International Journal of Evaluation and Research in Education (IJERE)
Vol. 14, No. 5, October 2025, pp. 3565~3573
ISSN: 2252-8822, DOI: 10.11591/ijere.v14i5.33288

Six-Sigma approach to improve industry engagement strategies in Malaysian apprenticeship program

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Article Info

Article history:

Received Oct 17, 2024
Revised Jun 16, 2025
Accepted Jun 25, 2025

Keywords:

Apprenticeship system
Industry engagement
National Dual Training System
PLS-SEM
Six-Sigma DMAIC

ABSTRACT

This empirical study develops an industry engagement model (IEM) by using the Six-Sigma define, measure, analyze, improve, and control (DMAIC) methodology to investigate the key strategies to enhance industry participation (IP) in the Malaysian apprenticeship program known as the National Dual Training System (NDTS). The relationship between five strategies, namely financial incentives (FI), digital administration (DA), productive collaboration (PC), flexible implementation (FT), and efficient promotion (EP) on IP, was examined. The 204 returned questionnaires were analyzed using partial least square-structural equation modelling (PLS-SEM). The findings reveal that FT, EP, and DA strongly influence IP in the NDTS program. In contrast, improvement in FI and PC has little impact on industry involvement. The development of IEM by demonstrating the DMAIC concept is novel and new to the research. It offers enormous potential and value in improving policymakers' decision-making in apprenticeship programs. It may also be extended to other areas of education in the future.

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1. INTRODUCTION

The Six-Sigma concept has gained popularity as a methodology for enhancing process and product effectiveness and continuously raising quality standards to exceed customer expectations [1]. It is a management strategy to analyze the root causes of business problems and solve them using a statistical approach and, at the same time, create transformation at a lower cost [2]. In manufacturing, the Six-Sigma focus is on delivering the required output to the customers; however, in service sectors, there is more emphasis on management strategies to enhance and align the process of working to meet customer satisfaction [3]. The Six-Sigma is more comprehensive prior to total quality management (TQM) and continuous improvement (CI) because this method includes measured and reported results using more advanced data analysis tools [4].

The Six-Sigma method is patterned after the plan-do-check-act (PDCA) for new product design; meanwhile, for process improvement, the five-step method is applied using define, measure, analyze, improve, and control (DMAIC) [5]. However, the DMAIC is preferred over the PDCA method in education sectors, as DMAIC provides consistent emphasis on problem-solving by integrating specific tools into each step of the phases, making it a unique statistical problem-solving method to achieve desired goals [6], [7].

The Six-Sigma DMAIC has been widely used to improve quality in education sectors, especially in higher education institutions (HEIs) [5], [8], [9].

Six-Sigma was developed by Bill Smith, an engineer at Motorola, in the mid-1980s to improve process and quality control at the company. Due to its success as a problem-solving tool, Motorola received its first Malcolm Baldridge National Quality Award in 1988. Since then, the Six-Sigma methodology attracted many large companies, including Texas instruments, International Business Machines Corporation (IBM), and digital electronics, to apply this concept in improving quality and services as well as optimize output while reducing waste. Nowadays, this concept has been adopted by many organizations in the service industry, such as healthcare, financial institutions, hospitality and tourism, government, non-profit organizations, and education sectors [10]–[12]. It has been said that the DMAIC methodology is the most successful process improvement concept in education sectors by applying the common tools as described by Bumjaid and Malik [13]. It more often used in HEIs to improve methods in most areas of education, such as curriculum design, student learning performance, and academic achievement, as well as teaching and learning [2], [9], [14]. Nevertheless, it is still in its infancy in the other education sectors.

Therefore, Chang *et al.* [3] begins demonstrating the DMAIC concept in school environments to assess and improve online learning experiences for students before and after COVID-19. Student learning experiences score improved from 55.81% during face-to-face lectures to 61.59% for online learning after the pandemic when DMAIC improvement initiatives were implemented. The results showed that the DMAIC seemed to work well with school environments, which raises the possibility that it could be applied to improve in other educational systems.

