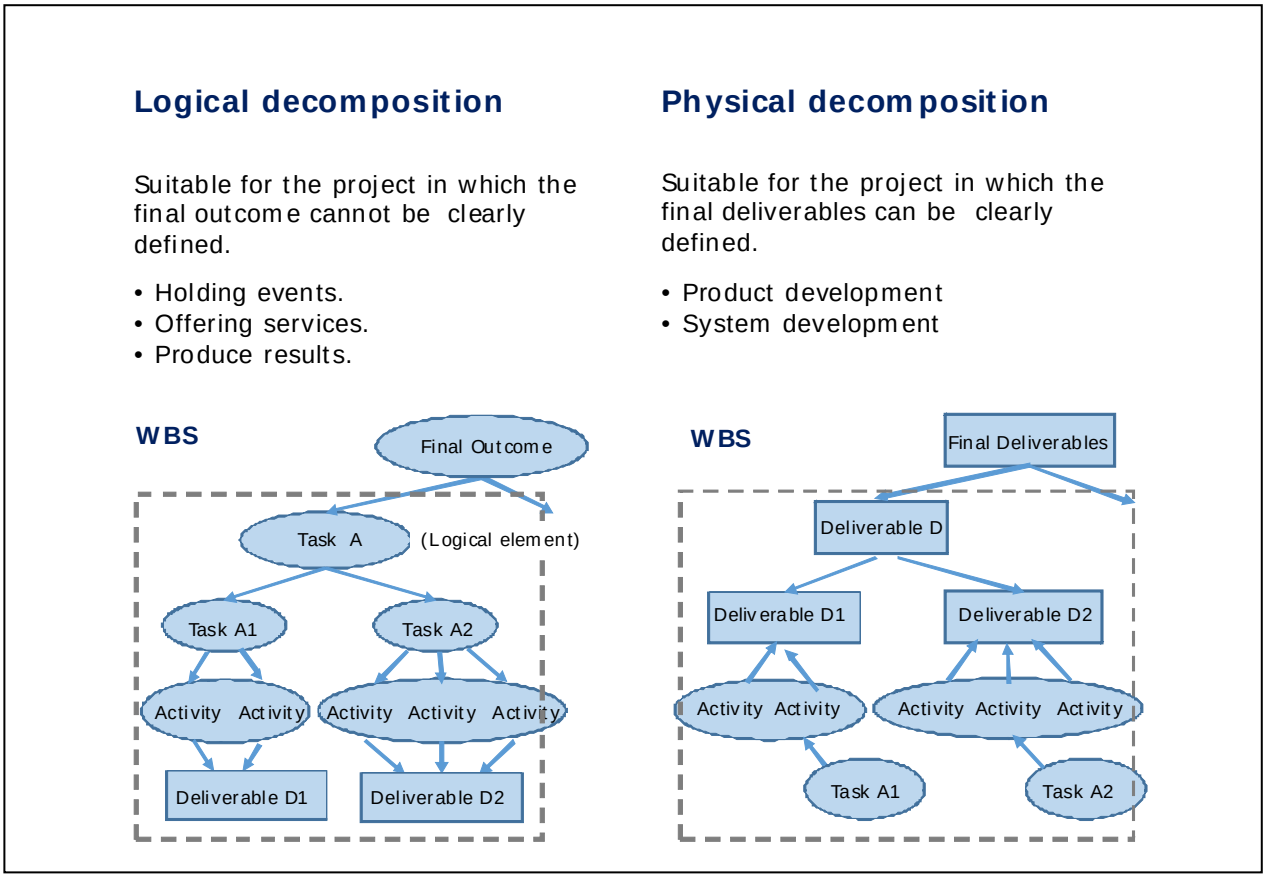


Figure 1. Two ways to create WBS.

Overview of M-IScM and DDM

This scheduling method mentioned above is basically activity-based and it is sometimes difficult to keep the consistency between the project schedule with activity-based and WBS with deliverables-based because of the change in activities or in WBS.

IScM is the method to create a highly feasible project schedule under the conditions below, which is the typical environment in a product development company.

Conditions in which IScM are applicable.

(1) A product is developed by functional organizations such as an electrical circuit design, a mechanical design, and a software design in a matrix organization.

(2) A product is developed by passing the intermediate deliverables (goods, parts, software, and data) from one functional organization to the next organizations.

(3) The functional organizations have a high capability in their major technical area, a rich experience of similar product developments in the past, and know the resource allocation plan, skills, and experience of individual engineer assigned to the project. Therefore, when the product specification is defined, they can understand well about what deliverables they need to develop as an output, and what deliverables they need as an input for producing their own deliverables. They also have a capability to estimate the work duration with relatively high accuracy to produce deliverables.

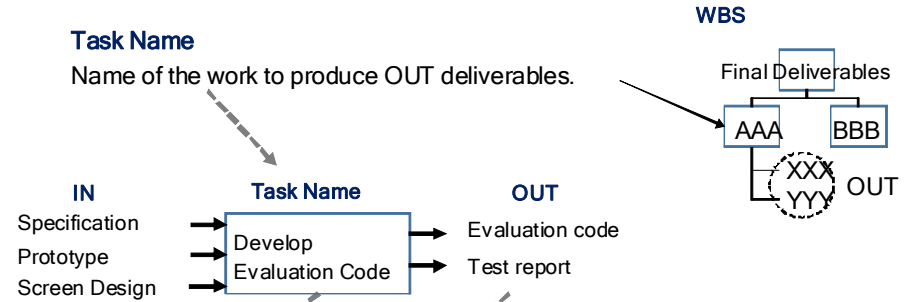
IScM and DDM were developed based on the following idea, given the assumptions noted above.

(1) The project schedule can be created with the flow of the intermediate deliverables passing from one functional organization to the next toward the final deliverables.

(2) It is important to focus on the transition timing of deliverables from the delivery side to the receiving side because there are various mismatches and gaps between them. Misunderstanding in the various delivery/receiving conditions of the deliverables and the ambiguity of the specification on both sides may cause a return of deliverables which means that the received deliverables are returned to the delivery side for some unsatisfactory reason. A return of deliverables will cause various negative impacts such as schedule delay, an increase in the development cost, and an emotional discord between the delivery and receiving sides. Solving the mismatches will reduce the uncertainty of the work and will increase the feasibility of the project schedule.

(3) The mismatch of the planned delivery date and the expected receiving date may reverse the order of the work. This reason will be addressed below in the explanation (2) in Figure 3. When the works are ordered sequentially, the project schedule will be extended much longer than the target project completion date. Solving mismatches mentioned in (2) may be able to reduce the uncertainty of the work to improve the feasibility of the schedule. It may also be able to squeeze the schedule buffer involved in the initial schedule, which may enable compressing the schedule toward the target project completion date.

DDM is the format to clarify what deliverables will be produced and, what deliverables are required, and clarify misunderstandings regarding deliverables and mismatch of date transferring deliverables in the delivery side and receiving side. Figure 2 shows the DDM format. Each column noted (A)~(F) is depicted as follows. The definitions of IN, OUT, IN deliverables, and OUT deliverables are specified in column (B).



(A) Task Name/ Responsible person	(B) Dependency	(C) Deliverables Name	(D) Conditions in delivery and receiving	(E) IN or OUT Responsible Org/Person	(F) Planned Delivery Date/Expected Receiving Date
Develop Evaluation Code/ PP	IN	Specification Prototype Screen Design	… … …	X1/ AA X2/ BB …	MM/DD/YY MM/DD/YY …
	OUT	Evaluation code Test Report	… …	… …	… …
…	IN	…	…	…	…
	OUT	…	…	…	…

Figure 2. DDM format.

(1) This column specifies the task name and the name of the responsible person. The task name is the name of the work to produce OUT deliverables.

