Identification and Analysis of Factors Influencing the Efficiency of Web Development Team Projects from the Students' Perspective

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CONTEXT
The postgraduate subject "Web Technologies" is offered to engineering students who have different engineering backgrounds. The students have generally studied other computer programming and design methodologies in their engineering domain. The major learning objectives of this subject include being able to critically evaluate web technologies, apply web design methodologies to web based systems, and work efficiently with groups. To achieve these objectives, we have designed a web development process to apply to the major assessment task of developing a web system as a group. This research is to study the efficiency of this process with regard to student learning.

PURPOSE
This research is to identify and analyse the factors that influence student learning in the postgraduate subject "Web Technologies" which is offered to students from different engineering domains.

APPROACH
To understand the efficiency of the web development process for the major assessment task, we designed interview questions and interviewed students using "potential speed" and "actual speed" of the web project development in each phase. The influence factors are identified from the interview results. A Causal Loop Diagram is used to analyse the relationships of these influence factors.

RESULTS
The major factors to influence the efficiency of the web development process for student learning are identified and analysed. These factors include the project leader's leadership, group members' previous experience, personal skill overlap, motivation, communication method, time pressure, and learning curve factor.

CONCLUSIONS
The identified influence factors to the web development process will be further analysed to identify ways to further increase the efficiency of the process. New strategies for subject improvement will be developed based on these influence factors.

KEYWORDS
Web development process, team work efficiency, influence factor

Introduction

The web has become a tool in the engineering domain. For example, civil engineers use web-based monitoring systems for utility pole health assessment. Road and traffic engineers use web-based systems to track and monitor vehicle locations and flows in vehicle networks. In engineering study, different engineering students often learn different programming languages and system design methodologies in their engineering domains, however web technologies and methodologies are not usually core subjects in undergraduate engineering study. At University of Technology Sydney (UTS), we have a postgraduate subject on “Web Technologies” for engineering students who are from different domains to learn current web technologies and web development methodologies. One of the major assignments is to develop a web project by applying web technologies and methodologies. In this paper, we discuss a web development process to support students’ learning, and factors that impact students’ efficiency in completing web development projects.

In commercial web development projects, most of the developers are specialised in particular web languages and frameworks, have experience of past projects, and follow the company’s web development process. These development processes include plan-driven process such as the waterfall model (Pressman et al. 2014) or agile methodologies (Matharu et al. 2015) including Extreme Programming, Scrum, Feature Driven Development, DSDM (Dynamic System Development Method), Adaptive Software Development, and Lean Development (Fowler 2001). In commercial web development processes, there are different roles such as project manager, business analyst, architect, programmer, tester, and configuration manager. The development timeline follows the client’s needs.

In students’ subject study, students learn web development by attending lectures for learning theory, and applying learnt theory to develop a web project. The outcomes of the students’ learning must meet the subject learning objectives and graduate attributes. These make student projects qualitatively different from commercial web development processes.

To understand the students’ learning in a web development subject, in this paper, we analyse the factors that influence the efficiency of the web development process in an educational context. We use a case study in a postgraduate subject on “Web Technologies” at University of Technology Sydney.

In literature, researchers use metrics in development processes to evaluate the efficiency of a development process. “Productivity” of a development process has been a metric to understand the process costs and benefits. There are two types of approaches to model the productivity: static and dynamic (Huang et al. 2016). In the static approach, parameters for productivity are identified. The dynamic approach uses an analytical model to simulate the productivity over time. Time is explicitly considered in the dynamic approach.

The following are some examples of static approaches. Researchers have used a survey of developers to understand the efficiency of pair programming in Extreme Programming (Begel et al. 2008). In this approach, researchers designed the survey with questions on the influence of pair programming. Lowe et al. developed an efficient web process model based on industry interviews and a survey of commercial web development companies (Lowe et al. 2002). A causal loop diagram approach has also been used to identify and analyse the efficiency of an agile development method –“Critical Feature Matrix” (Kong et al. 2005). Examples of the dynamic approach in literature include analysing productivity for new software product development using simulation for economic values (Liu et al. 2015).

In this research, we use one of the static approaches “Causal Loop Diagram” to analyse the efficiency of the web development process for student learning.

