AN APPLICATION OF DELIVERABLES DEPENDENCY MATRIX (DDM) TO PROJECT BASED LEARNING

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Abstract

Project-Based Learning (PBL) is a popular teaching method because of the effectiveness of PBL to educate a student 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, and (3) a difficulty to fairly evaluate the grade of each student. Integrated Scheduling Method (IScM), which uses a project management tool called Deliverables Dependency Matrix (DDM), has been proposed to create a highly feasible project schedule for new product development and the effectiveness of this approach has been reported in an actual product development project. That paper pointed out the possibility to resolve the PBL issues noted above by applying IScM and DDM to PBL. IScM is a process to create a highly feasible project schedule, while DDM is a tool to specify the various conditions of the deliverables. The basic idea of IScM is that the project schedule can be created with the flow of the deliverables passing from one functional organization to the next and the major source of the schedule delay is a return of deliverables caused by various gaps or mismatches in deliverables between the delivery side and the receiving side. Examples include the misunderstanding or ambiguity of the specification, the delivery / receiving conditions, and the planned delivery date / the expected receiving date. IScM and DDM can help create a highly feasible project schedule by filling those gaps. Since DDM can clarify the ownership of the deliverables and the interdependency of deliverables in the whole schedule, DDM can strengthen a sense of responsibility and so create an expectation to solve the PBL issue (1). DDM can help develop the project schedule by reducing the uncertainty of the work which can increase the feasibility of the schedule and the possibility to compress the schedule. The project control arising from the project schedule will resolve the PBL issue (2). DDM also clarifies the contribution of each student to the assigned deliverables in the PBL project, which will resolve the PBL issue (3). DDM is being applied to an actual PBL course in the second semester, 2016, as a trial. This paper provides an overview of IScM and DDM, describes how to apply them to PBL and reports on the preliminary result of the trial.

Keywords: Project-Based Learning, Project Management, Work Breakdown Structure, Project Scheduling, Product Development.

1 INTRODUCTION

Project-Based Learning (PBL) is a popular teaching method because the effectiveness of PBL has been well recognized to educate a student to become working members of society. The reference [1] reports the whole course program structure of the undergraduate and graduate school, in which technical courses and PBL courses spiral up interdependently. The reference [2] reports the expansion of the PBL scope to a collaboration with industry and local communities. However, the following issues in PBL has been recognized.

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 [3].
2 The range of achievement levels among project teams varies.
3 It is difficult to fairly evaluate the grade of each student [4].

The following issues are also observed in PBL courses.
4 The final deliverables are developed at the last minutes of the project, since students tend to spend most of their time to set the objectives, the goal, or to create the concept.
The project management in the PBL project is not well done because the actual work has a higher priority than the project management work such as a creation of Work Breakdown Structure (WBS), a project schedule, and a project control with them.

It is important for students to view PBL as a project and to learn how to manage it. The core part of the project management is the creation of the project schedule 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. The references [5], [6], [7] describe the typical scheduling procedure in which the final deliverables are decomposed as sub-deliverables until the work package, and the project schedule is created with the interdependency of activities to produce the work package. This scheduling method is basically activity based and it is sometimes difficult to keep the consistency of the project schedule with WBS which is deliverables based. A scheduling method which is suitable for a small project with 5~6 members like PBL and can resolve the issues noted above is desired.

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 paper revealed the effectiveness of IScM and DDM for the schedule creation in a large-scale project [8]. The paper pointed out the possibility to resolve the PBL issues noted above by applying IScM and DDM to PBL. The slightly modified IScM is being applied to the actual PBL course in the second semester, 2016 as a trial. IScM is basically a deliverables-based scheduling method instead of activity-based.

This paper describes the overview of IScM and DDM in chapter 2. Chapter 3 describes the trial of IScM and DDM application to PBL. Chapter 4 reports the preliminary result and findings. Chapter 5 describes the conclusion and the research plan.

2 OVERVIEW OF IScM AND DDM

IScM is proposed under the conditions below, which is the typical development environment in a product development company.

