Six sigma application for raising student academic achievement

Mazen Arafeh[a*], Mais Khader[a], Tamer F. Desouky[b], Nour Azzam[a] and Aishah Aljundi[a]

[a]Industrial Engineering Department, School of Engineering, The University of Jordan, Jordan
[b]Department of Psychology, College of Humanities, Effat University, Saudi Arabia

CHRONICLE	ABSTRACT
	This paper presents a case study on how Six Sigma methodology can be used to improve student academic performance in three main subjects (Math, Arabic, and English) in a private secondary school located in the Middle East. The Six Sigma methodology of Define, Measure, Analyze, Improve and Control (DMAIC) was used to improve student performance along with several improvement tools such as Fishbone diagram, Pareto charts, and Critical-To-Quality (CTQ) tree. Introducing quality improvement concepts and tools resulted in a series of improvements leading to an increase in student academic achievement quantified by Sigma Quality Level (SQL). The SQL improved in Math from (2.01) to (2.37) and in Arabic from (1.86) to (2.38). On the other hand, English grades did not increase from baseline. The results of this study provide a clear, step-by-step approach to systematically approaching and solving educational problems using the DMAIC model. Practically speaking, the results of this study provides clear evidence that the DMAIC can be used in the educational sector by school administrators and teachers to improve student grades.

1. Introduction

Six Sigma (SS) is defined as a disciplined, data driven approach of continually improving process quality and productivity to result in bottom line profitability (Ehrlich, 2002). Although many frameworks exist to use SS, perhaps the most useful is the DMAIC continuous improvement process; a standardized step by step process with specific tools for conducting improvement projects. DMAIC stands for Define, Measure, Analyze, Improve, and Control. From the time it was originated in Motorola in the late 1980s, SS has been successfully implemented in different transactional service environments, including healthcare, financial services, logistics, airline industry, and government to mention few (Antony, Jiju Antony, Kumar, & Rae Cho, 2007; Hasan, 2012; Nakhai & Neves, 2009). Several researchers and practitioners attempted to apply SS in educational institutions both in schools and universities to improve process and student performance (Mazumder, 2014).

2. Literature Review

The research literature in this field has shown two general approaches to applying SS in an educational environment. The first approach focuses on improving overall administrative processes while the second approach targets student performance directly.

2.1 Six Sigma for Improving Operations and Processes Improvement

With respect to improving operations and processes in an educational environment, Kumi and Morrow (2006) collaborated with a university library to successfully introduce SS practices in improving self-issue services. As a result of the project they

---

* Corresponding author. Tel.: + 962 6 535 5000 (Ext. 22940)

E-mail address: hfmazen@gmail.com (M. Arafeh)

were able to reduce the number of staff on the issue desk, move the self-issue units to more appropriate locations, increase the number of users who could use self-issue by increasing the fine limit, extend periods of user training throughout the year so that users know how to use the system; and make sure as much stock as possible can be issued in this way by fixing faulty barcodes and allowing CD-ROMs to be self-issued. Additionally, other researchers have proposed establishing information infrastructure, secure service competitiveness, and efficient knowledge management by applying SS in a university library (Kim, 2006). An extension of this area was reported by Sunder (2016) where book search times in a university library was reduced down to five minutes from the average fifteen minutes.

2.2 Six Sigma Student Performance Improvement

However, as a proven successful strategy in many industries and organizations, it is largely under-utilized in university settings. The challenges include difficulty in defining the customer for a university, the nature of the product, and the difficulty of measuring quality and reward systems for employees. Applying SS in a university is challenging due to the intangible nature of the educational product, the diversity of departmental and individual goals and viewpoints, and the administrative focus on seeking funding for the university's programs (Hoerl & Bryce, 2004). Additionally, the nature of the product, customer definition, quality measurement and employee reward systems differ significantly (Holmes, Kumar, & Jenicke, 2005). For example, while a company operates for 12 months a year, a university is in full operation for only 9 months. Add to that the complex shared governance in academia, this can lead to a much slower decision making process (Holmes et al., 2005). Perhaps these challenges stem from the fundamental differences the education sector has compared to manufacturing and service-based sectors (Mehrotra, 2012). First, it is quite difficult to observe "change" due to the longitudinal nature of academic learning and performance. Second, engaging with the human element in the study plays a significant role in the process that cannot be altered easily, as opposed to machines, which makes culture change much more difficult. Third, education often produces heterogeneous output, that is, each student has different features and responds to changes uniquely. Although it may sound difficult to apply traditional SS practices to the educational sector, researchers have re-conceptualized standard educational metrics as analogues to industry-based metrics. For example, student attrition been taken as a measure of defects for the process (Kaushik & Khanduja, 2010). With this type of reframing, promising results were reported based on case studies carried out by Prasad, Subbaiah, and Padmavathi (2012), Dhariwal and Bhagchandani (2013), and Chow and Downing (2014). Specifically, research has supported the idea that SS can also be used to directly affect student performance. For example, Hargrove and Burge (2002) applied the SS methodology to increase the retention rates of minority students to address the needs of highly skilled employees for the industry. Others, like Zahn (2003) discussed how introducing the SS DMAIC methodology may improve the engagement and understanding of students in a statistics course. As long as proper customizations and modifications are made prior to a SS intervention, it is quite possible to affect academic-based metrics, from overall retention rate (Chow & Downing, 2014), to more specific individual-based metrics like student engagement and academic performance. Recently, we demonstrated how quality improvement tools can be introduced and successfully applied in an elementary school to improve student performance and communication between the school administration, students, teachers, and parents (Arafeh, 2016). The project was carried out in English language classes for students in the first three grades at a private school.