This paper is organised as follows. The web development process for student projects is presented first. Impact factors to efficiently deliver project artifacts are identified and

analysed in the third section. Research approach and results are presented in this section. Finally, conclusions and further research are outlined.

Web development process for student projects

The postgraduate subject on “Web Technologies” in UTS is designed for engineering students from different engineering majors, including civil, electrical, mechatronic, mechanical, telecommunications, and software engineering. The enrolled students who are not from a software engineering background do not have knowledge of web programming, databases, web frameworks and web development methodologies. But all enrolled students have an engineering undergraduate degree, and have programming skills and are competent in engineering design in their engineering domain.

Upon completion of this subject, students should be able to critically evaluate current web technologies and databases, apply web design and management methodologies to web systems, and work effectively in groups (UTS, 2016). To help students demonstrate these learning outcomes, they work in teams to develop a web project.

In this group project, 4 to 5 students from different engineering majors form a development team. The web project development goes through the whole development lifecycle. The web development methodology is “Object, View, and Interaction Design” (OVID) (Berry et al. 2003). The theory of OVID is taught in the beginning of the semester. The students’ web project development process using OVID is illustrated in Figure 1.

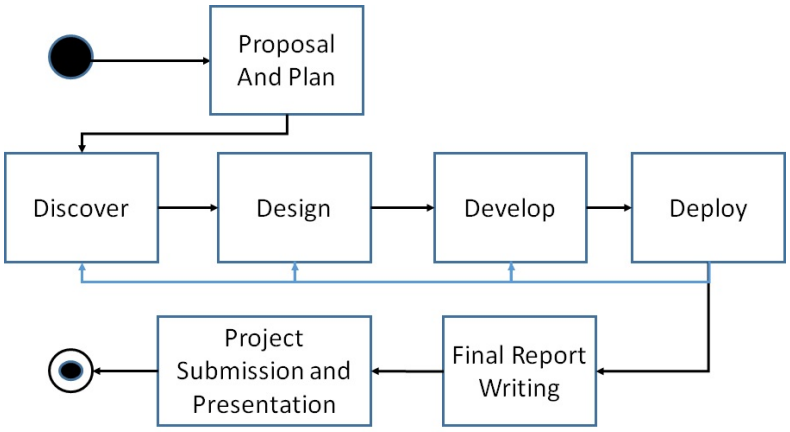

Figure 1: Web development process for student team projects

The four internal phases “Discover, Design, Develop, and Deploy” are modified from standard OVID methodology. OVID is a user-centred object-oriented methodology (Berry et al. 2003). The other phases are for student assignment planning, writing and submission.

Different from commercial web development, in the academic context, students within a group have the opportunity to experience each role during the project lifecycle. Every student practices all the tasks for project manager, business analyst, architect, programmer, tester, and configuration manager in different phases of this development process. The OVID process is new to the students, so this gives them a broader experience than in industry.

Students prepare a project proposal, and once the proposal is approved, they start the OVID Discover phase. They identify scenarios of the project, analyse stakeholders and their goals, tasks, and user experience. The artifacts of discovery are modelled using Unified Modeling Language (UML).

Based on the diagrams from *discovery* phase, students start *design* using UML. Design artifacts are carried forward into the *development* phase to implement the web project. Implemented systems are *deployed* to the hosting server for testing. They adopt an iterative process and can revisit previous phases.

After completion of system testing, students finalise the assignment report, documenting the artifacts from all phases. Finally, groups present their projects in class and receive feedback.

This process is designed by the academic teaching staff based on the subject learning objectives and graduate attributes. The students need to meet the timeline of 11 weeks', practice all the development tasks and deliver all the required artifacts with required quality.

Identify and analyse influence factors for efficient delivery of student projects

To understand students' learning and help students to achieve the learning objectives, in this research, we identify and analyse factors that influence the efficiency of project delivery from the students' perspective. The findings from this research can be applied to improve the teaching and learning approach for this subject, and similar subjects elsewhere.

The research questions are:

- What are the factors to influence the students' project work using the designed web development process (as in Figure 1)?
- How to improve student learning efficiency using the findings in this research?

Approach for interview design to identify the impact factors for the efficiency of the web development process

We interviewed the students in the subject. The interview questions were designed by considering the following factors that impact the efficiency of student learning.