Conditions in which IScM is applicable

1. A product is developed with functional organizations in a matrix organization.
2. The product is developed by passing the intermediate deliverables (goods, parts, software, and data) from one functional organization to the next organization.
3. The functional organizations such as an electrical circuit design, a mechanical design and a software design have a high capability in their major technical area and a rich experience in past similar product development. Therefore, when the product specification is defined, they can understand well about what deliverables they need to produce as an output, and what deliverables they need for producing their deliverables as an input. They also have a capability to estimate the work duration with relatively high accuracy to produce deliverables because they have a resource allocation plan, know the skills and experience of individual engineers in their functional organization, and have a rich experience in past similar product development.

IScM is the method to create the highly feasible project schedule based on the following ideas under the assumptions noted above.

1. The project schedule can be created with the flow of the 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 receiver side because there are various mismatches or gaps between them. Mismatches or gaps in understanding, the ambiguity of the specification, or the delivery / receiving conditions will cause a return of deliverables, and it will cause project delay. Solving the mismatch 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 receive date will cause the reversed order of the work in time. When the works are ordered sequentially, the project schedule will be extended much longer. Solving the mismatch (2) will reduce the uncertainty of
the work and squeeze the schedule buffer involved in the initial schedule, which will enable compressing the schedule toward the target project completion date.

IScM focuses on the transition of the deliverables between the functional organizations. DDM is a tool to clearly specify the attributes of deliverables. DDM format is shown in the figure 1.

IScM steps using DDM are shown in Figure 2.

<table>
<thead>
<tr>
<th>(A) Task Name/Responsible person</th>
<th>(B) Dependency</th>
<th>(C) Deliverables Name</th>
<th>(D) Conditions in delivery and receive</th>
<th>(E) IN or OUT Responsible Org/Person</th>
<th>(F) Planned Delivery Date/Expected Receive Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop Evaluation Code/PP</td>
<td>IN</td>
<td>Specification Prototype Screen Design</td>
<td>... X1/AA X2/BB MM/DD/YY ...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>OUT</td>
<td>Evaluation code Test Report</td>
<td>... ... ... ...</td>
<td>... ... ... ...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>IN</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>OUT</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

*Figure 1. DDM Format.*

Each column noted (A)∼(F) is depicted as follows.

a) This column specifies the task name and the name of the responsible person. The task name can be specified with the following way.

1. Name of an activity to produce the deliverables under which OUT deliverables are placed.
   “Develop AAA” is the task name in Figure 1.

2. Generic task name of an activity to produce OUTs.

b) This column specifies the type of dependency, IN or OUT, for the deliverables specified in the column (C). IN means the deliverables our organization needs. OUT means the deliverables our organization will produce.

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

d) This column specifies the conditions of deliverables in the delivery time or the receiving time. The examples of the condition are “A review completed”, “Approved by XXX”, “A test report attached”, “Meet the specification XXX”, “Endorsed by Quality Assurance”, etc. Some mismatches are normally recognized between the delivery side and the receiving side.

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

f) This column specifies the planned delivery date or the expected receive date for the IN or OUT deliverables. Mismatches are normally recognized between the delivery side and the receiving side.
Following is the explanation of each step.

1. Each functional organization fills in DDM independently. The schedule in DDM needs to satisfy the target milestone and the project completion date. Each functional organization is required to make a commitment to achieve the schedule.

2. The planned delivery date and the expected receiving date prepared by each functional organization is entered in project schedule software like MS Project with the attribute of the task as “start at the specified 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 because of uncertainty, risks, desire not to be scolded, or taking it easy.

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

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

Then, the attribute of the task is changed to “start as early as possible”. This action changes the order of the works sequentially. As a result, the project schedule will be extended much longer beyond the target project completion date. This schedule is called the initial Integrated Master Schedule (IMS).

Attention needs to be paid that the same deliverables name has a different meaning or the different deliverables name has the same meaning in each organization. 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, no organization has a plan to produce it. The project team needs to check whether an organization misses to produce it or not. If a dangling OUT is found, no organization has a plan to receive it. The project team needs to check if an organization misses to receive it or an organization does not need to produce it.