3. Project Background

In this study the project team attempted to generalize the benefits of applying SS in educational institutions by expanding the scope of the (Arafeh, 2016) study to include three different subjects (Math, Arabic, and English) and to also include grades in the primary and secondary level (3rd to the 7th grades) within the same school. The environment of the school concerned in this study is much more challenging with much fewer resources than the first. In this way, it can be established that the SS method in educational systems can be applied regardless of the circumstances involved. This project is an atypical SS project in the sense that it was initiated by the quality improvement (QI) project team and not the school administration. The project was carried out at private secondary school in Amman, Jordan. The school has two hundred and twenty-six students, includes fifteen classes, and a total of twenty-nine teachers. The school consists of four main subdivisions which include male division, female division, primary division, and kindergarten. This project focuses on classes in both the male and female divisions.

4. Methodology

The DMAIC framework (Define, Measure, Analyze, Improve, and Control) was exclusively used in this project.

4.1 Define

4.1.1 Project Scope

A project charter was agreed to and signed once consensus was reached regarding the project's scope, methodology, and stakeholder responsibilities (see Table 1 for project goals). Achieving the objectives would start by having a deep understanding of the ongoing process of teaching and learning which has been sought by applying a standardized approach looking the Suppliers, Inputs, Process, Outputs, and Customers (SIPOC) for the school (see Table 2 for SIPOC analysis).

Table 1
SMART Goals for Project

S	Specific	Students from third to seventh grade with the collaboration of 20 staff members working with the project team aiming to decrease the percentage of students with GPA lower than 70% in a private school
M	Measurable	Quantified through student first and second month exam results
A	Attainable	Pursuing this goal is attainable through the administration's commitment, as well as the project team's knowledge and the staff's skills
R	Relevant	Project goals align with the school's overall strategy
T	Time Bounded	From February 2016 to December 2016 with specific milestones

Table 2
SIPOC Analysis

S - Suppliers	I - Inputs	P - Process	O - Outputs	C - Customers
• Ministry Of Education • School Administration	• State Educational Standards • Curriculum • School's Strategic Plan	Preparing Teaching Plan	• Classes Schedule • Books • Handouts • Projects • Year Plan	• Students • Teachers • School Administration
Teachers	Class Schedule	Conducting Classes	• Lecturing & Teaching • Assignments	Students
Parents	• Handouts • Homework	Tutoring	Prepared Students	• Students • Teachers • School Administration
Students	Assignments	Completing Assignments	Completed Assignments	• Parents • Teachers • School Administration
Teachers	• Prepared Students • Completed Assignments	Evaluating Student Performance	Grades	• Students • Parents • School Administration

4.1.2 Collecting the Stakeholder's Voices

One of SS's main characteristics is that it is driven by understanding the stakeholders' requirements. In this project, stakeholders were identified as the school administration, teachers, students, and parents. Stakeholders were further sub-divided into external (students, parents) and internal groups (teachers, school administration). Additionally, quality drivers were measured and given special attention due to their large influence. Quality drivers are the major factors that affect academic achievement. As a result, these factors will be targeted as the main area of improvement (to be discussed more in detail in section 4.1.7).

4.1.3 Voice of Business

Frequent communication was conducted with the school administration in order to deliver the project team's message and receive the needed information about the process and the problems that might face the project implementation, as well as list the quality drivers that contribute in the academic achievement from the point of view of the business side.

4.1.4 Voice of Process

Seeking to better understand the ongoing process, the QI team observed thirteen classes, covering all the grades, subjects, and teachers in the scope. Multiple conclusions were drawn from these observations about the strengths and weaknesses of the current process. As a result, these observations were used in the subsequent phases.

4.1.5 Voice of Employee

Multiple meetings with the teachers were conducted in order to ensure full understanding of the project's goals, procedure and the method of execution. Sessions were conducted to collect data on the list of quality drivers affecting the academic achievement of students through the voice of employee. In addition, an affinity diagram was built to group the ideas resulting from the brainstorming session based on their relationship, in order to sort and organize it.

4.1.6 Voice of Customer

One of SS's main characteristics is that it's driven by customer requirements. Their voices were collected to identify the quality drivers that will have the greatest impact on the improvement process, which satisfies the customer's requirements.

4.1.6.1 Teacher Survey

A survey was administered to teachers seeking information on quality drivers with respect to treatment of students, training of teachers, incentive and rewarding system, ability to incorporate weak students with the rest of the class, dynamic classes,

peer influence on academic performance, positive effect of homework on the student comprehension, effect of student socio-economic status on performance, effect of classroom environment, and lastly effect of class duration.

4.1.6.2 Parent Survey

The quality drivers that were investigated with respect to parents were their opinions on peer influence on academic performance, effect of student subject preferences, effect of teacher-student relationship, extracurricular activities, dynamic classes, amount of homework, and positive effect of homework.

4.1.6.3 Student Survey

Students responded to a survey measuring their opinions on the quality drivers of teacher's treatment of students, non-traditional methods of teaching, dynamic classes, classroom environment, homework effect on subject's understanding, parents following up with homework, parents monitoring academic achievement, and student preference for academic subjects.

4.1.7 Team Diagnosis

After stakeholder voices were collected and analyzes, a subsequent session with the project team was initiated in order to understand causal relationships. Subsequently, identification of the causes (quality drivers) that affect the academic achievement was finalized via a fishbone diagram (see Fig. 1).
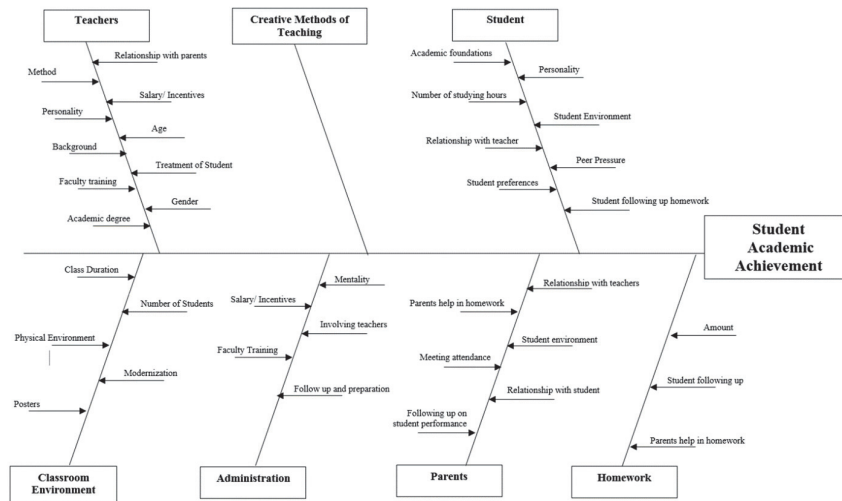

Fig. 1. Fishbone Diagram

4.2 Measurement

The measurement phase aims to measure the quality drivers of the current process as well as quantifying the variable of interest (student grades).