(2) This column specifies the type of dependency, IN, or OUT. A dependency of deliverables that the task will produce is called OUT, and the deliverables with OUT dependency are called OUT deliverables. A dependency of deliverables that the task needs to get is called IN, and the deliverables with IN dependency are called IN deliverables. OUT deliverables to be produced are connected to the corresponding IN deliverables to be received by the next person or organization.

(3) This column specifies the deliverables name corresponding to IN or OUT.

(4) This column specifies the conditions in delivering OUT deliverables and receiving IN deliverables independently filled in by the delivery side and the receiving side. When the conditions of OUT deliverables are matched with the conditions of the corresponding IN deliverables in the receiving side, mismatches may be revealed. Since IN deliverables expect to get the quality deliverables, the conditions of IN deliverables are, for examples, “A review completed”, “Approved by XXX”, “A test report attached”, “Meet the specification XXX”, “Endorsed by Quality Assurance”, etc.

(5) This column specifies the name of the responsible organization or person for IN or OUT deliverables.

(6) This column specifies the planned delivery date or the expected receiving date for IN or OUT deliverables independently filled in by the delivery side and the receiving side.

The original IScM was developed for product development. When IScM was applied to PBL, the job assignment to each student was required. Therefore, the WBS creation step for the job assignment was added to the original IScM. This modified IScM is called M-IScM. Figure 3 shows the M-IScM steps.

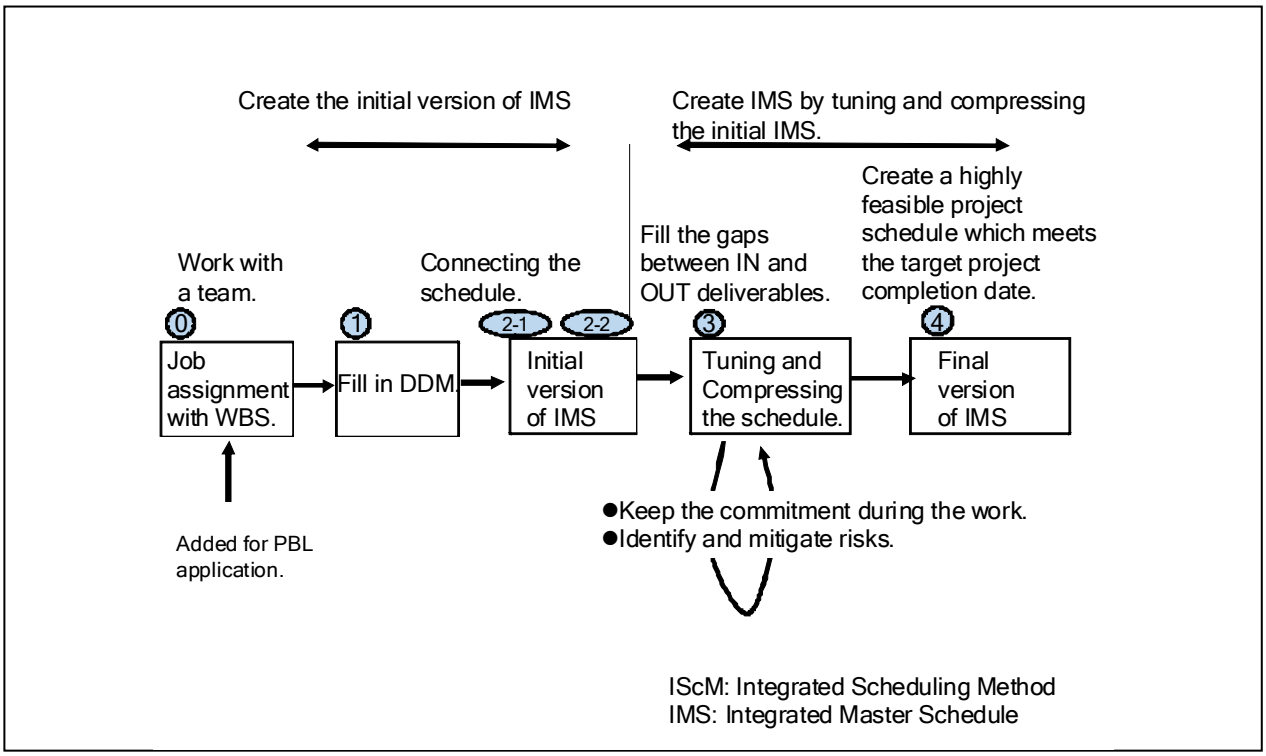


Figure 3. M-IScM steps.

Figure 4 shows the schematic flow to make it easy to understand M-IScM.

Sample project: Project starts on January 11 and ends on February 22.

The following is an explanation of each step.

(0) WBS of the final outcome is created. The decomposed deliverables are assigned to the PBL team members.

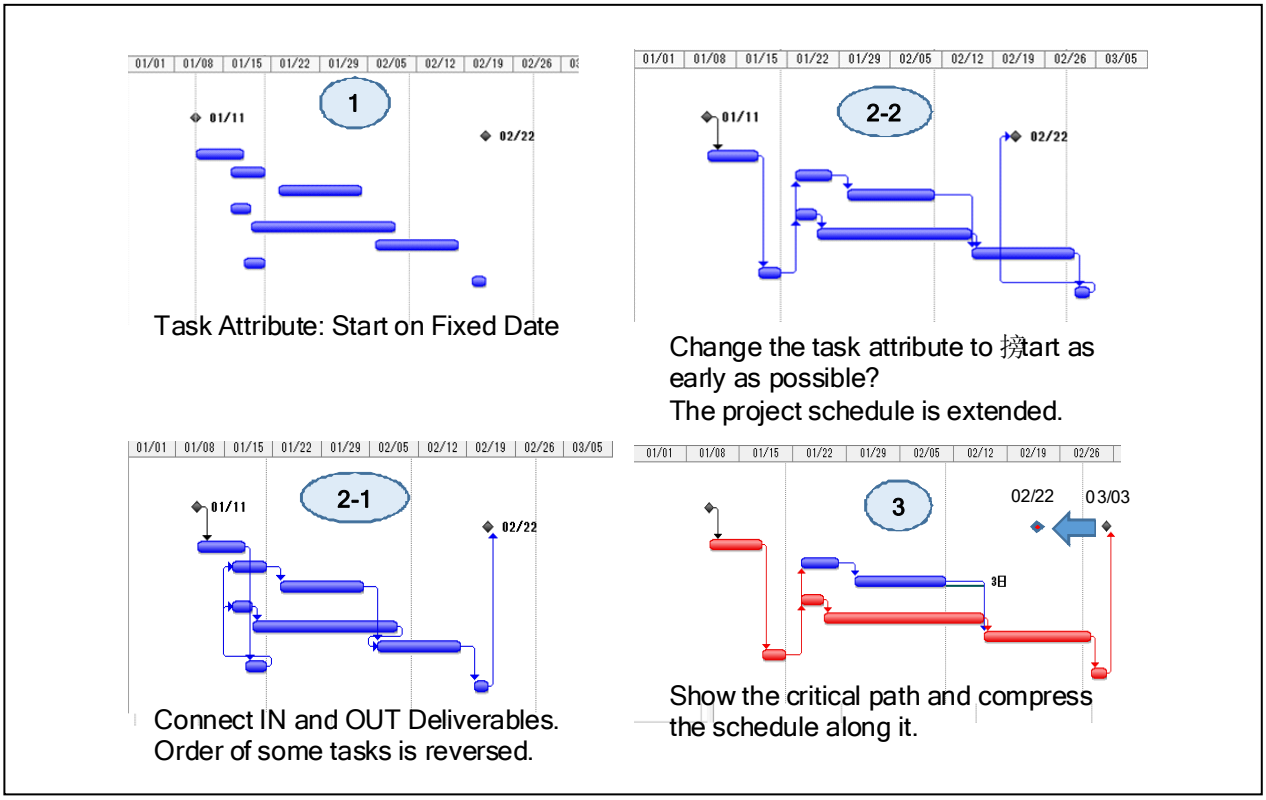


Figure 4. Conceptual flow of M-IScM.