3. The project team members have a meeting to find the mismatches and to solve them with the agreement between the delivery side and the receive side. As a result, the uncertainty and risk can be reduced. They can lead to reducing a chance of a return of deliverables and to increase the feasibility of the schedule. They can also compress the schedule by squeezing the schedule buffer, taking fast tracking, or crashing which are the known technique to compress the schedule along the critical path toward the target project completion date.
During the 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.

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

3 ISCM TRIAL APPLICATION TO PBL

3.1 Change of conditions

When ISCM is applied to PBL, the condition (1) and (3) mentioned in chapter 2 are not valid. Students do not have the experience, knowledge nor speciality about the PBL theme. Therefore, the ISCM steps are slightly modified as follows.

1 WBS creation

The job assignment to the PBL team members need to be done. To do this, WBS needs to be created. The final deliverables at the top level of WBS are decomposed to the second level deliverables to which the PBL team member is assigned.

2 Team work

It is better that the PBL team members work together through the course work because the team members can support other members during the PBL work, which will help the effective learning and strengthen a sense of unity of the team.

3.2 PBL course for trial

ISCM has been applied to the PBL course collaborating with Industry and Local Communities called “Industrial Project Based Learning”. This course is served as a selective course for the graduate students in the second semester at Shibaura Institute of Technology in 2016. The overview of this course is as follows.

Course overview: Industrial Project Based Learning

1 This course is an advanced PBL course following the PBL course called “Exercises in Systems Engineering” in the first semester.

2 This course aims to implement a prototype or proposing a more sophisticated plan based on the idea created in the first semester.


4 5 teams are formed.

5 The course sets the following three milestones called Design Review (DR).
   a) DR-1: Plan proposal
   b) DR-2: Project plan and Design proposal
   c) DR-3: Final presentation

6 Themes of 5 PBL projects are as follows.
   a) Team A: Master of ceremony (MC) robot for a marriage party.
   b) Team B: Data collecting device for crow protection.
   c) Team C: Activation of local factories.
   d) Team D: Fish promotion for children.
   e) Team E: Rental cycle promotion.

ISCM and DDM are explained shortly at the beginning of the course.
4 PRELIMINARY RESULT AND FINDINGS

Table 1 shows the preliminary result of the PBL course work. The ranking was decided by the voting of professors, students, and attendees in the final presentation. IScM and DDM were evaluated by participated students.

Table 1. Result of the PBL course work.

<table>
<thead>
<tr>
<th>Team</th>
<th>Project Theme</th>
<th>Project Type</th>
<th>Rank</th>
<th>Evaluation to ISM and DDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Master of ceremony (MC) robot for a marriage party.</td>
<td>Development Type</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3: Very Effective</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2: Effective</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1: Not changed or not in use</td>
</tr>
<tr>
<td>B</td>
<td>Data collecting device for crow protection.</td>
<td>Development Type</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>Activation of local factories.</td>
<td>Proposal Type</td>
<td>2</td>
<td>1 (Not in use)</td>
</tr>
<tr>
<td>D</td>
<td>Fish promotion for children.</td>
<td>Proposal Type</td>
<td>4</td>
<td>1 (Not in use)</td>
</tr>
<tr>
<td>E</td>
<td>Rental cycle promotion.</td>
<td>Proposal Type</td>
<td>5</td>
<td>1 (Not in use)</td>
</tr>
</tbody>
</table>

Table 2 are the summary of the comments from team members and a team leader.

Table 2 (1). Summary of the comments from team members and a team leader.

<table>
<thead>
<tr>
<th>Team</th>
<th>Comments</th>
</tr>
</thead>
</table>
| A    | ● My work attitude became active because I understood my roles and responsibility, 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 2 (2). Summary of the comments from team members and a team leader.

<table>
<thead>
<tr>
<th>Team</th>
<th>Project Theme</th>
<th>Comments</th>
</tr>
</thead>
</table>
| 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 created 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.  
*In the past, I participated in PBL to create a new wheel chair. DDM may be useful for such a project. |
| 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. |

As team A seemed to utilize DDM well and made a workable prototype, the project outcomes of team A were reviewed as follows.

