Six Sigma Quality Improvement Methods for Creating and Revising Computer Science Degree Programs and Curricula

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Abstract - The first Bachelor of Science in computer science program was offered by our department 25 years ago. Today, as a School of Information Technology, we offer six computer science undergraduate degree programs, two graduate degree programs, and one doctoral degree program. In this paper, we report how our existing undergraduate degree programs have been revised using the Six Sigma DMAIC methodology to guarantee the continuous quality improvement of the programs and the quality of the graduates. We report on how two new unique undergraduate degree programs (B.Sc. in Computer and Cyber Security and B.Sc. in Office Computer Technology) were created by applying the DFSS Six Sigma concept. This not only guarantees the quality of the program and our graduates, but also ensures that we can meet the future demands of employers. We also report DFSS results on our two unique graduate programs: the M.Sc. in Computer Education Technology, a multi-disciplinary program combining computing, learning psychology, education, computer business, and ethics, and the M.Sc. in Information Technology Strategy which has derived from a combination of information technology, management, ethics, and strategies. Our doctoral program called Quality Information Technology, opened in 2005, is also briefly reported as our newest curriculum resulting from our Six Sigma-based research and development project.

Index Terms - Computer Science Curriculum, Computer Science Degree Program, DFSS, DMAIC, Six Sigma

INTRODUCTION

This paper presents a working method we have used for continuously improving and controlling quality of all curricula offered by our school. Such an approach has derived from the famous Motorola Six Sigma methodology. Results from the method are chronologically presented here in phases to reflect the continuous efforts for the “quality” curricula.

A brief overview on the Six Sigma methodology and a concept of quality used at the SCAAT is presented before our work is described.

We, the School of Information Technology at Phetchaburi Rajabhat University (widely known as the School of Computer and Advanced Technologies (SCAAT)), have found that the Six Sigma is the most suitable methodology for us to improve and control quality of present and future products and services in the SCAAT.

The Six Sigma is a continuous quality improvement methodology originally implemented successfully in business sectors [4],[10]. When implemented successfully, an organisation will enjoy, for example, significant profit increments while providing ‘quality’ products and/or services to customers. Customers for the Six Sigma are, for example, consumers who use products and/or services either directly or indirectly, or employees of an organisation. Table I shows the SCAAT customers.

Table I: The SCAAT Customers

<table>
<thead>
<tr>
<th>Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
</tr>
<tr>
<td>Parents</td>
</tr>
<tr>
<td>Organizations, companies, employers</td>
</tr>
<tr>
<td>Teachers, instructors, faculty, Dean, Deputy Dean</td>
</tr>
<tr>
<td>Administrative Staff, support staff</td>
</tr>
</tbody>
</table>

We believe that the educational sector is guaranteed to receive the same level of benefits when suitable methods are used. At the SCAAT, we use the Define-Measure-Analyze-Improve-Control (DMAIC) and the Design For Six Sigma (DFSS) methods. We summarize the DMAIC concepts in Table II and DFSS is described in Section 5.

In general, and specifically at SCAAT, the former is suitable for our existing products and services while the latter is used to create new products and services [1],[3].
TABLE II: DMAIC BRIEF EXPLANATION [4]

<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define</td>
<td>To identify problems, form a team, identify customers, identify key outputs, to prioritize customer requirements, to document the current process, to complete the requirement definition</td>
</tr>
<tr>
<td>Measure</td>
<td>To identify what to measure, types of variation, measure what you value, accuracy of measurements, conduct the measurement, calculate current sigma level, determine process capability</td>
</tr>
<tr>
<td>Analysis</td>
<td>To determine what caused the variation, brainstorms ideas for process improvements, determine which improvements have the greatest impact on customer requirements, develop proposed process map, assess risks associated with revised process</td>
</tr>
<tr>
<td>Improvement</td>
<td>To gain approval for the proposed changes, the impact assessment, finalize the implementation plan, implement the approved changes</td>
</tr>
<tr>
<td>Control</td>
<td>To establish key metrics, develop the control strategy, celebrate and communicate success, implement the control plan, measure and communicate improvements</td>
</tr>
</tbody>
</table>

We guarantee the quality of our curricula by combining three perspectives of quality [4] which are:

1. Customer perspective - making sure that each curriculum meets or exceeds our customers expectations,
2. Design perspective - each curriculum is designed not only to match with the IEEE/ACM computer science standards, but also to be competitive and unique,
3. Operations perspective – our faculty has the depth of knowledge to deliver (brand new) courses from each curriculum.

In the next section, we described the SCAAT method that combined all the above principles chronologically based on either the DMAIC or DFSS of each SCAAT curriculum.