4.2.1 Student Grades

The mean, standard deviation, proportion of students below the lower specification limit (LSL) (70%), and Sigma Quality Level (SQL) were measured. The SQL is computed by taking the difference between the Upper Specification Limit (USL) and the process average ($\bar{x}$) divided by the standard deviation (s). The SQL is expressed mathematically according to the following equation:

$$SQL = \frac{(USL - \bar{x})}{s} \tag{1}$$

As indicated by the data collected, the proportion of the students below the lower specification limit (LSL) (70%) is quite high. Also, the SQL for Math, Arabic, and English is 2.01, 1.86, and 2.11 respectively, which indicates a need for improvement. Based on agreement with the school's administration, the objective for the academic achievement was set to lower the proportion of the students under the LSL (70%) by 5% for each subject (see Table 3).

Table 3
Assessment of Student Grades *before* DMAIC Implementation

	Math Grades	Arabic Grades	English Grades
Mean	79.94	76.71	80.83
Standard Deviation	19.44	18.67	17.83
Proportion Below 70%	26.4%	29.7%	27.2%
Sigma Quality Level (SQL)	2.01	1.86	2.11

4.2.2 Survey Results

4.2.2.1 Teacher Survey

Teachers strongly agreed on four key factors which consist of (1) teacher treatment of student impacts willingness to learn, (2) students tend to develop a better understanding for a subject when it is given in an interactive and dynamic class, (3) students tend to develop a better understanding for a subject when non-traditional methods of teaching is used, and (4) the classroom environment plays a key role in the student's ability to concentrate in class. Also, a neutral stand was measured from teacher attitude towards the incentive and rewarding system in the school. In addition, there was a big deviation in teacher point of view about the positive effect of homework on student comprehension of the subject taught.

4.2.2.2 Parent Survey

Parents strongly agreed on five key factors, (1) peers influence the academic performance of students, (2) student subject preferences play a key role in the student's academic achievement, (3) teacher-student relationship motivates the students to achieve a better understanding of the subject, (4) students tend to develop a better understanding for a subject when it is given in an interactive and dynamic class, and (5) the positive effect of homework on students' comprehension of the subject taught. There was a big deviation on whether extracurricular activities distracts students or not, the effect of student's personalities on their ability to learn in interactive and dynamic classes, and that the current amount of homework creates a burden on the students.

4.2.2.3 Student Survey

Students strongly agreed on two key factors, (1) teacher treatment of student impacts willingness to learn, and (2) parents monitoring academic achievement thoroughly. Students varied in their point of view on their tendency to develop a better understanding for a subject when non-traditional methods of teaching is used, their tendency to develop a better understanding for a subject when it is given in an interactive and dynamic class, and whether their parents are involved in helping them with solving their homework.

4.3 Analyze

4.3.1 Pareto Charts

During the analyze phase the aim is to specify the root causes of the poor performance. Based on the previous measurements and evaluations of the current process, the authors of this study were able to identify the major areas of improvement through studying the impact of each quality driver on the academic achievement. The results of three surveys given to teachers, parents, and students were analyzed to identify the relative importance of each quality driver to find the most significant factors through designing a Pareto Chart (see Figs. 2, 3, and 4). The Pareto principle states that, for many events, roughly 80% of the effects come from 20% of the causes.
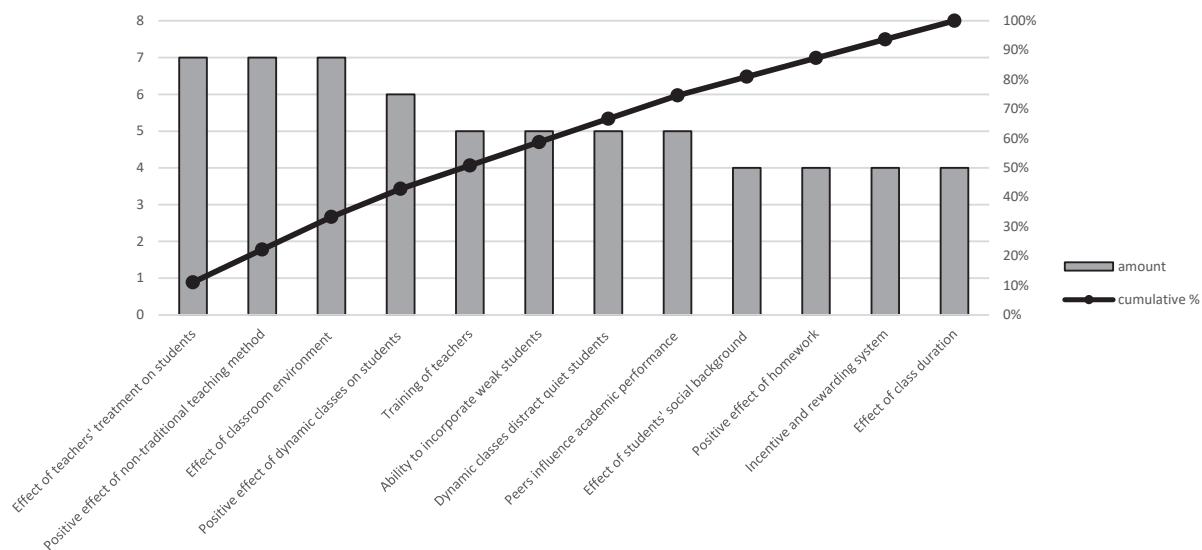
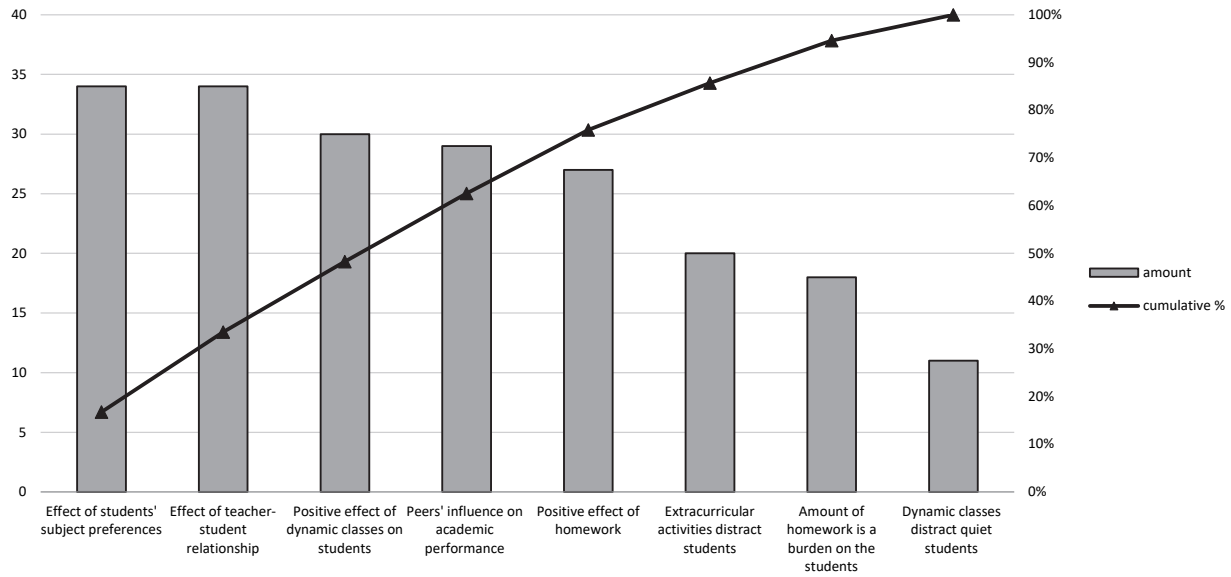