(1) Team members fill in DDM by referring to WBS. The relationship between WBS and DDM is shown in Figure 5. Each member fills in the task he or she is assigned independently, which can help reveal the various mismatches of deliverables in the delivery side and receiving side.

(2) (2-1) The planned delivery date and the expected receiving date as described in the DDM are entered in the project schedule software with the attribute of the task as “start at the specified date” to fix the date. Then, the planned delivery date is connected to the expected receiving date for the same deliverables. At this time, the order of the work may be reversed in time. The reversed order is caused by human factors as follows.

(a) Humans tend to put some schedule buffer into the responsible schedule because they are afraid of uncertainty, risks, and desire not to be scolded, or minimize the amount of work they need to do.

(b) Humans tend to get the deliverables as early as possible to reduce the risk of schedule delay.

(c) Humans tend to set the delivery date as late as possible because of the reason (a) noted above.

(2-2) The attribute of the task is changed to “start as early as possible”. This action rearranges the order of the tasks sequentially. As a result, the project schedule may be extended beyond the target project completion date. This schedule is called the initial Integrated Master Schedule (IMS). Attention needs to be paid to cases where the same deliverables’ name has a different meaning or the different deliverables’ name has the same meaning in the connection of OUT and IN deliverables. To avoid these cases, the name list for the known deliverables is helpful. Dangling IN or OUT is sometimes found. If a dangling IN is found, nobody has a plan

to produce it. If a dangling OUT is found, nobody has a plan to receive it. The project team needs to check if someone misses them or if OUT or IN deliverables are not necessary.

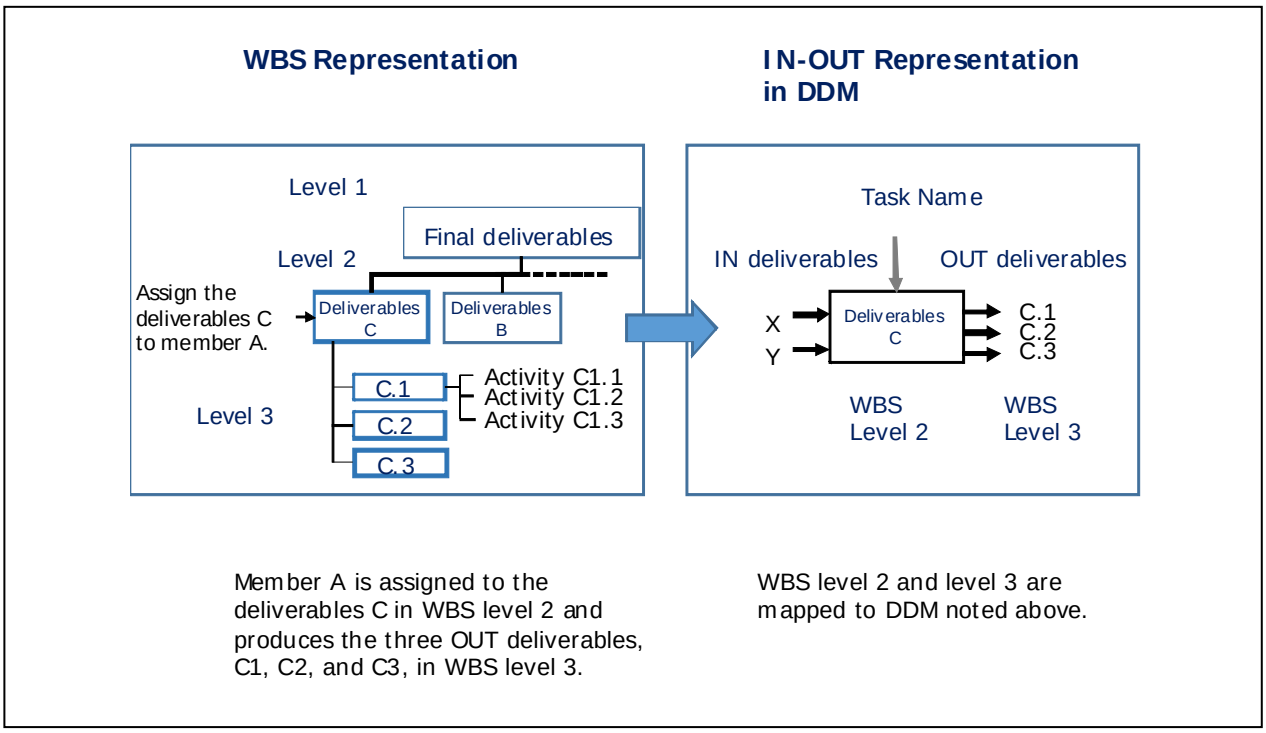


Figure 5. Relationship between WBS and DDM.

(3) The project team members have a meeting to find and solve the mismatches and to get an agreement between the delivery side and the receiving side. As a result, the uncertainty and risk can be reduced, which can reduce the occurrence of a return of deliverables and increase the feasibility of the schedule. They can also compress the schedule by squeezing the schedule buffer, taking the fast tracking which means splitting the task in parallel, or crashing which means adding a resource, to compress the schedule along the critical path toward the target project completion date. During the team discussion, the team can identify new issues and risks, and can take actions to mitigate them. In addition, the hot discussion will create a mutually reliable relationship among team members which will lead to unify the team.

(4) The completed schedule which meets the target project completion date and is supported by commitment of all members is called Integrated Master Schedule (IMS).

When the project schedule is created with project members, the clarification of roles and responsibilities of project members and a commitment to the delivery schedule can strengthen a sense of responsibility, which is expected to resolve the PBL issue (1). The dense discussion with team members can unify the team, which is expected to resolve the PBL issue (2). The clarification of roles and responsibilities of project members and the individual contribution to the final deliverables may enable to evaluate the performance of the individual student, which may resolve the PBL issue (3). The creation of WBS, DDM, and the project schedule enables students to manage PBL as a project, which may resolve the PBL issues (4) and (6). The solution for the PBL issue (5) will be addressed by the findings of the trial. The trial application of M-IScM and DDM to PBL was conducted to see if they can resolve the PBL issues as expected.

Trial Application of M-IScM and DDM to PBL

PBL Courses for Trial

Two trials have been done in the PBL courses. M-IScM and DDM have been applied to the first PBL to see if the PBL issues can be resolved and to see some findings. Those findings have been applied to the second trial to improve the project management competencies of students. The overview of two PBL courses is as follows.

First PBL course: Industrial Project Based Learning

(1) This PBL course collaborates with industry and local government and is an elective course for the graduate students in the second semester at Shibaura Institute of Technology. This course is an advanced PBL course following the PBL course called “Exercises in Systems Engineering” in the first semester. This trial was done in 2016.

(2) This course aims at implementing a prototype or proposing a sophisticated plan based on the idea created in the first semester.

(3) Twenty-nine students took this course. Japanese: 23, non-Japanese: six.

(4) Five teams with the following themes were formed.

(a) Team A: Master of ceremony (MC) robot for a marriage party.

(b) Team B: Data collecting device for crow protection.

(c) Team C: Revitalizing local factories.

(d) Team D: Fish promotion for children.

(e) Team E: Rental cycle promotion.

Second PBL course: Exercises in Systems Engineering

(1) This PBL course shows how to proceed on a project with system engineering knowledge. This course is offered as a compulsory course for the graduate students in the first semester at Shibaura Institute of Technology. The trial was done in 2017.

(2) Seventy-nine students took this course. Japanese: 74, non-Japanese: five.

Fourteen teams were formed.

PBL Course Structure

The PBL course has the following milestones called Design Review (DR).

(1) PBL kicks off: The PBL themes presented by companies and local government are given to the team.

(2) DR-1 (plan proposal): The project planed to solve the problem in the theme is presented.