Lasiana and Hidayatulloh [5] deploy the Six-Sigma DMAIC methodology to improve the learning process at high schools in Indonesia. The study uses a qualitative approach through observation, interviews, and documentation for data collection with the principal, vice principal, and other related stakeholders as research participants. Results show that the DMAIC concept improves the learning process procedure among teachers, and complaints among parents are gradually reduced.

Research by Al-Ghamdi *et al.* [8] combined the Six-Sigma DMAIC method with structural equation modelling (SEM) to improve job performance in the technical and vocational training corporation (TVTC) in Saudi Arabia. The study highlights that the application of the Six-Sigma DMAIC provides a structured methodology for conducting the research study. Meanwhile, the SEM application assists in statistically examining the mediator variables.

In addition, Pal and Gosh [15] demonstrate the application of the DMAIC concept to develop a research framework to satisfy students' needs and reduce the school dropout rate in India. An uninteresting curriculum, one-way communication, a rigid system, and passive learning are among the issues that constrain effective education delivery. Nevertheless, the development of a research framework statistically reduces the dropout rate in the education system while providing good quality education to the students.

Nevertheless, applying Six-Sigma DMAIC in education is different from manufacturing. According to Davidson *et al.* [9], education sectors offer services that are predominantly intangible, perishable, and heterogeneous with a wider range of causes and knowledge. Therefore, it is difficult to systematically measure the key metrics, such as customer satisfaction. Measuring defects also becomes complex in education. In manufacturing, the defect definition could be a poor product or a missed characteristic of the completed product. In the case of the education sector, the defect is an indefinable area since service processes are less transparent than manufacturing, concerning a high level of human involvement, making it even more difficult to pinpoint where the process is broken in order to trace back the root cause of the problem [16].

In addressing this challenges, Kumar *et al.* [17] carried out a thorough literature review, examining 25 DMAIC models and taking expert viewpoints into account before proposing a general DMAIC framework that enables policymakers and practitioners to strategically implement the DMAIC methodology across various sectors. The recommendation of improvement in this general DMAIC framework may produce both visible outcomes, as is often the case in the manufacturing industry, and intangible outcomes like frameworks and action plans. The summary description of the five steps of DMAIC framework according to Kumar *et al.* [17], as in Table 1.

Prior literature effectively applied the Six-Sigma DMAIC methodology to address a range of education challenges in other countries. However, this concept has not yet been largely explored in the Malaysian education setting particularly in the apprenticeship system. Therefore, the novelty of this study is to develop an industry engagement model (IEM) by extending the application of DMAIC methodology proposed by Kumar *et al.* [17] to identify the key strategies to improve industry engagement in the Malaysian apprenticeship program known as the National Dual Training System (NDTS). The findings benefited to assist policymakers in making decisions to enhance service and quality in apprenticeship programs, particularly, and provide a possible direction for future research on other education fields in Malaysia.

Table 1. Summary of Six-Sigma DMAIC general framework

DMAIC 5-phases	DMAIC description
Define (D)	Definition and description of problem
Measure (M)	Data collection
Analysis (A)	Data analysis
Improve (I)	Determine possible areas of improvements
Control (C)	Determine action plan

2. METHOD

2.1. Phase 1 (define): research variables and research hypotheses

The define phase intends to explore the research variables to develop the research hypotheses of the current study. A systematic literature review was carried out using Scopus, Science Direct, and Mendeley Web Search for articles published between 2017 and 2022 using the search strings "Employer Engagement" OR "Industry Engagement" AND "Apprenticeship," "Employer Engagement" OR "Industry Engagement" AND "Work-based Learning," "Employer Engagement" OR "Industry Engagement" AND "Dual Training," and "Employer Engagement" OR "Industry Engagement" AND "Vocational Education and Training." From the initial 173 articles, 76 articles were removed due to inconclusive results, full articles were not accessible and overlapped, thus the final articles to be reviewed were reduced to 97 articles. The 97 articles were uploaded to the ATLAS.ti software for thematic analysis to scrutinize the articles according to relevant codes and sort out potential themes and items for research hypotheses and research instrument development.