- The students of this subject are from different undergraduate engineering majors. Students have a "*potential speed*" for learning and practicing "Discover, Design, Develop and Deploy" phases in the time frame of one semester.
- The students are outcome-oriented. Therefore the efficiency of the process can be designed using the learning outcome of the web development process. We use the "development speed - number of artifacts completed in unit time" during the internal phases in the development process for measuring process efficiency.

The two related metrics for speed used in this study are defined as follows:

Table 1: Metrics used in web process efficiency (Kong et al. 2005)

Metric	Definition
Potential speed	The speed attained if the student project team uses the resources at the maximum level.
Actual speed	The total number of completed artifacts in a phase divided by total hours used in that phase.

The interview questions are designed as:

- What are the factors impacting the "potential speed" in your web development process?
- What are the factors impacting the "actual speed" in your web development process?
- What are the relationships among these identified factors?

From the interview findings, the direct influence factors on "potential speed" and "actual speed" for web project development are identified and classified separately into major groups. Subgroups of influence factors that influence these direct factors are identified next. Finally the relationships among all these factors are analysed using a Causal Loop Diagram from a System Dynamics approach.

Identify and analyse influence factors on a web development process in student projects using a Causal Loop Diagram

We use Causal Loop Diagram approach to transmit the students' answers to findings. The students linked the answers to the keywords "Potential Speed" and "Actual Speed" in the diagram. The sub-relationships of these answers were linked in the diagram. The keywords of the answers are identified as influence factors. Finally the students and the researchers together analysed the Causal Loop Diagram using the keywords and relationships. The finalized Causal Loop Diagram is illustrated in Figure 2. They are described in more detail as follows.

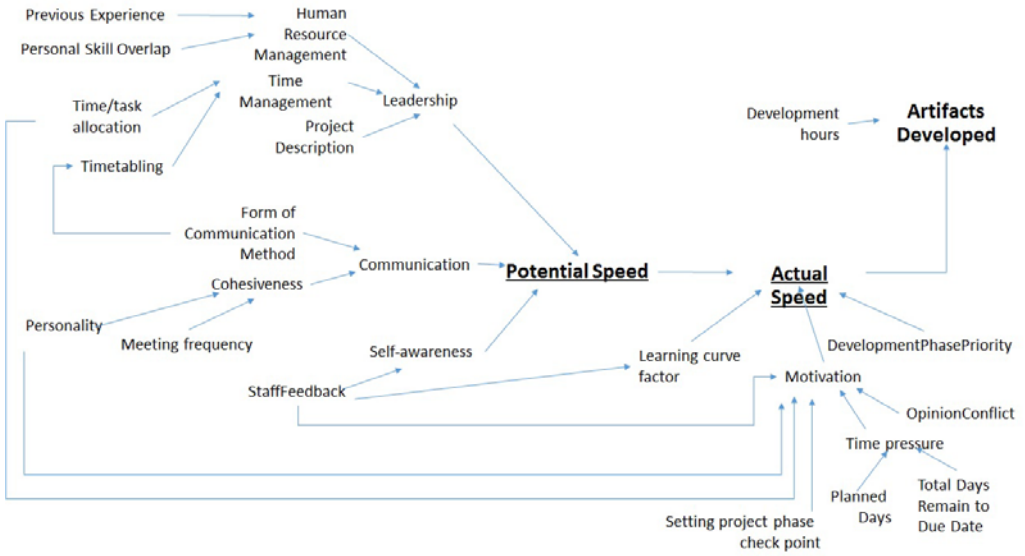

Figure 2: Causal loop diagram - influence factors to potential speed and actual speed

*Factors Influencing "**Potential Speed**":*

The direct influence factors on potential speed are: "Leadership", "Communication" and "Self-awareness".

- Leadership

The "Leadership" factor is the ability for the project leader to lead the student team through the process and complete the project. In the subject "Web Technologies", students work in teams of 4 or 5. One of the students in each team will be voted as the project leader.

The factors that influence leadership are identified as: "Human Resource Management", "Time Management", and "Project Question Description".

- Human Resource Management

The "Human Resource Management" factor is the ability to manage the students in the team to complete the process.

Factors that influence "Human Resource Management" include

- "Previous Experience" in work or projects
- "Personal Skill Overlap"

The students are from different engineering backgrounds. We found that if the overlap of students' personal skills in their project are smallest, they will approach maximum potential speed in the web development process.