(3) DR-2 (project plan and design proposal): The refined project plan and system design are presented.

(4) DR-3 (final presentation): The final outcome is presented.

Results of Trials

Results in the First Trial

Table 1 shows the results of the PBL course (Yokemura & Inoue, 2017). The ranking was decided through voting by professors, students, and attendees in the final presentation. M-IScM and DDM were evaluated by participating students. Two types of project were identified in the final presentation, a development type and a value creation type. The development type project means that it develops something functional. The value creation type project means that it proposes a valuable idea or plan to solve the problem. Team A successfully developed a prototype and presented it with a promotional video. Team A received the top ranking.

Table 1

Result of the PBL Course Work

Team	Project Theme	Project Type	Ranking	Evaluation to M-IScM and DDM
A	Master of ceremony (MC) robot for a marriage party.	Development Type	1	3 3: Very Effective 2: Effective 1: Not changed or not in use
B	Data collecting device for crow protection.	Development Type	3	2
C	Revitalizing local factories.	Value Creation Type	2	1 (Not in use)
D	Fish promotion for children.	Value Creation Type	4	1 (Not in use)
E	Rental cycle promotion.	Value Creation Type	5	1 (Not in use)

Tables 2 and 3 show the comments of the team A and the team B through E respectively.

Table 2

Comments of Team A

Team	Project Theme	Comments
A	Master of ceremony (MC) robot for a marriage party.	● My work attitude became active because I understood my roles and responsibilities, and how to behave in my team. ● I was conscious of the due date because the due date was specified in DDM. I was also conscious of producing my responsible deliverables because I understood the dependency on the other members. ● I did not see a value for DDM in the stage of the idea creation. But, when I became busy for the development work, I was conscious of my responsibility because all members started to work along the agreed schedule. ● As a team leader, it was easy to find a missing work and a work not assigned. ● As a team leader, DDM was a good tool because DDM could make it easy to do the job assignment to the team members. DDM helped to find a job to which an additional resource needs to be added. ● If DDM was not used, we would not have developed the prototype. ● We found many mismatches by referring to DDM. For example, we noticed the work to which no one was assigned. ● Especially, IN in DDM made it easy to find mismatches.

Table 3

Comments of Team B through E

Team	Project Theme	Comments
B	Data collecting device for crow protection.	● I think DDM helped encourage the active attitude of the team members. ● As a team leader, it made it easy to assign a job to the team members. ● We could share the whole schedule, and understood the flow of the work. ● Our consciousness to finish the work by the due date became strong. As a result, we did it. ● When we compare the workload with the benefit in creating DDM, the benefit is more valuable than the workload. ● During the idea creation time, the action-oriented thinking is better than the deliverables-oriented thinking.
C	Activation of local factories.	● Since our work was just to create a new idea, we did not need to use DDM. ● We crated the project schedule. But, we could not perform the work along the schedule because the ideas changed many times. ● We ordered the cast-metal good as a sample product. At that time, DDM worked. ● I am doing the research work as a team in my Lab. DDM may be useful to create the project schedule toward the milestone by dividing the work to the project members.
D	Fish promotion for children.	● As our work was just a proposal creation, we did not need to use DDM.
E	Rental cycle promotion.	● As our work was just a proposal creation, we did not need to use DDM. ● In the past, I participated in PBL to create a new wheel chair. DDM may be useful for such a project.

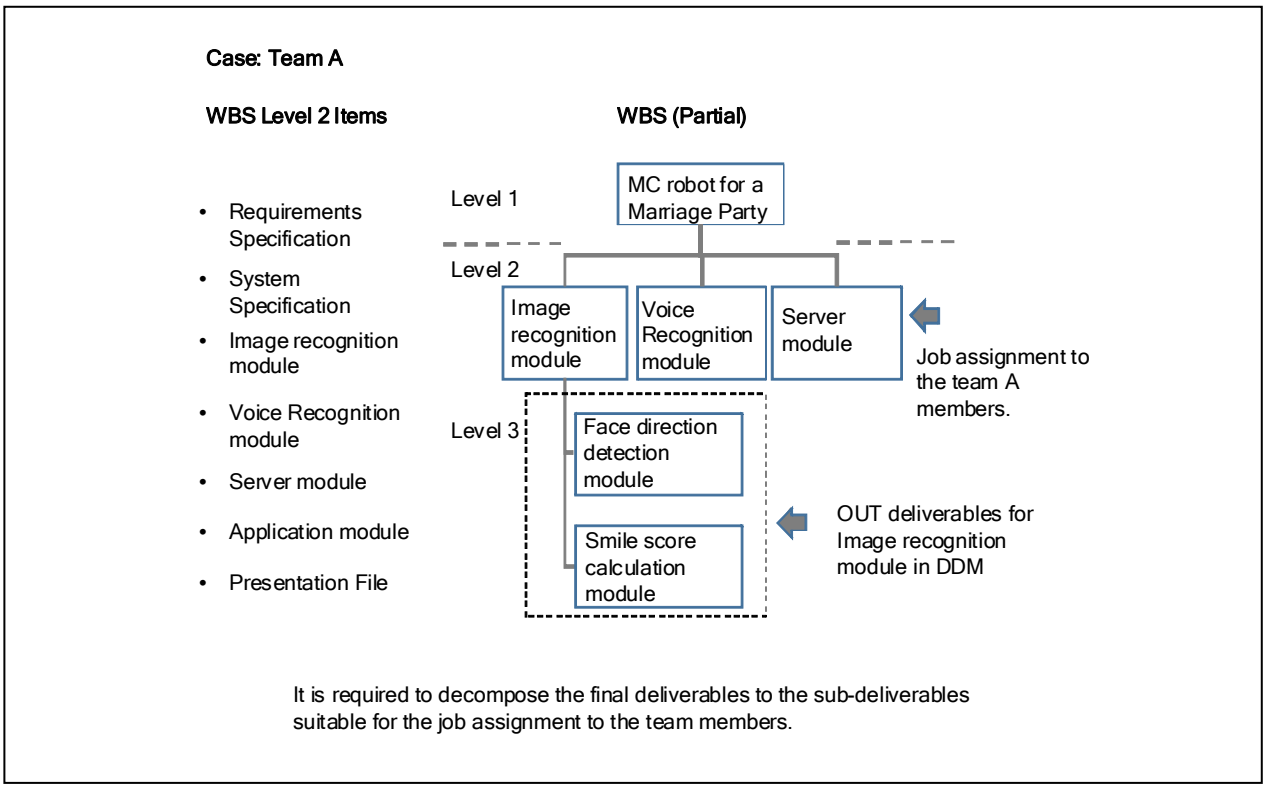


Figure 6. WBS structure in Team A.

Figure 6 shows the second level deliverables of WBS and the partial WBS created by Team A. The second level deliverables were assigned to the team A members.

Team A commented that they found many mismatches and gaps. The major mismatches were as follows.

(1) Lack of technical skill. →Action: One member with high skill was assigned to help him.

(2) Choice of functions. → Action: Take on an easier function because of the limited schedule.

(3) Lack of development time. → Action: Work overtime.

(4) Found that the integrated test was missing. →Actions: Add the test work to the schedule.

(5) Detected the delay of the work by DDM. →Add members to accelerate the task.

Results in the Second Trial

Figure 7 shows the ranking change of teams in DR1 through DR3.