Fig. 2. Pareto Chart of Teacher Survey Results

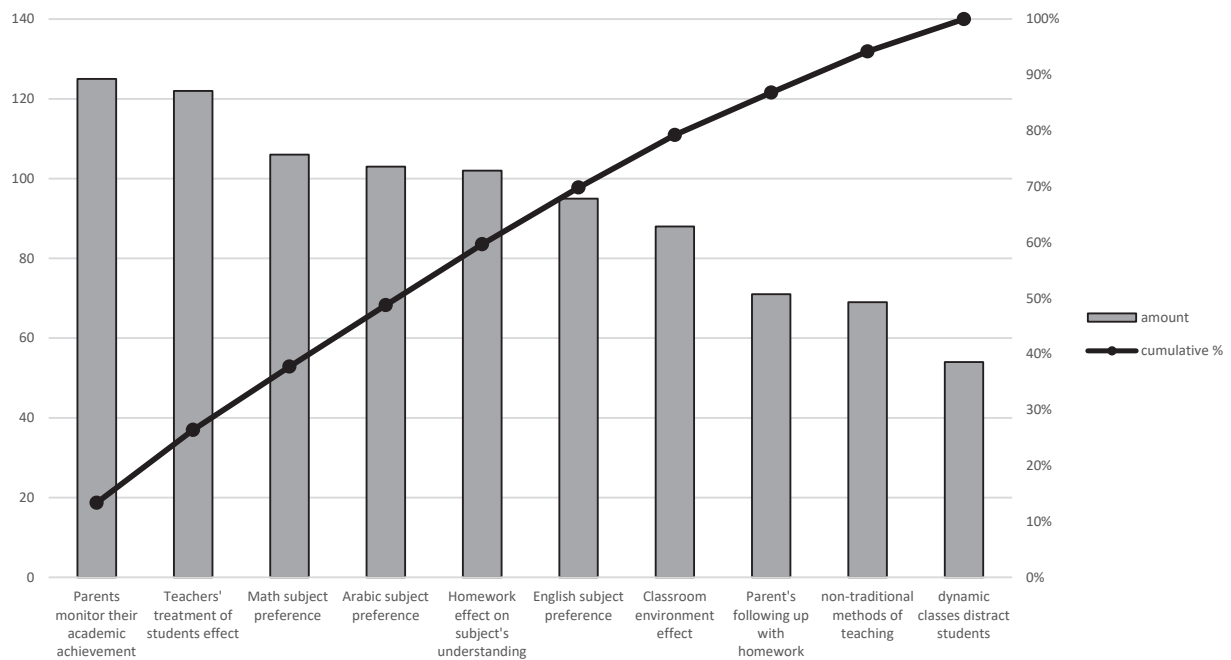**Fig. 3.** Pareto Chart of Parent Survey Results

Fig. 4. Pareto Chart of Student Survey Results

Based on the voices collected from the previous phases and the analysis that was done through the Pareto Chart, the final quality drivers with the highest impact on the academic achievement of the students are:

1. Efficiency of the homework system
2. Classroom environment
3. Creative teaching methods
4. Parents' engagement
5. Student-teacher relationship
6. Extracurricular activities
7. Academic support program
8. Teacher satisfaction

Due to the fact that student grades consist of many quality drivers that develop over a long period of time, it was decided to focus on the improvement of these quality drivers as objectives of the study. The following table illustrates each quality driver and its corresponding from the study objectives (see Table 4). These objectives were considered as key process input variables (KPIV) for the academic achievement which will be the key process output variable (KPOV)

Table 4
The Quality Drivers and the Study Objectives Relationship

	Quality Driver	Objective
1	Efficiency of the homework system	Enhance Homework system efficiency
2	Classroom environment	Improving the classroom environment
3	Creative teaching methods Student-teacher relationship	Increasing class participation
4	Parents' engagement	Enhancing Parents involvement in meetings from
5	Student-teacher relationship Extracurricular activities	Increase the satisfaction about school activities
6	Academic support program	Creating an efficient tutoring program
7	Teacher satisfaction	Increase teacher Satisfaction

To set specific goals for the objectives, an assessment of the current status for each objective was necessary. The assessment was done through a Satisfaction Survey that was distributed to the teachers to state their current evaluation. Objectives were set to be improved by 10% for each goal as requested by the school's administration, however due to the fact that the current state of satisfaction about the school activities is very low, the objective was set to be improved by 20%. Table 5 illustrates the current status of each objective and its goal.