- Time Management

"Time Management" is the ability to manage the team working hours and tasks in all phases of the project. The factors that influence time management are identified as different subject timetabling for each student, and the task and time allocation for each team member.

- Timetabling

The students in each group are from different engineering majors. Full-time students study 4 subjects each semester, and the timetables for other 3 subjects will vary. This makes group time coordination difficult, and results in a negative influence on time management.

- Task/Time Allocation

Each student in a team has different skills and working styles. The ability to understand how to allocate tasks and time will impact on time management. The "Form of communication method", such as online texting/email/face to face meetings, will also impact on time management.

- Project Description

The team proposes their project at the "Proposal and Plan" stage (see Figure 1). At this initial phase, the team has the project vision. They have not precisely defined a System Requirements Specification (SRS). The SRS is identified and analysed in the "Discover" phase. The ability of the project leader to describe the project in these two phases (Proposal/Plan and Discovery) will influence leadership of the team to understand the complexity and architecture of the final web system.

- Communication

Communication is the key for a successful team project, and it manifests in all phases. For example, in the OVID Design phase, Student A's task is to design the abstract view. Student B's task is to design procedural outline tasks using swim lane diagrams. The abstract view for Student A should reflect the outline task/swim lane diagram for Student B. The two students need to work together to create these design artifacts. This is illustrated in Figure 3.

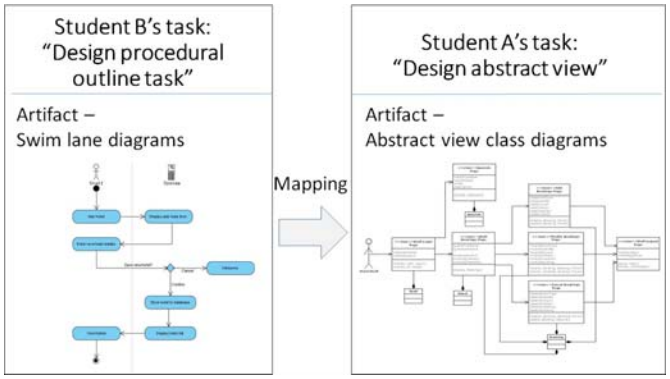

Figure 3: Students' tasks are related.

The factors that influence communication are "Form of Communication Method", and "Cohesiveness".

- Form of Communication Method

The teams typically communicate in the forms of online/email/face to face meetings. We found that the communication method "face to face meeting" is most efficient in this context. The more that team members participate in team discussions in each phase, the more efficiently tasks will be completed.

- Cohesiveness

In a team project, students need to "stick together" to complete the tasks. The influence factors for cohesiveness are student's personality, and meeting frequency.

- Personality

Some students are good at communicating and collaborating with others. Some students prefer working individually, and are not good at collaboration. Using the task example in Figure 3, if Student A insists working on the task "Design abstract view" without discussing it with Student B, the abstract view diagram will not match the view class or the task flow in Student B's design.

- Meeting Frequency

It was found that more group meetings in a week increases the understanding of each other and positively impacts the team cohesiveness.

- Self-awareness

Self-awareness is one student's view of his/her study ability, strength/weakness, interest, and needs. Students with poor self-awareness will slow down the potential speed for project development. We found that staff feedback and encouragement during development can increase students' self-awareness.

*Factors Influencing "**Actual Speed**":*

At the end of each phase, the developed artifacts are the product of actual speed and the total development hours in each phase. See Figure 2.

The direct factors to influence "Actual Speed" are identified from the survey. These include: "Potential Speed", "Learning Curve Factor", "Motivation" and "Development Phase Priority".