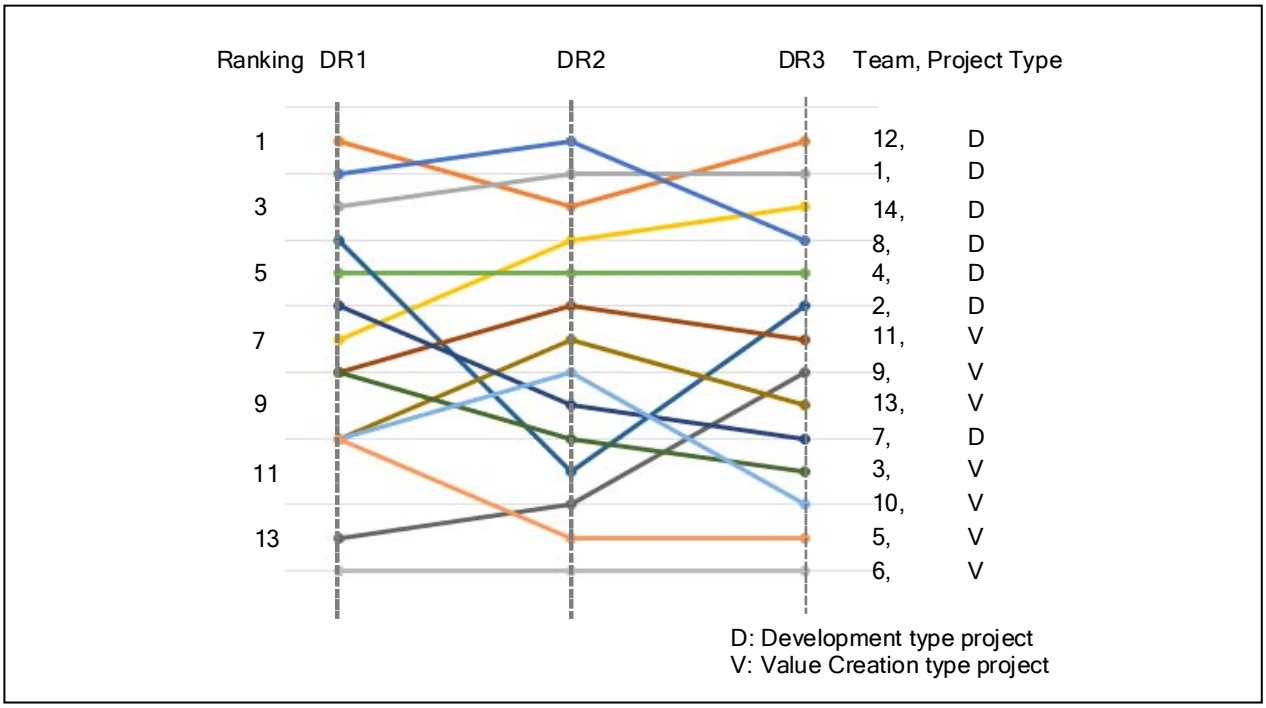


Figure 7. Ranking change and project type.

It was noticed that most of the higher rankings were occupied by the development type projects. The ranking change from DR2 to DR3 was as follows.

Development type project

Ranking up: Team 2, 12, 14

Ranking down: Team 7, 8

Value creation type project

Ranking up: Team 9

Ranking down: Team 3, 10, 11, 13

The number of the ranking up teams in the development type project is more than in the value creation type project. The number of the ranking down teams in the value creation type project is more than in the development type project.

Major comments of students for the lecture prior to PBL are summarized as follows.

(1) Attention changed from process-oriented to result-oriented

Some students thought that PBL was a course to just learn the process to create a new idea. But, since the

importance of the result in PBL was stressed in the lecture prior to PBL, an attention of students seems to have been changed from process-oriented to result-oriented. Therefore, students recognized the importance of project management deliverables like WBS and to manage PBL as a project with them to surely produce a final outcome.

(2) Deeper understanding of system engineering

The lecture prior to PBL was done alongside of the work flow of PBL. It made it easy for students to understand the contents of the lecture. Some students had thought of the various system engineering methods as independent. They understood the relationship of them and the work sequence connected with data created by them.

(3) Feasibility of project schedule

Some students commented that the project schedule was impacted by the reviewers' comments in DR and the research work in the master course. Hence, some teams could not progress the PBL work along the project schedule and could not maintain it well.

(4) Understanding of practical use of project management in society

Many students recognized the importance of project management in society. They requested to extend the time of the lecture to learn more.

Considerations

Following points are some findings and considerations of the trials.

(1) Team ranking and project type

There are two types of PBL projects as observed during the final presentation: the development type and the value creation type. The development type projects tended to get a higher ranking. The reason seems to be that the functioning prototype can convey more convincing messages to reviewers than just presenting a new idea which is hard to verify. The other reason may be an influence of the lecture as mentioned in the summary of comments. Further study will be required to make the outcome of the value creation type project more attractive. It is also observed that PBL can be divided into two project types: one to look for the goal or objective to be achieved, and the other to implement it. The former project from the PBL kick off to DR1 is called the Goal Search Project in this paper, and the latter project from DR1 to DR3 is called the Goal Oriented Project. The Goal Search Project requires to find a better goal in the open solution space, and the appropriate thinking style is the hypothesis thinking which is popular in consulting firms. Hypothesis thinking is the way to efficiently find a better solution. In the PBL case, the first step is to assume some hypotheses about the root causes of the problem and choose a better one by analysing them. The second step is to assume some hypotheses for the solutions to the root cause and choose a better one by analysing them. Hypothesis thinking is expected to improve the work efficiency to find a better solution. The Goal Oriented Project requires surely to achieve the goal, and the thinking method is the goal oriented thinking backward from the goal to achieve the goal. This thinking method is the typical thinking style in a project. The points mentioned so far are summarized in Figure 8.

(2) Effectiveness of DDM and its improvement

As more DDM is utilized, the higher the ranking is observed in the first trial. Since DDM was originally developed for product development, DDM is suitable for the development of type project. Team A received the number one ranking. One of the reasons was that there was a student in Team A who was familiar with

M-IScM and DDM and led the team to utilize them. This indicates the necessity of a lecture prior to PBL. Team A commented in the first trial that if DDM was not used, they would not have developed the prototype. This means that DDM has a positive effect to improve the quality of the final deliverables in the development of type project. Since project schedule creation is a core part of project management, the application of M-IScM and DDM to PBL encourages students to prepare the deliverables of project management such as WBS, a job assignment list, DDM, and the project schedule. Then, students can learn how to more effectively manage PBL or a project with them. Those findings may lead to the solution of the PBL issues (4) and (6).

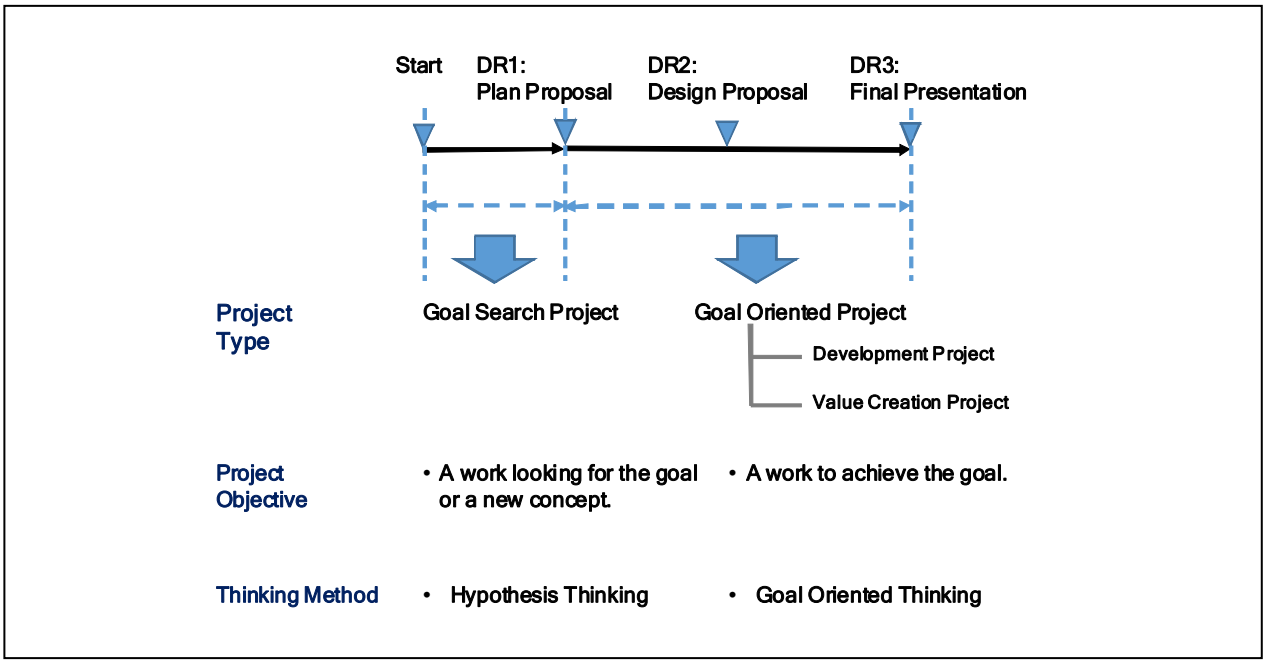


Figure 8. Project types and thinking method.