Table 5
Measurement of Objectives *before* DMAIC Implementation

	Objective	Before DMAIC	Goal
1	Enhance homework system efficiency	80%	90%
2	Increasing class participation	68%	78%
3	Enhancing parent involvement in meetings	60%	70%
4	Increase satisfaction about school activities	30%	50%
5	Increase teacher satisfaction	54%	64%

4.3.1 Critical-To-Quality Tree

Critical-To-Quality (CTQ) Tree relates the quality drivers that were driven from customer needs to specific, actionable, and measurable improvements. The improvement actions were generated from the consultancy of educational experts and school administration suggestions (see Fig. 5 for more information).
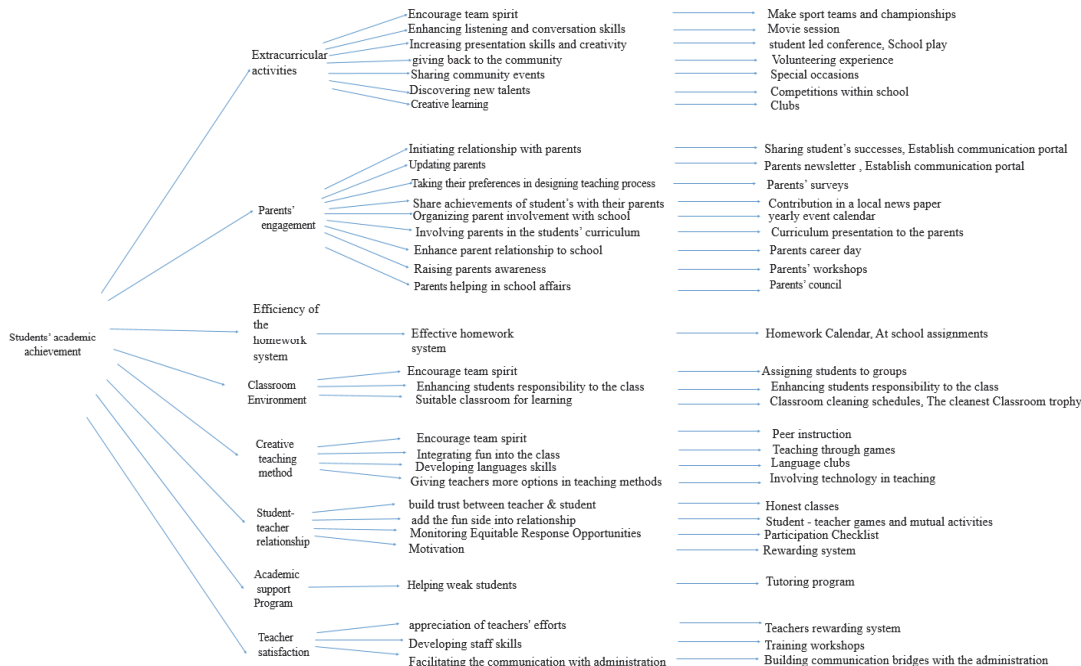

Fig. 5. CTQ Tree

4.4 Improve

This phase aims to identify potential improvements for the quality drivers resulting from the previous phase, prioritize their implementation, test hypothetical solutions, and implement actual improvements. Figure 6 is a graphical display of all the quality drivers and their associated improvement actions.
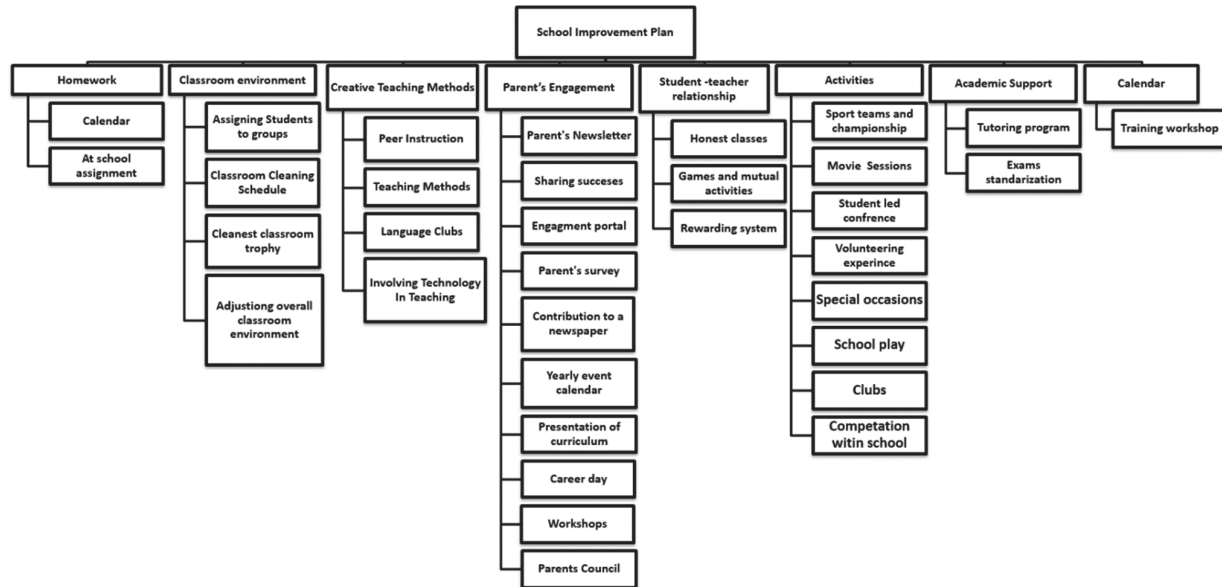

Fig. 6. Improvement Actions

Driven from the actions identified in the CTQ Tree, the action plan of improvements was formulated to specify the targets of each action, the action points to accomplish it, the roles and responsibilities, the resources needed, the priority of each action, and the ultimate objective that served by the actions. Thirty six actions were derived from the customer requirements based on the main quality drivers. Also, one hundred and ten action points were needed to achieve the actions.