- Learning Curve Factor

Students learn the theory of the OVID methodology at the beginning of the semester. They learn and practice analysis, design, and implementation in the phases "Discover", "Design", "Develop" and "Deploy". As the project proceeds through each phase, their knowledge and skills increase. Students get feedback from the teaching staff during each phase, which helps the team gain more understanding of the process. The learning curve factor is illustrated in Figure 4. (Abdel-Hamid and Madnick, 1991; Kong et al. 2005, Weinberg, 1982)

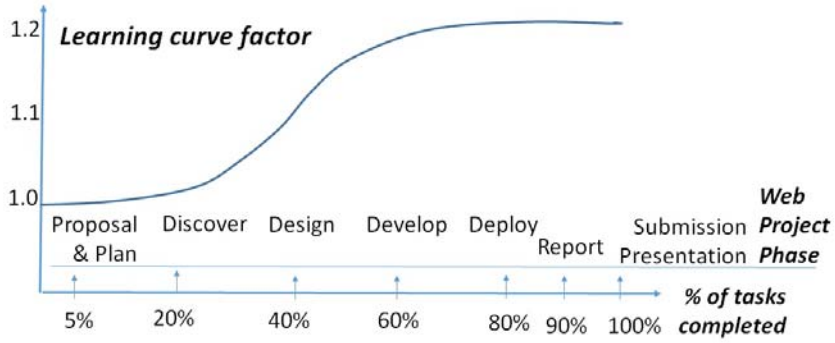

Figure 4: Learning curve factor and development phases

The learning curve and the development phases can be matched using the percentage of completed tasks as in Figure 4. We found that "Staff Feedback" on development artifacts during each phase positively influenced the learning curve factor.

- Motivation

Motivation is a large factor influencing the Actual Speed. Each group member has a different degree of motivation in development process. The major factors to impact the motivation include "Time Pressure", "Staff Feedback", individual member "Personality", "Time/Task Allocation" for each member, team member "Opinion Conflict", and "Setting project phase check point" during small time frames in each phase.

  - Time Pressure

We found that "Time Pressure" is influenced by "Planned Days" for each phase and "Total Days Remain to Due Date". The student project is constrained by the subject timeline for each assessment task. The project leader allocates individual tasks to each team member with estimated days. For example, in the "Design" phase, the project leader might allocate 10 days to Student A to complete the design task "Design Abstract View". See Figure 3 and the example in Table 2. Student D is the project leader in this example. In the beginning of the Design phase, the "Total Days Remain to Due Date" is 25 days. If the design progress is approaching the due date, the time pressure will increase. This will positively impact the motivation.

Table 2: Task Allocation and Estimated/Planned Days in Design Phase

Student	Task	Planned Days	Total Days Remain To Due Date
A	Design abstract view	10	25
B	Design outline tasks	10	25
C	Design detailed task diagrams	10	25
D	Design user objects	2	25
D	Map object and view states	6	25
D	Team coordination	-	25

  - Time/Task Allocation

If a team member sees the time/task allocated to him/her is unfair compared to other members, this will result in lower motivation.

  - Opinion Conflict

During team communication, if the team decides to choose a development artifact that conflicts with one team member's opinion, this may lower the motivation for this student. Design is a creative activity, and there are multiple alternative solutions. If teams do not have a robust method for decision-making, resulting in one student feeling that their input is not valued, it can lower their motivation.

  - Staff Feedback

Teaching staff feedback and encouragement can increase student motivation.

  - Setting Project Phase Check Point

The project is assessed in two stages. At each internal phase, there is no minor check point that is formally assessed, and consequently some students lack motivation until the final assessment due date is approaching.

- Development Phase Priority

A final factor to influence the Actual Speed is "Development Phase Priority".

The students in a team have different views to the importance of each phase in the development process in Figure 1. In the entire process, some students see the "Final Report

and Writing” and “Project Submission” as the most important phases, and consequently put more effort into these phases. Some students assign a lower priority to the early phases. If the web project descriptions for content/information/function, project deliverables, phase time line, and risk management are not very well planned with sufficient effort in early phases, there is lower actual speed in later phases.

The findings of this research are the above identified influence factors and their relationships from interviews. These findings can be applied to improve student learning in future.

Conclusions and future development

To understand student learning in a web development process for university study, in this research, we identified and analysed influence factors for project delivery efficiency. These findings can be applied to develop strategies for improving the student experience.

For example, we found out “Setting a small check point for internal phases” is an impact factor to “Motivation”. In the future subject development, we plan to develop a strategy around this factor. However understanding the relationships between factors is also important. For example, we could introduce a group weekly report, but this may increase the workload for the project leader and then reduce the actual speed. Further research is needed to understand how to balance the costs and benefits of various interventions based on the factors identified in this research.

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