2.2. Phase 2 (measure): research instrument and data collection

The measure phase develops the research instrument and describes the procedure for data collection. In this study, a set of questionnaires was developed through the content validation index (CVI) assessment by experts in the field, following the guidelines by Kishore *et al.* [18] and Shrotryia and Dhanda [19]. A pilot test was then conducted to check the performance of the research instrument before distributing it for a field study.

2.3. Phase 3 (analyze): research model development

The analysis phase examines the data to understand the relationship between research variables and develop a research model. The partial least square-structural equation modelling (PLS-SEM) software is the most suitable tool to employ for this research due to its significant analysis of the relationship between variables using quantitative data for hypothesis testing, measuring critical success factors, and the capability to derive managerial recommendations [20]. The analysis involves: i) measurement model to investigate the relationship between items and their latent variable (construct) and ii) structural model to examine the relationship among the construct and evaluate the significance and relevance between the research variables to answer the research hypotheses and develop the research model [21].

2.4. Phase 4 (improve): examine the key strategies

The improve phase extends the analysis of the research model in PLS-SEM using importance-performance analysis (IPMA) to identify which constructs in the structural model are relatively critical for prior improvement based on rank in importance and performance [22]. The higher the ranking, the more important the strategies, whereby enhancements in this field greatly boost industry involvement in the NDTS program [23].

2.5. Phase 5 (control): suggest action plan

The control phase suggests the action items to monitor the improvement strategies and avoid performance deviation [24]. The items with a factor loading of more than 0.7 in the measurement model analysis are considered a practical action plan due to the ability to significantly explain the construct [21]. The DMAIC methodology in this study is summarized and unfolded in a manner as in Figure 1.

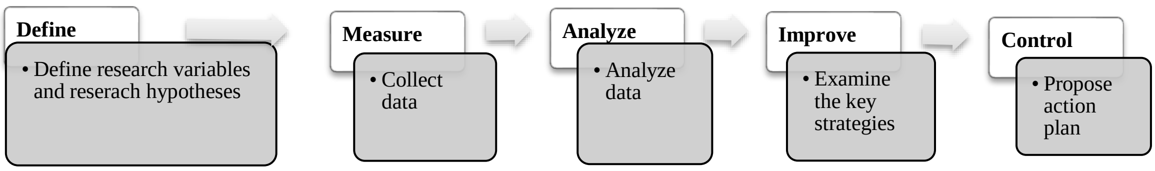

Figure 1. The application of DMAIC methodology for current study

3. RESULTS
3.1. Phase 1 (define): identify research variables and develop research hypotheses

After a thorough synthesizing and scrutinizing process in thematic analysis, the final variables were categorized into five themes for independent variables (IVs), namely: financial incentive or FI (H1), digital administration or DA (H2), productive collaboration or PC (H3), flexible implementation or FT (H4), and efficient promotion or EP (H5), and one theme for dependent variable (DV), namely industry participation (IP). The identification of research variables leads to research hypotheses development whereby all the IVs (H1 to H5) have a significant positive direct relationship on DV as described in the research conceptual framework in Figure 2. In addition, the thematic analysis also identifies items to explain the IVs and DV.

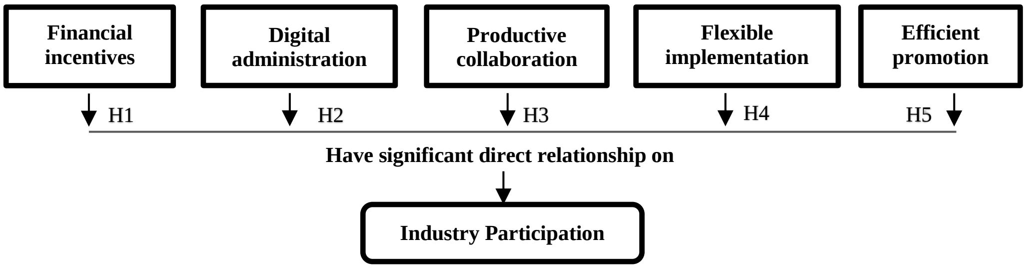

Figure 2. Research conceptual framework

3.2. Phase 2 (measure): research instrument development and data collection

A set of questionnaires using a 5-point Likert scale (1=strongly disagree, 2=disagree, 3=not sure, 4=agree, and 5=strongly agree) was developed, which includes 44 items to explain all the constructs. It was validated by seven experts, with the CVI value above the accepted threshold of 0.80, and tested for internal consistency through a pilot test with a high Cronbach's alpha value ranging from 0.751 to 0.972. The results indicate that the survey instrument was trustworthy and reliable for field study.