The different comments for DDM were found in the first trial such as “I did not see a value for DDM in the stage of the idea creation”, “During the idea creation time, the action-oriented is better than the deliverables-oriented”, and “As our work was just a proposal creation, we did not need to use DDM”. These comments mean that DDM does not work as well in the Goal Search Project. In the second trial, WBS was created by all teams with the decomposition to the logical elements at the beginning of the second trial. The project schedule referring to WBS was made in the following two ways.

(1) Use of project management software

The logical elements or activities were connected by their dependency with the project management software.

(2) Use DDM

The logical elements or activities were entered into the column of IN and OUT deliverables of DDM. The logical elements or activities were connected on their dependency with DDM.

This inconsistency happened because the handling of the logical elements and activities was not addressed in the original DDM, since the original DDM was designed for the physical elements of WBS. Those situations indicate the necessity to revise DDM so it can handle both the logical elements and activities of WBS in the Goal Search Project in which the final deliverables cannot be clearly defined and physical elements of WBS in

the Goal Oriented Project in which the final deliverables can be clearly defined. As a result, it is noticed that the revision to DDM in the following two points is required.

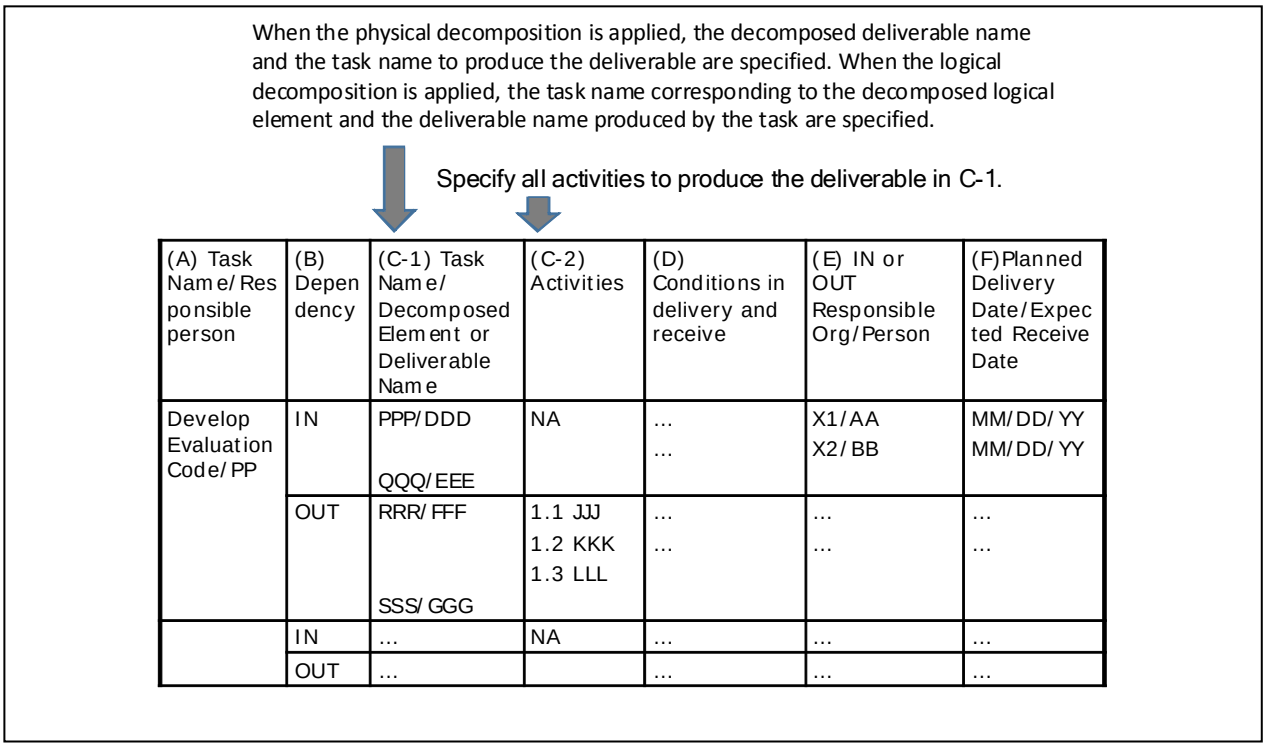
(1) Handling of deliverables in two decomposition methods consistently

DDM format needs to be revised to handle two types of deliverables decomposed by the logical and the physical decomposition.

(2) Clarify the handling of activities

The original DDM format assumed that functional organizations in the matrix organization are familiar with activities to develop OUT deliverables they are responsible for. But, students in PBL do not have knowledge about the assigned job. So, DDM format needs to be revised to fill in the all activities where students develop the OUT deliverables or perform the assigned logical elements.

Figure 9 shows the revised DDM format in which the columns C-1 and C-2 are added. The deliverable name and the task name to produce the deliverable are specified in the column C-1. The task name is the group name of activities, and all activities to produce the deliverable are specified in the column C-2. When the physical decomposition is applied, the decomposed deliverable name and the task name to produce the deliverable are specified in the column C-1. When the logical decomposition is applied, the task name corresponding to the decomposed logical element and the deliverable name produced by the task are specified in the column C-1. The revised DDM can be used in the same creation sequence both in the Goal Search Project and the Goal Oriented Project, namely, WBS creation, DDM creation, then schedule creation. The column (D) is valid even when C-1 is filled in with logical elements because some deliverables produced by the logical element, namely, the task, are passed from delivery side to receiving side. Therefore, the gaps and mismatches can be discussed both in the physical and logical decomposition.



(A) Task Name/ Responsible person	(B) Dependency	(C-1) Task Name/ Decomposed Element or Deliverable Name	(C-2) Activities	(D) Conditions in delivery and receive	(E) IN or OUT Responsible Org/Person	(F)Planned Delivery Date/Expected Receive Date
Develop Evaluation Code/ PP	IN	PPP/ DDD QQQ/ EEE	NA	… …	X1/ AA X2/ BB	MM/ DD/ YY MM/ DD/ YY
	OUT	RRR/ FFF SSS/ GGG	1.1 JJJ 1.2 KKK 1.3 LLL	… …	… …	… …
	IN	…	NA	…	…	…
	OUT	…		…	…	…

Figure 9. Revised DDM format.

Figure 10 is the summary of the relationship between WBS, the revised DDM, and Gantt chart (project schedule) in both the logical decomposition and the physical decomposition. The revised DDM, placed between WBS and Gantt chart, can improve the feasibility of the project schedule, the possibility to compress it, and the unity of the team as mentioned in the overview of M-IScM and DDM. The Gantt chart can be created by connecting the task or the deliverable, or by connecting activities, based on their dependencies.