1. Team A commented that they found many mismatches. The major mismatches they found were as follows.
   a) Lack of technical skill. -> Action: One member with high skill was assigned to help him.
   b) Choice of functions -> Action: Take on an easier function because of the limited schedule.
   c) Lack of development time. -> Action: Work overtime.
   d) Found the integrated test was missing. -> Actions: Add the test work.
   e) Detect the delay of the work with DDM. -> Add members to accelerate the work.

2. The second level deliverables of WBS in team A are as follows and are assigned to the team members.
   a) Request definition document
   b) System specification
   c) Image recognition
   d) Voice recognition
   e) Server part
   f) Application program
   g) Presentation document

3. The partial WBS structure of the team A is shown in Figure 3.
The following are some findings.

1. There are two types of PBL projects, the development type and the plan proposal type. The development type project is the project to develop something to work. The plan proposal type project is the project to make a superior proposal for the theme. Teams A and B belong to the former and Teams C, D, and E belong to the latter.

2. The evaluation to IScM and DDM by the development type project is higher than one by the plan proposal type. The ranking of the development type project is higher than one of the plan proposal type projects.

3. Team A commented that if DDM was not used, they would not have developed the prototype. DDM has a positive effect to improve the quality of the final deliverables.

4. According to the comments, DDM has a positive effect to increase a sense of responsibility and an active attitude to the work.

5. 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. DDM seems to make a job assignment easy as a part of the WBS creation process.

6. DDM can be used to monitor the project progress by comparing the actual progress with the planned schedule.

By referring to the findings noted above, the following points can be considered.

1. The more a team utilizes IScM and DDM well, the higher the quality of the final deliverables is. There was a student in Team A who was familiar with IScM and DDM and led the team to utilize them.

   Action (A): It is important to educate students well about IScM and DDM prior to the PBL work.

2. Teams A and B created WBS. The WBS decomposition style was different, the deliverables-based decomposition by team A as shown in Figure 3, and the activity-based one by team B. Since one member of Team B said that the workload to create WBS was heavy, the WBS was checked. It was found that the size of WBS was large because many activities were listed.

   Action (B): The WBS creation method needs to be taught before the PBL course.

3. Team A mentioned that they found many mismatches. Especially, IN in DDM helped find mismatches. The reason may be (1) people tend to pay attention to the IN deliverables just before starting the work, (2) WBS cannot show the IN deliverables to produce the deliverables included in WBS.

   Action (C): Encourage to think IN to find mismatches more in the discussion time.
4 IScM and DDM are suitable for the development type project. The plan proposal type project needs other methods to create new ideas. One method is to use the hypothesis thinking method. If it works, the team work may increase the chance creating good ideas and completing the work by the due date.

Action (D): Further study is required to find a better method for PBL to create new ideas and to complete the goal setting in a shorter time.

5 CONCLUSION
The paper described the overview of IScM and DDM and the trial of them to the actual PBL course in a graduate school. Some preliminary results are as follows.

1 IScM and DDM may have a positive effect for the issue (1) and (2) noted in 1.INTRODUCTION.
2 IScM and DDM may have a possibility to evaluate the grade of individual students (issue (3)) by comparing the job assignment with the final deliverables. Further study is required.
3 A method to create new ideas and to set a project goal is required as referred to in issue (4). One candidate is to use the hypothesis thinking method. Further study is required.
4 Team A created WBS, a list of roles and responsibility, DDM, a project schedule with MS project, a list of mismatches. They utilized them to manage the project. The issue (5) may be resolved with IScM and DDM.

It was a notable result of this trial that at least one team, namely Team A, fully utilized IScM and DDM, and could develop a good workable prototype. Based on the considerations, the following actions will be taken.

1 Give a lecture to students about IScM and DDM prior to PBL.
2 Study the idea creation method like hypothesis thinking method in an actual PBL work and verify the effectiveness of it.
3 Study a method to evaluate the grade of an individual student.

The authors will continue the research work for the actions noted above on an actual PBL. The authors also hope that IScM and DDM will be deployed widely in PBL courses.

REFERENCES