4.4.1 Criteria for Prioritizing Implementation of Improvement Actions

Two main criteria were taken to prioritize the actions. The first one is the impact of each action on the project and stakeholders, with a rank in the range of (1-5). The second criterion taken is the ease of application, with a rank in the range of (1-3). Then the data was divided into 3 levels (A, B, and C). Level "A" having the highest priority with rank (7-8), B level with rank (5-6), and level "C" having the lowest priority with rank (2-4). After prioritizing the action plan, 18% of the actions were concluded to have a level "A" priority, 50% with a level "B" priority, and 32% with a level "C" priority.

4.4.2 Roles and Responsibilities

The presence of several grades and different subjects included in the scope of the project, and the presence of both academic and non-academic improvement actions, required the need for "moderators" to facilitate and organize the process to guarantee that the improvement actions run smoothly. A responsibility matrix was designed to assign each staff member to their roles; either to be responsible of the task, accountable for it, informed of it, or supports the execution of the task.

4.4.3 Timeline for Execution of Action Plan

To regulate the implementation of the action plan, a timeline was constructed with the help of the staff and with the consideration of the school calendar.

4.4.4 Follow-Up System

To keep up with the action plan, two main approaches were used; the task checklist and periodic meetings. The checklist that included all the tasks required is used to monitor the progress throughout the assigned time period for each teacher on the basis of one month. A total of 30 meetings was held to follow up, listen to feedback, and refine each action in order to optimize its benefit. To analyze the risks facing the implementation of the action plan, the Process Decision Program Chart (PDPC) was designed. The PDPC gives the researcher a systematic overview of risks during plan development, and as result, risk mitigation can be implemented for prevention purposes (Mehrotra, 2012). Follow-up meetings were conducted in order to listen to feedback and refine each action in order to optimize its benefit.

4.4.5 Implementation of Action Plan

The action plan was implemented with the help of all the different tools shown above in a period of three months. Many of the actions were accomplished, several were partially accomplished, and some are in the progress of implementation. To measure the impact of the improvements, an assessment of the recent status was necessary. The assessment was done through a survey that was distributed to the teachers to state their evaluation after the improvements. Also, a visual assessment was used to evaluate the upgraded classroom environment. Table 6 illustrates the status before improvement for each objective, its preset goal, and its recent status after improvement:

Table 6
Measurement of Objectives after DMAIC Implementation

	Objective	Before DMAIC	Goal	After DMAIC
1	Enhance Homework system efficiency	80%	90%	92%
2	Increasing class participation	68%	78%	88%
3	Enhancing Parents involvement in meetings	60%	70%	72%
4	Increase the satisfaction about school activities	30%	50%	64%
5	Increase teacher's Satisfaction	54%	64%	68%

Overall, this indicates that the stakeholders are satisfied with the improvements made and with their corresponding results. Consequently, and as discussed earlier, the improvement of these objectives will eventually lead to an increase in the academic achievement on the long term. The following are the examples on the improvements made on the classroom environment:

- Students are seated in groups which motivate teamwork and allow the students to help one another to have a better understanding of the subjects given.
- The curtains are placed so that it covers the sunlight and the lights are sufficient which gives a suitable learning environment, so the whiteboard is now clear and the students are able to see what is written.
- The walls are full of posters that are related to the students and shape a motivational environment. One of the posters is the cleaning schedule to ensure that the classrooms stay clean and are suitable for learning.
- A clear rewarding system for teachers was designed to increse teachers' statisfaction and increase the inclass participation. A contest was announced for the teacher of the month and a clear pointing system was desgined.
- A tutoring program was held after school hours to increase students academic achivement and support the learninig process.
- Regular meetings were held between the school staff to build communication bridges and facilitate communication between the teachers and the school administration.

A series of side measurements were taken to get a better understanding of how the improvements affected the educational process in the eyes of the costumers. A satisfaction survey was distributed to the parents and interviews were held for students. The Parent Survey was designed to measure their satisfaction about the process' new improvements. Based on the survey results (see Table 7), parents are satisfied with the main improvements which indicate that the project is directed in the right path for change.

Table 7
Parent Satisfaction Survey

	Improvement Actions	Parent Satisfaction
1	New homework system	99%
2	Current class participation	91%
3	Extra-curricular activities	95%
4	Student's group system in class	92%
5	Peers' instruction in class	96%
6	Parents' WhatsApp portal	97%

Students were interviewed about the improvements and it was found that the students are satisfied and appreciated the actions implemented in the school. Also, the students gave suggestions of what can be done to enforce change in a broader manner and the suggestions were communicated to the administration by the project team to be implemented in future semesters.

4.4.6 Student Grades

As an indicator for student academic achievement throughout the improvement phase, data was collected from the first month grades (baseline) and second month grades (post intervention). Grade marks for the first month were taken to represent the academic achievement of the students as a first indicator for the beginning of the implementation of the improvement actions. After analyzing the first month marks it was found that the SQL for Math is 2.15, for Arabic is 2.18, and for English is 1.58. This indicates that for both Arabic and Math the SQL improved while dropping for the English subject.