The SCAAT was founded in 1983. However, originally, SCAAT was only a department under the School of Science and Technology and successfully changed its status to a school in 1998.

In 1984, the SCAAT was the first among all Rajabhat universities to offer computer science undergraduate degree programs. These degree programs were developed by the SCAAT and received accreditation by the Thailand Ministry of Education (MOE). It was the first case in which a curriculum was developed by a school instead of by the Educational Supervisory unit under MOE. Furthermore, the SCAAT received accreditation and its programs were recognised equally.

School Goals and Program Philosophy

Our 4-year plan when receiving the school status included:

- to offer six undergraduate degrees which were Computer Education, Computer Science, Computer Applications, Information Technology and Management, Mechatronics, and Computer and Data Communication,
- to ensure that our graduates were to be competent computer programmers with a full understanding of computer theory, and have the diligence to guarantee deadlines are met,
- to run computer laboratories with microcomputers which were shown to be sufficient when compared with other computer platforms,

Among the six degrees above, the first two being offered were Computer Education and Computer Science.

The philosophy of the Computer Education curriculum was to produce graduates who could teach computer science courses at the high school level or higher. The Computer Science curriculum philosophy was to produce graduates who could teach computer science courses at least at a 2-year college level or higher, could develop computer-assisted teaching software, could work in computer departments of organizations, could develop computer programs, had a positive attitude, and could systematically utilise computers in the workplace.

SCAAT Procedures and Environment

Here, we report two select cases that in later years were changed according to the Six Sigma initiatives:

- Student Recruitment Procedure: From 1983-1998 the SCAAT accepted 40-60 local applicants annually via an entrance examination, and offered 120 invitations to good academic-standing students countrywide. There was only one intake per academic year.
- Teaching Environment: In 1997, the SCAAT implemented the internet-related technology to improve teaching and the teaching environment. This was the first such use of technology among Rajabhat universities in Thailand. Websites owned by the SCAAT teachers and students were created and maintained.

SIX SIGMA-BASED INITIATIVES (1999 – PRESENT)
The SCAAT re-evaluated their customer base. Influenced by the Six Sigma methodology, their customers then and now are listed in Table I.

The First DMAIC Experience started when the SCAAT defined a problem as “to improve quality of their products (curricula) to meet customers’ expectations,” and resulted in two changes.

Revised Program Philosophy

The first group of customers being considered was students. As a result, all programs have their unique philosophy that enabled students to better understand the SCAAT products.

The philosophy of the Computer Education program was revised to produce graduates who could be teachers and/or educators, and who were able to teach as well as develop software. Also, the philosophy of the Computer Science program was revised to produce graduates who could develop computer application programs for both public and private sectors. Such computer programs could be used to improve organisations productivity and/or efficiency.

Four other curricula that were part of the 4-year plan had their own philosophies:

- Computer Applications – to produce graduates who were competent in improving computer systems especially for business sectors,
- Information Technology and Management – to produce graduates who planned to be executives having knowledge and skills related to human and resource management, and information technology management and projects,
- Mechatronics – to produce scientists or engineers with inter-disciplinary knowledge of electronics, mechanics, computers, and controlling the design and development of automatic tools and/or products,
- Computer and Data Communication – to produce scientists or engineers who were competent in controlling and designing remote- and local-information technology systems.

Revised Student Recruitment Procedure

The SCAAT customers, who were members of the local community, high schools, or companies/organisations, all identified their needs regarding the SCAAT internship programs. The SCAAT aimed to meet this requirement (expectation) and as a result, a new recruitment procedure was introduced.

Starting in 1999, the SCAAT was the first school to accept two intakes per academic year in order to respond to local high schools needs. It is still the only university school in Thailand to have multiple intakes. High schools from four neighbouring provinces are in need of SCAAT internships. With two intakes per academic year, the SCAAT was able to provide continuous support to those high schools (two semesters per academic year instead of only one semester). The SCAAT has successfully provided continued academic support to local communities because of the improved intake strategy.

DMAIC FOR QUALITY GRADUATES (1999-PRESENT)

In this section, we chose to present the Six Sigma project in two DMAIC cycles so that the big picture of the project could be shown clearly. This project is to improve and control quality of graduates based on the SCAAT programs philosophies.

DMAIC Cycle 1

The SCAAT defined that they must produce quality graduates. Therefore, additional characteristics of quality graduates were added in 2000. “Punyadee, Meewinai, Namjai-ngam” (“Intelligent, Disciplined, Courteous”) were added to the original characteristics of being a competent computer programmer with a full understanding of theory and having a high level of diligence and commitment stated in 1999.