The survey instrument was distributed to NDTS manufacturing companies in Malaysia during the NDTS engagement seminar organized by the department of skills development (DSD). The respondents were limited to top management, the NDTS coordinator, and the NDTS coach of the company. Participants are encouraged to complete and submit the survey form at the end of the seminar. A total of 164 datasets were collected, which are below the minimum sample size of S=175 as referred to the Krejcie and Morgan sample size determination table [18]. However, the DSD officers assisted in distributing the questionnaire during their visits to NDTS companies, which managed to obtain an additional 43 datasets, making a total of 207 datasets for this study. However, three datasets were excluded from the study due to ambiguity error; thus, only 204 datasets were fit for further analysis.

The demographic profile of the study's respondents, as in Table 2, shows that the majority of the respondents were NDTS coordinators ages between 31 and 40 years old from small and medium enterprises (SMEs) and held diplomas in skills. The NDTS coordinator is a person who is responsible for administering the NDTS program within the company. Meanwhile, more than 60% of NDTS companies are SMEs. Therefore, respondents of the current study persuaded the researcher that the participants were suitable to reflect the study's target group.

3.3. Phase 3 (analyze): research model development
3.3.1. Measurement model analysis

Items that have an outer loading lower than 0.4 are significantly not explaining the construct and therefore must be deleted from the measurement model [21]. In this case study, out of 44 items in the questionnaire, 6 items were discarded from the measurement model with an outer loading value less than 0.4. The remaining 38 items with outer loading ranging between 0.550 and 0.876 were tested for the internal consistency reliability, convergent validity, and discriminant validity assessment. Results show that all the 38 items met the observed criteria, thus satisfying the measurement model requirements and ready for structural model analysis.

3.3.2. Structural model analysis

A path model for structural model analysis is significant when the t-value is above 1.96, the p-value is less than 0.05, and there is a strong positive relationship when the path coefficient (B) value is above 0.1 [25]. The result of this study, as shown in Table 3, reveals that the H1-FI (B=0.164, t=3.105, p=0.02), H4-FT

(B=0.691, t=10.694, p=0.000), and H5-EP (B=0.287, t=2.911, p=0.004) significantly showed a positive direct relationship with the IP. Thus, the research hypotheses of H1, H4, and H5 were accepted. However, H2-DA (B=-0.173, t=2.194, p=0.028) and H3-PC (B=-0.160, t=2.727, p=0.006) showed a significantly negative direct relationship with the IP when the path coefficient value was closer to -1. Therefore, the finding failed to support hypotheses H2 and H3.

Table 2. Demographic profile of respondent

Demographics		Frequency	Percent (%)
Gender	Male	91	44.6
	Female	113	55.4
Age	18-30	38	18.6
	31-40	77	37.7
	41-50	63	30.9
	>51	26	12.7
Skills qualification	DLKM	34	16.7
	DKM	77	37.7
	SKM3	64	31.4
	SKM2	23	11.3
	SKM1	3	1.5
	None	3	1.5
Position in the company	Top management	37	18.1
	Management dept	65	31.9
	NDTS coordinator	70	34.3
	NDTS coach	32	15.7
Type of company	SME	85	41.7
	GLC	75	36.8
	MNC	40	19.6
	Others	4	2.0

SKM=Malaysia skill certificate, DKM=diploma skills certificate, DLKM=advanced diploma skills certificate, GLC=government link company, MNC=multinational corporation