4.4.6.1 Math Grades

The SQL for Math grades showed a substantial increase in the SQL, as it was 2.01 before improvement and 2.37 after improvement (see Fig. 7). The mean for the population also increased from 79.94 to 84.91. The proportion for defects under the

LSL (70%) improved from 26.40% to 20.79%. Finally, the standard deviation for the population before the improvements was 19.44 and now decreased to 17.08. All of the statistics indicate a significant positive change in student grades.
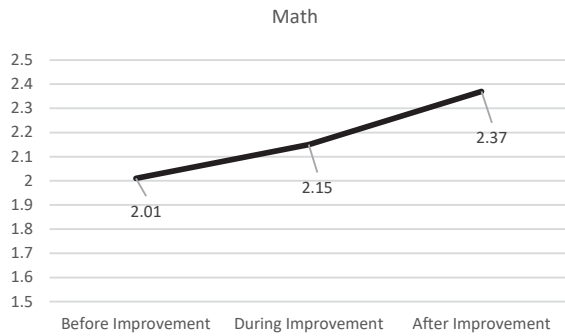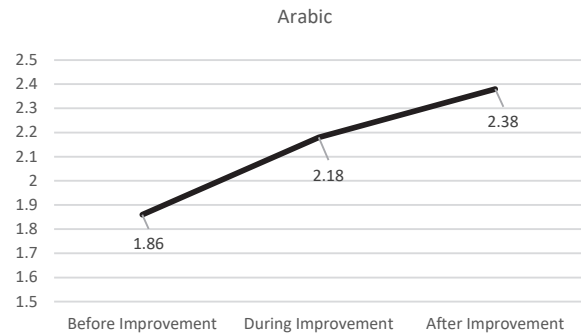

Fig. 7. Sigma Quality Level (SQL) for Math

Fig. 8. Sigma Quality Level (SQL) for Arabic

4.4.6.2 Arabic Grades

There was a substantial increase in the SQL for Arabic grades, as it was 1.86 and after improvement it became 2.38 (see Fig. 8). The mean for the population also increased from 76.71 to 83.6. The proportion for defects under the LSL (70%) was 29.7% and is now only 18.26%. Finally, the standard deviation for the population improved from 18.67 to 15.38. All of the statistics indicate a positive and large effect in student grades.

4.4.6.3 English Grades.

For English grades, the SQL dropped from 2.11 to 1.91 (see Fig. 9). Also, the mean dropped from 80.83 to 78.79 and the proportion of defects under the LSL actually increased from 27.2% to 30.27%. Additionally, the standard deviation increased from 17.83 to 21.5. The statistics measured indicate that there is a fault in the system for teaching English. Further investigation uncovered that this particular subject had only one teacher who taught four classes out of the five under study. The teacher was inexperienced in teaching (4–7th) level grades, and this created extra load on the teacher to prepare for the classes properly as well as provide sufficient attention to students. The other teacher who was teaching the fifth class resigned from the school during the project implementation and a substitute teacher was assigned that was not well aware of the project. This issue was discussed with the school administration and preventive measures were taken. Refer to Fig. 9 to view the change of the SQL for the academic achievement before, while, and after improving.
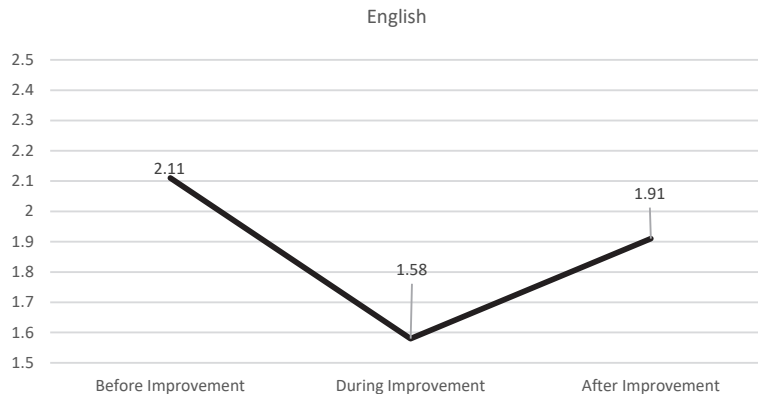

Fig. 9. Sigma Quality Level (SQL) for English

4.5 Control

Multiple techniques were used to monitor and adjust future process variations, such as the use of the sustainability plan, an incentive and rewarding system for the staff, and generalizing the concept on the rest of the school. Additionally, the project team used a table of potential problems along with respective corrective actions in order to ensure process stability (see Table 8 for more information). Upon the completion of the project, lessons learned and findings were discussed between the QI team, the school administration, and the teachers. The evident positive results from the Arabic and Math classes and the enthusiasm of the participating teachers motivated the teachers of other subjects and other grade levels to participate in the next cycle of the project, learn about, and adopt the quality tools and techniques used.

Table 8
Corrective Actions during Control Phase

	Challenges	Suggested Solutions
1	Lack Of Communication	• Building trust bridges between administration and project team. • Periodic meetings between administration and project team. • Constant follow ups with the new updates.
2	Irresolute Actions	• Disciplinary actions have to be taken towards teachers who do not comply. • Authority should be practiced when decisions are made by the school administration.
3	Teamwork	• Engage teachers in designing the process in order to gain their loyalty and enhance teamwork. • Work on administration ability to lead teachers toward goals.
4	Poor Preparation	• Take announcements from project team earnestly and go forth with prerequisites for tasks.
5	Poor Follow Up	• Proactive following up techniques
6	Unclear Expectations	• Clear explanations for the school staff that changes happen gradually and need time to show. • Clarify administration expectations with project team.
7	Tool Pushing	• Institutionalized foundations should be put for the tools used. • Tools should be given time to show their effectiveness and added value. • Sustaining useful tools overtime. • Appropriate feasible tools only should be applied.
8	Lack Of Commitment	• Project team suggestions should be taken into account and applied thoroughly throughout the school processes.