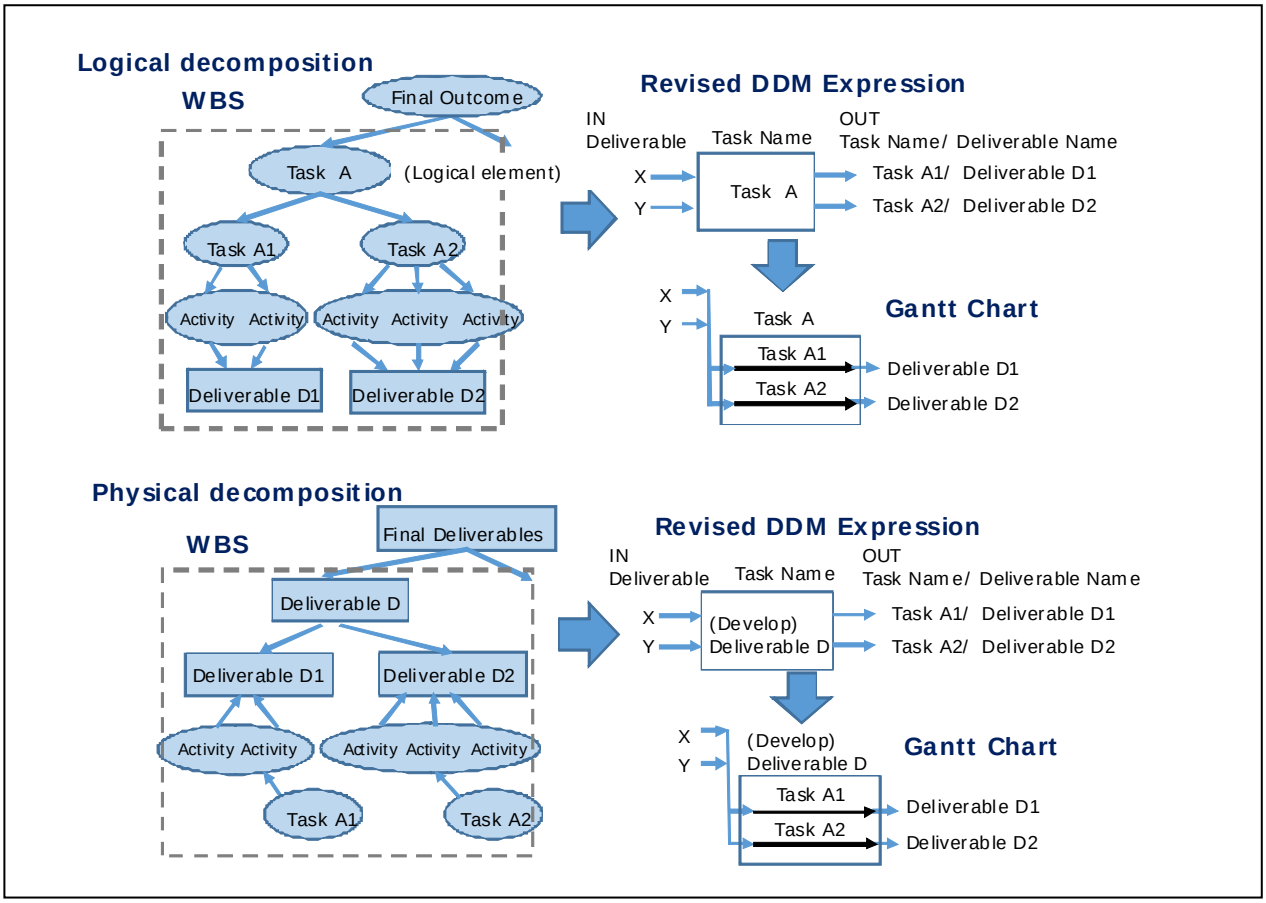


Figure 10. Relationship between WBS, the revised DDM, and Gantt chart.

(3) Reinforcement of a sense of responsibility

Some comments found in the first trial are “My work attitude became active because I understood my roles and responsibilities, and how to behave in my team”, “I was conscious of the due date because the due date was specified in DDM. I was also conscious of producing my responsible deliverables because I understood the dependency on the other members”, “I think DDM helped encourage the active attitude of the team members”, and “our consciousness to finish the work by the due date became strong. As a result, we did it”. These comments showed that job assignment with WBS and DDM enforced a sense of responsibility, a feeling of involvement in PBL, and an active attitude to the work. Project schedule creation through working with all team members can make members feel that the delay of the work will cause trouble for the next person, and encourage them not to cause a schedule delay. This finding leads to the solution of the PBL issue (1).

(4) Detection of gaps and mismatches

Team A mentioned in the first trial that they found many mismatches. In particular, IN deliverables in DDM helped find gaps and mismatches. The reason may be that (1) people tend to pay attention to the IN deliverables just before starting the work, and (2) WBS cannot show the IN deliverables to produce the deliverables decomposed in WBS. From these perspectives, IN deliverables in DDM work well in detecting the gaps and mismatches among project members.

(5) Leadership training

Leaders of two development type projects in the first trial commented that DDM helped assign a job to team members. It is easy to assign a job to a project member in a company. But, it is difficult for a team leader in PBL to assign a job to the members because they stand on an equal footing. This was not anticipated before PBL. WBS and DDM creation seems to make a job assignment easy, since the job assignment becomes a part of those work. This may mean that WBS and DDM can help nurture the leadership of the team leader. This finding leads to the solution of PBL issue (2). The hot discussion among the team members also helped form a good team. The clarification of the roles and responsibilities of the team members and the individual contribution to the final outcome may enable fairly to evaluate the performance of the individual student, which may resolve PBL issue (3).

DDM can be used to monitor the project progress by comparing the actual progress with the planned schedule. A leader of Team A puts an engineer to the delayed work to recover the delayed task. This may mean that DDM will help nurture leadership of the team leader to manage a project like a project manager.