Table 3. Analysis of structural model

Hypothesis	IV	M	DV	Path coefficient	T-value	P-value	Result	Effect
H1	FI	-	IP	0.164	3.105	0.002	Accepted	Direct effect
H2	DA	-	IP	-0.173	2.194	0.028	Rejected	Mediator testing
H3	PC	-	IP	-0.160	2.727	0.006	Rejected	Mediator testing
H4	FT	-	IP	0.691	10.694	0.000	Accepted	Direct effect
H5	EP	-	IP	0.287	2.911	0.004	Accepted	Direct effect
Mediator testing								
H6	DA	EP	IP	0.640	14.352	0.000	Accepted	Indirect effect
H7	PC	EP	IP	0.249	3.690	0.000	Accepted	Indirect effect

Note: M (mediator)

However, Sarstedt and Moisescu [26] suggest additional examination of the rejected hypotheses on accepted hypotheses as mediators in order to look at the indirect relationship between the IVs on DV. The mediator testing on H2 and H3 develops new hypotheses of H6: DA and H7: PC. Results reveal that H6 (B=0.640, t=14.352, p=0.000) and H7 (B=0.249, t=3.690, p=0.000) achieved a significant positive indirect relationship on IP when H5-EP served as a mediator.

Results from structural model analysis develop a research model known as the IEM, as shown in Figure 3. The explanatory analysis (R^2) for this model is substantial, with 58.3% of changes in IP accounted by H1, H4, and H5, and 60.6% of changes in EP described by H6 and H7. The model also has strong predictive power with the Q^2 value for both IP and EP being at 0.521 and 0.589, respectively.

3.3.3. Phase 4 (improve): examining the key strategies

Results from the IEM were further analyzed in PLS-SEM through IPMA, and the results are in Table 4. The findings depict that FT is highly ranked in importance, while both EP and DA are highly ranked in performance. Therefore, these three elements marked as the key strategies to enhance IP in NDTS program, thus met the research objective of this study. The FI and PC do not significantly promote IP because both were ranked low in importance and performance.

3.3.4. Phase 5 (control): proposed action plan

Items in the measurement model that have a factor loading of more than 0.7, as in Table 5, indicate the practical action plan to be addressed by policymakers in improving industry engagement, thus promoting greater participation in the NDTS program. In summary, policymakers should permit flexibility with regard to the tools and assessment requirements to facilitate training. Additionally, policymakers should engage in digitalization in administration to eliminate bureaucracy and explore social media networks for promotion strategies that would provide better coverage at lower cost.

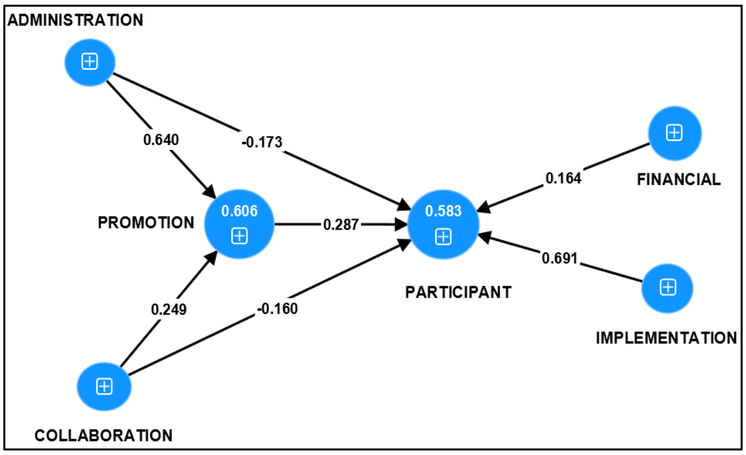

Figure 3. IEM

Table 4. Results of IPMA

Construct	Importance	Performance
FT	0.691	77.110
EP	0.287	80.568
DA	0.011	79.129
FI	0.164	65.883
PC	-0.089	74.143