5. Conclusion

5.1 Implications and Summary

The SS quality improvement philosophy, and specifically, the DMAIC model, is a powerful tool to achieve quality improvement in practically any industry from manufacturing to educational. In this study, a thorough approach to defining, measuring, analyzing, improving, and controlling factors affecting student academic performance (measured by grades) was used with success. The results from this study mirrors what others have done. Quality improvement tools may be used to identify shortcomings and find solutions to improve the academic achievement of students. This study brings a unique approach to the usage of SS in educational environments. It was found from this study that SS can be used to improve the academic achievement of students in cases with different parameters. That is, it can be used in a gender segregated school environment, primary or secondary class students, and for subjects that require various skills and cognitive ability (e.g. math and different languages). The authors believes that school adoption for SS will have a large and significant effect not only on the students, but also on parents, school administration, teachers, and school staff. One of the most important factors that contributed to the success of the application of SS was the school administration's strong desire to change and their commitment to continuously motivate teachers and school staff to the process of change.

5.2 Limitations

The present study is not without limitations. First, during the measurement phase it was found that some of the survey results for teachers and students were found to be contradictory with respect to the preconceived expectations and the reality of the situation. The proposed reason for this is the fear of being forthright with their opinions, and their lack of understanding the purpose of the survey. Second, during the analyze phase, there was a need to expand the project's objectives due to additional information that was made present after the project charter was completed. Although this did not drastically affect the overall project, it did provide a challenge. Third, statistical inference was impacted by the lack of diversity especially with English classes. Only one teacher taught English to several students in different grade levels. As a result, this study suffered from bias and the SQL for English grades showed a decreased performance during and after DMAIC implementation. Fourth, the new culture of continuous improvement that developed while applying the action plan resulted in identifying staff members incapable of working in such a culture. This caused one of the staff members to quit on the basis of not being able to catch up with the rest of the team. Finally, as stated previously, a series of refinements for the actions were taken while applying the improvements in the light of their efficiency, effectiveness and stakeholder suggestions. We view these refinements as minor, however, they do provide a limitation from a strict research point of view.

5.3 Recommendations

Recommendations and lessons learned from this study stems mainly from the human interaction with school administrators, teachers, and parents. It is strongly suggested that a much more detailed approach to implementation is discussed beforehand in order to ensure project success and minimize deviation from the project plan. Furthermore, a cross-examination with other schools could provide additional information on factors affecting academic performance that was not identified in this study. Finally, it is suggested that the assigned moderators are provided with much more detailed training before project implementation.

5.4 Further Work

Future work should look at differences between private and public schools due to resource allocation, public support, and educational quality, which are additional factors in affecting academic performance. Moreover, moving this approach to university-level academic performance may provide interesting results. Finally, it is recommended to examine cross-cultural

factors that affect academic performance in order to fully understand how DMAIC can be successfully used in the educational sector.

References

Antony, J., Jiju Antony, F., Kumar, M., & Rae Cho, B. (2007). Six sigma in service organisations: Benefits, challenges and difficulties, common myths, empirical observations and success factors. *International Journal of Quality & Reliability Management, 24*(3), 294-311.

Arafeh, M. (2016). Leveraging Six Sigma Tools and Methodology to Improve Student English Language Performance at Elementary School. *American Journal of Operations Research, 6*(4), 720-726.

Chow, T., & Downing, C. G. (2014). *A Case for Implementing Six Sigma Improvement Methodology in Academia.* Paper presented at the IIE Annual Conference. Proceedings.

Dhariwal, P., & Bhagchandani, M. (2013). Implementation of Six Sigma Methodology in Academics. *International Journal of Sustainable Development and Green Economics*, *2*(1-2), 17-21.

Ehrlich, B. H. (2002). *Transactional six sigma and lean servicing: leveraging manufacturing concepts to achieve world-class service*: CRC Press.

Hargrove, S. K., & Burge, L. (2002). *Developing a six sigma methodology for improving retention in engineering education.* Paper presented at the Frontiers in Education, 2002. FIE 2002. 32nd Annual.

Hasan, M. (2012). Six Sigma in Service Organizations. *Journal of Modern Accounting and Auditing, 8*(6), 900.

Hoerl, R., & Bryce, G. R. (2004). What influence is the six sigma movement having in universities? What influence should it be having? *Lean & Six Sigma Review, 3*(2), 37.

Holmes, M. C., Kumar, A., & Jenicke, L. O. (2005). Improving the effectiveness of the academic delivery process utilizing Six Sigma. *Sigma, 1*(4), 15.

Kaushik, P., & Khanduja, D. (2010). Utilising six sigma for improving pass percentage of students: A technical institute case study. *Educational Research and Reviews, 5*(9), 471-483.

Kim, D. S. (2006). *A study on introducing six sigma theory in the library for service competitiveness enhancement.* Paper presented at the the Proceedings of the World Library and Information Congress: 72nd IFLA General Conference and Council, Seoul, Korea.

Kumi, S., & Morrow, J. (2006). Improving self service the six sigma way at Newcastle University Library. *Program, 40*(2), 123-136.

Mazumder, Q. H. (2014). *Applying six sigma in higher education quality improvement.* Paper presented at the 21st ASEE Annual Conference and Exposition.

Mehrotra, D. (2012). *Implementing Six Sigma in Education Towards TQM in Academics* (1 Ed.). New Delhi: S. Chand Publishing.

Nakhai, B., & Neves, J. S. (2009). The challenges of six sigma in improving service quality. *International Journal of Quality & Reliability Management, 26*(7), 663-684.

Prasad, K. D., Subbaiah, K. V., & Padmavathi, G. (2012). Application of Six Sigma methodology in an engineering educational institution. *International Journal of Emerging Sciences, 2*(2), 210-221.

Sunder, V. M. (2016). Lean Six Sigma in higher education institutions. *International Journal of Quality and Service Sciences, 8*(2), 159-178.

Zahn, D., Watson, G. H., Voelkel, J. G., & Patterson, A. (2003). *What influence is the Six Sigma movement having in universities? What influence should it be having?* Paper presented at the ASQ Six Sigma Forum Magazine.