(6) Work process and methods on project types

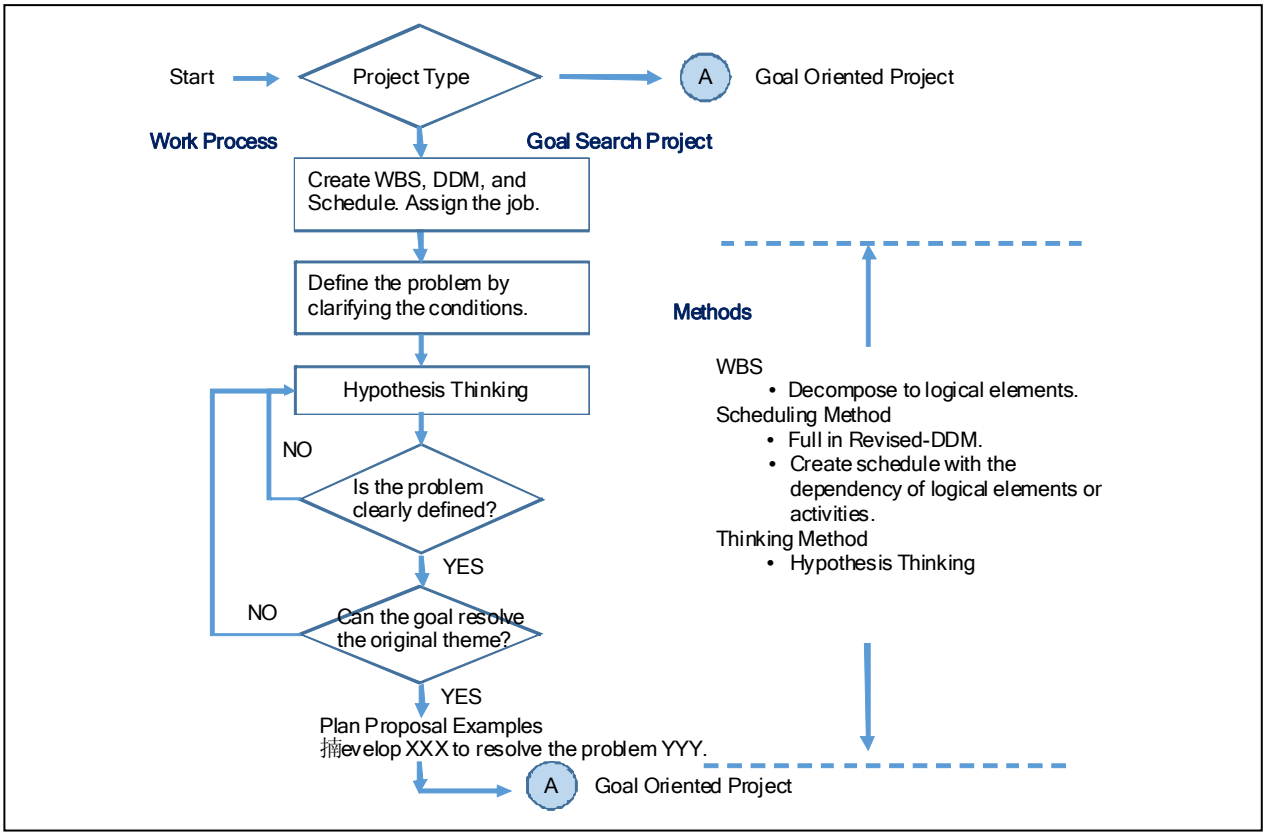


Figure 11. Goal search project: Work processes and tools.

It makes it possible to clarify the flow of the work process and the associated methods based on the consideration above both in the Goal Search Project and the Goal Oriented Project. Figure 11 is for the Goal Search Project. First of all, WBS of the deliverables at DR1 is created by the decomposition to logical elements. Then, DDM and the project schedule are created by referring to the WBS. A job is assigned to the team members based on the logical elements of the WBS. The next step is to define the problem clearly, then hypothesis thinking is applied to find the root cause of the project and the good solution for it. Then, the problem definition is verified if it clearly states the problem of the theme to be solved, and the solution is verified if it can resolve the problem. As for the methods, the WBS for the Goal Search Project is decomposed to logical elements and the project schedule is created with the connection of logical elements or activities based on their dependency. The thinking method is hypothesis thinking.

Figure 12 shows the flow of the work process and the associated methods for the Goal Oriented Project. They are the same as the normal project.

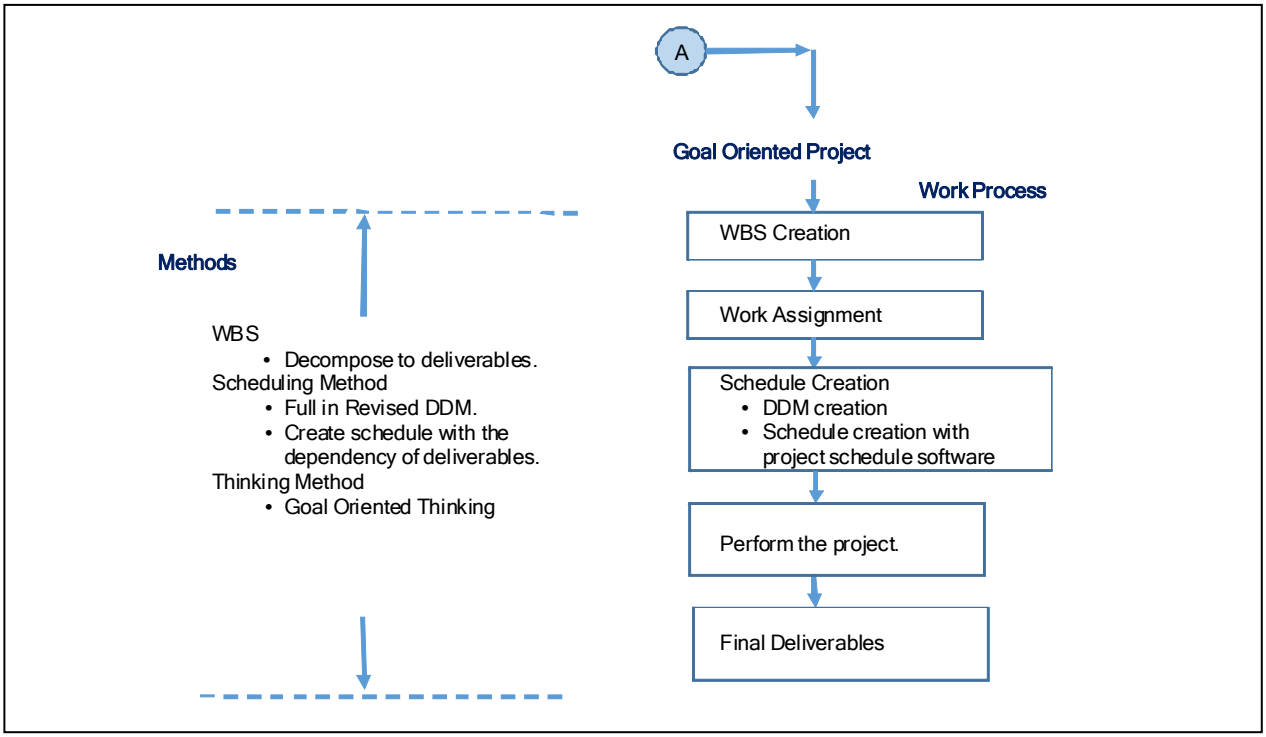


Figure 12. Goal oriented project: Work processes and tools.

Judging the project type and selecting methods can improve the work efficiency in PBL and may be possible to resolve the PBL issue (5).

As some part of the work process and methods were taught during the PBL course, it was observed that students could judge the project type, and based on the project type, they selected appropriate work processes and methods. They also utilized hypothesis thinking when the discussion came to a deadlock.

Conclusions

The paper described the overview of M-IScM and DDM and the trials of them in an actual PBL course at a graduate school. It was a notable result of the trials that at least one team, namely Team A, fully utilized

M-IScM and DDM, to develop a good working prototype and proved the effectiveness of M-IScM and DDM to some degree. M-IScM and DDM placed the deliverables among project members for discussion, which might draw out very valuable discussions and findings such as gaps, new issues, and risks.

The trials showed the possibility to resolve the PBL issues as follows.

(1) M-IScM and DDM may have a positive effect for issues (1) and (2) as mentioned in conclusions (3) and (5) respectively.

(2) M-IScM and DDM may have the potential to evaluate the grade of individual student (issue (3)) by comparing the roles and responsibilities of the individual student with the individual contribution to the final deliverables, though further study is required.

(3) As mentioned in conclusion (6), the work process and methods have the possibility to improve the productivity in PBL and to resolve the PBL issue (5).

(4) A method to improve the quality of the outcome in a value creation project is required. Further study is required.

(5) Team A created WBS, a list of roles and responsibilities, DDM, a project schedule, and a list of mismatches. They utilized them to manage PBL as a project. They also commented “If DDM was not used, we would not have developed the prototype”. Because of these reasons, M-IScM and DDM may resolve the PBL issues (4) and (6).

The trials lead to the idea of the PBL internal project structure, the Goal Search Project type, the Goal Oriented Project type, the WBS creation method, the revision of DDM and their associated work process and methods. A lecture about them prior to PBL will give students the knowledge regarding project management to judge the project type by themselves and select the appropriate work processes and methods to conduct the project work effectively. The competencies acquired through PBL can be thought of as the capability to actively lead a project, and can help develop the leadership and the fundamental skills to be a capable business person.

The following items require further study.

(1) Study the degree of the productivity improvement in PBL by introducing the idea of the PBL internal structure and applying the WBS creation method, the work processes and methods for the two internal project types.

(2) Study the effectiveness of the hypothesis thinking method in the Goal Search Project.

(3) Study a method to evaluate the grade of an individual student.

(4) Study a method to improve the quality of the outcome in the value creation project.

The authors will continue the research work for the items noted above on an actual PBL. The authors also hope that M-IScM and the revised DDM will be deployed widely in both PBL courses and projects within a company.

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