During the define phase, processes used to guarantee the original characteristics were documented:

1. Competent computer programmers – students took three required computer programming courses along with elective courses. Students also produced individual final projects in the last year of studying.
2. Full understanding of theory – students needed to score at least 60% on the comprehensive exam called Rajabhat Institute Phetchaburi Achievement Test in Computer Abilities (RIPATICA), formally known as Miscellaneous Test, in order to graduate.
3. Diligence and commitment – The final project and the RIPATICA exam were used to test students on these two attributes. Students needed to have an A grade for the final projects to graduate. They were allowed to re-submit the project till the A grade was given. They were allowed to take the RIPATICA exam until their score was more than 60%.

Processes that helped refine every student to acquire the additional characteristics were:

4. Orientation Event – all new students attended this session to learn about the SCAAT, how to learn and study with us, how to adjust to the SCAAT environment, how to teach themselves to fit well with the expected professional etiquette,
5. Classroom Discipline – each professor took responsibility in this process, students were taught both academics and the SCAAT culture and values,
The Final Meeting – before graduation, a 2-day-1-night off-campus activity was set up primarily for the final-year students. However, any students were able to participate in this activity. Alumni, former, and current faculty shared working experiences and challenges, and exchanged information regarding further education, and careers. The overnight stay was designed to improve the sense of community among the group.

From the above processes, the SCAAT faced a dilemma that while maintaining a very high quality of graduates, the number of students graduating did not meet employer demands. Some students were able to get jobs before they officially graduated but they could not graduate on time due to the process (2) and (3) mentioned.

DMAIC Cycle 2

In 2004, the SCAAT used the Supplier-Input-Process-Output-Customer (SIPOC) [10] to study this dilemma further and was able to define that the SCAAT should graduate as many students as possible. The critical-to-quality (CTQ) factors for such ‘defined’ were [2]:

• Time: our students can graduate in a timely manner,
• Organisation: SCAAT needs to reduce its cycle time for graduate students,
• Organisation: SCAAT needs to be flexible by providing suitable alternatives for students to graduate,
• Value: SCAAT graduates have qualities that meet expectations for every group of customers.

The measure phase used the number of students graduated to measure for quality needed to solve the dilemma (problem) in the define phase.

The analysis phase identified what caused the problem and results were (1) having only an A grade for a senior project was one obstacle, and (2) allowing students to take the RIPATICA exam only in the last semester of the last year was the other obstacle.

The analysis phase proposed that students could graduate with the options such as (further details on this phase results can be found in [2]):

1. Pass the exam with the examination committee to receive a grade of A or B+,
2. Pass the exam with two project advisors to receive a grade of C+,
3. Pass the exam with a project advisor to receive a grade of D+,
4. Pass the exam by getting credits from work done at a workplace, receiving a grade of A or B+.

Also, students were allowed to take the RIPATICA exam when they completed their study of at least 6 semesters.

The improve phase allowed the new processes to be implemented. The ratio of the number of students graduated against those who could not graduate each semester was improved.

The control phase was implemented when the results from the improve phase were realised.

Since those new processes required full cooperation from all customers (faculty, staff, Dean, students, employers), another project was set up to develop an information system as a (automatic) tool to facilitate all customers involved in the processes to familiar with the new processes quickly [2].

DFSS PROJECTS 1999-2005

We report in this section four new degree programs that were created by applying the concept of DFSS.

The DFSS can have many methods of implementation. We combined the Define, Measure, Analyse, Design and Verify (DMADV) with the four basic activities (Concept Development, Design Development, Design Optimisation, and Design Verification) [4]. Our method can be outlined as follows:

1. Step 1: similar to the Define and the Measure states and the Concept Development, it is recommended to set goals of the design activity for new products and/or services. Such design should incorporate the CTQs, technology and economic possibilities. In our case, the SCAAT created new computer science curricula.
2. Step 2: as recommended in the Analyse and the Design states and Design Development, we should confirm to our team that the new products and/or services will meet the future demands of our customers. Also, they will be possible to implement and will be affordable and at the same time profitable. In our case, the new curricula have higher tuition fees than current curricula offered. However, customers (students) receive better benefits, for example, newer classrooms, comfortable time tables, and competitive degrees when looking for jobs.
3. Step 3: from the Verify state, Design Optimisation, and Design Verification, there should be mechanisms to pre-check that the production of new products and/or services is possible and the quality level can be guaranteed. In our case, we have a committee for each program created.

Even though the SIPOC diagram (Table III) is used in DMAIC, this diagram gave us a wider perspective when developing new curricula.
Upon graduation. We started to develop this program in computer and information technology security immediately. The need is to have computer scientists who specialise in private organisations, Thai government, and students. The SCAAT customers from Table I especially, public and new students for these new programs.