Table 5. Practical action items

Improvement strategy	No. Item	Item	Outer loading
FT	FT4	My company is permitted to enhance the assessment criteria to meet company's requirements	0.797
	FT6	The final assessment of apprentices could be based on their training performance rather than the training duration specified in the curriculum	0.770
	FT7	My company is permitted to use suitable training equipment other than specified in curriculum	0.716
DA	DA3	NDTS documentations status can be self-checked conveniently	0.841
	DA4	Assessable on any devices	0.802
	DA5	Online payment system is practical	0.875
EP	EP1	Interactive social media networks are the latest digital medium to promote NDTS	0.784
	EP2	Face-to-face consultation services is still needed to obtain NDTS information directly	0.743
	EP9	DSD could implement dual certification by merging NDTS with the company's in-house training program	0.874

4. DISCUSSION

The Six-Sigma DMAIC is a methodology that has gained popularity for improving services and quality in the education sector, particularly in the setting of HEIs. However, this approach has not been thoroughly explored in the Malaysian education setting. Due to this opportunity, the current study intends to add to the body of knowledge to demonstrate the application of the DMAIC methodology to develop and IEM in improving industry engagement in the Malaysian apprenticeship system known as NDTS.

The current study begins by identifying the research variables to develop research hypotheses. The combination of systematic literature review to identify the best related articles on industry engagement in apprenticeship programs and thematic analysis to scrutinize themes leads to research variable identification, namely: FI (H1), DA (H2), PC (H3), FT (H4), and EP (H5). All the variables are predicted to have a significant direct relationship with IP. A 5-point Likert scale questionnaire was developed and validated by experts in fields to measure the research variables. The NDTS manufacturing industries in Malaysia were selected as the study's sample because this sector accounted for the largest NDTS population. Respondents were limited to top management, NDTS coordinators, and NDTS coaches at NDTS companies whose accreditation is still in effect. In return, 204 datasets were collected during the industry engagement seminar and company visit, which is above the minimum sample size required.

Data collected were analyzed using PLS-SEM, statistical software to examine linear relationships between variables, test for mediators, and develop a research model [21]. Results from PLS-SEM analysis demonstrated that FI, FT, and EP significantly have a direct relationship with IP; thus, hypotheses on this variable are accepted. However, DA and PC require EP as a mediator to have a significant impact on IP. With the findings, a research model known as the IEM was developed with substantial predictive power.

However, as the IEM only describes the relationship between variables and does not specify which variables are crucial among others, the IPMA may be able to explain this. Results of IPMA reveal that the key strategies that have ranked high in both importance and performance were FT, effective promotion, and DA. On the other hand, improvement in FI and PC has little impact on engaging industry effectively in the NDTS program. The results of the IPMA analysis conclude the study objectives.

The results of current study align with several studies [27], [28] that highlight the importance of flexibility in training design and curriculum as well as the freedom to train apprentices to meet the industry needs as "customers". In addition, Huddleston and Branch-Haddow [29] claims that traditional methods of promotion could be time-consuming as compared to online platforms such as social media networks, which are simple to engage with, inform, and interact with stakeholders. Furthermore, Decuypere and Lewis [30] agree that digitalization in administration assists private sectors in communicating with the government with more transparency, less bureaucracy, and less paperwork, which would develop higher public trust in government processes. On the other hand, Syauqi *et al.* [31] asserted that strong collaboration requires clear communication and direction to share understanding of each partner's commitment. Therefore, improvement in the digitalization of promotion as well as administration promotes better communication that will lead to sustainable collaboration. Even though FI encourage IP, nevertheless, this strategy alone could not sustain the participation in the long run, especially when governments are facing severe budgets [32].

5. CONCLUSION

The current study proved that the DMAIC methodology can be applied as a tool to improve education quality in the Malaysian education system. The deployment of 5-phase DMAIC methodology successfully develops an IEM to identify the key strategies to enhance IP in the NDTS. Finding revealed that FT, EP, and DA are the high-impact strategies for the policymakers to focus on in order to influence IP in the NDTS program. Meanwhile, improvement in FI and PC only brings a small impact on IP. The results further support the idea that the Six-Sigma DMAIC concept may be used to enhance service and delivery in various areas of education in Malaysia.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Siti Azfanizam Ahmad	✓			✓				✓		✓	✓	✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author [RA], upon reasonable request.

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