This program was designed to respond to the need of the SCAAT customers from Table I especially, public and private organisations, Thai government, and students. The need is to have computer scientists who specialise in computer and information technology security immediately upon graduation. We started to develop this program in 2005 and the first batch of students was accepted in the first semester of the 2007 academic year.

The classroom and modern facility is one of the requirements in the SIPOC. Therefore, the physical environment of the SCAAT has been improved to welcome new students for these new programs.

### B.Sc. in Computer and Cyber Security

This program was designed to respond to the need of the SCAAT customers from Table I especially, public and private organisations, Thai government, and students. The need is to have computer scientists who specialise in computer and information technology security immediately upon graduation. We started to develop this program in 2005 and the first batch of students was accepted in the first semester of the 2007 academic year.

The other quality that graduates from this program must possess is in the English language. Today’s information technology allows communication at the global level, so familiarity with the English language becomes a necessity.


### B.Sc. in Office Computer Technology – a continuing program

The need for our graduates to be able to apply computer applications to their future workplaces effectively and strategically is similar to all the SCAAT customers. This program philosophy includes (1) graduates have the necessary knowledge and skills to manage computer resources in organisations according to organisational IT strategies, (2) graduates would be intelligent end users of current computer applications, (3) graduates practice strict computer ethics and are ready to be accountable for the use of information technology and society under their management.


### M.Sc. in Computer Education Technology

This master degree program from the SCAAT is designed to serve the need of the educational community. Educators who are able to use technology to resolve classic problems in education appropriately are needed. A classic problem could be a technologist knows how to build computer software brilliantly but the software is not designed to solve specific educators’ issues. Conversely, educators know how to solve the problem but they can not utilise technologies or build software.

This program, therefore, is a multi-disciplinary program combining computing, learning psychology, education, computer business, and ethics. Graduates from this program are able to be researchers who perform research before starting to create computer software to meet the needs of end users; such software should be of sufficient quality to be marketable. Graduates can become leaders in educational technology and innovations, and deeply appreciate their roles in education development with high levels of professional ethics.

We currently have eight batches of students enrolled to this program. Courses offered include Database Systems Technology, Educational Computer Ethics, Management of Computer Business, Information Technology for Education, Educational Software Development, Knowledge Management, Models of Teaching Computing, Computers and Curriculum Development, Research Methodology in Computing Technology and Education [6].

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**TABLE III: SUMMARY OF SIPOC FOR SCAAT**

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppliers</td>
<td>High school students, Colleges, Universities, Local communities</td>
</tr>
<tr>
<td>Inputs</td>
<td>Research work, Lecture notes, teaching materials, Knowledge, Buildings, Information Technology, Office and classroom supplies, Budget and/or funding, Government Educational Framework</td>
</tr>
<tr>
<td>Process</td>
<td>Registration, Teaching and learning, Examinations, Phetchaburi Rajabhat University Achievement Test in Computer Ability (PRUATICA), Senior Project</td>
</tr>
<tr>
<td>Output</td>
<td>Curriculum, Textbooks, Classroom and modern facilities, Extra curricula activities, General services, Research results</td>
</tr>
<tr>
<td>Customer</td>
<td>See Table I</td>
</tr>
</tbody>
</table>
M.Sc. in Information Technology Strategy

This program is designed to produce graduates who can be information technology strategists as well as researchers in the information technology field. They will have collaborative knowledge from information technology, management, ethics, and strategies. They will become executives who not only manage technology effectively but also strategically and ethically for organisations. Based on the use of technology, their organisations should be able to retain their competitive advantage.

We have accepted four batches for this program so far. Courses that are designed for this program include Strategy Synthesis, Business Computer Ethics, Research Methods for Information Technology Strategy, Principles of Information Technology Strategies, Information Technology Project Management, Distance Management Technology, R&D Strategy and Organisation of IT, Boundary-less Organisation Theory and Design, Information Technology for Six Sigma Strategy [8].

Ph.D. in Quality Information Technology

This newest program by the SCAAT focuses on quality for information technology. The term quality for this program includes its principles and methodologies, as well as its tools and techniques. Graduates will be able to use the quality as a strategy to create innovative products and/or services providing a competitive advantage in information technology society. Such products and/or services can be for government sectors, private and for-profit organisations, and non-for-profit organisations. Graduates also are high quality researchers and information system developers.


CONCLUSION

In this paper, we present our experience in terms of using the Six Sigma methodology to continuously improve quality of the SCAAT computer science curriculum. We have both applied and modified DMAIC and DFSS methods in order for the methods to fit well in our domain - a school within a university. All the projects stem from our continuous efforts in quality improvement. Therefore the results reported here will used again in the next cycle of each project, and will be reported in a subsequent paper.

REFERENCES