Text Mining Analysis for Assessing Washington Accord Graduate Attribute Profiles through Techno-Socio Project-Based Learning Program

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Keyword:

Project-Based Learning (PBL), global engineer education, interdisciplinary education, global competence, text mining, Washington Accord, Graduate Attribute Profile, qualitative assessment

Abstract

Techno-socio Project-Based Learning programs (PBLs) are a very effective instruction method to nurture engineering students' skillsets and mindsets as future professionals by identifying, analyzing, and solving issues through group work with a wide variety of teammates. This is a highly practical learning experience for participants to communicate with industry professionals, local government officers, and other local people about societal issues and possible technology applications. This program especially puts strong emphasis on experiential learning "outside the classroom," namely field research activities that can supplement the limitations of conventional lecture style studies. Engineering students can absorb what they need through practical experiences together with teammates from different backgrounds. While these experiences are valuable, in most cases they are not quantitatively measurable.

Meanwhile, PBLs are highly suitable for achieving the 11 Graduate Attribute Profile (GAP) skills and awareness essential for global engineers defined by the Washington Accord (WA). They can be acquired through real-world experiences, as "practice makes perfect." However, these GAPs contain many unmeasurable factors. Moreover, even in cases in which GAPs are acquired, it is difficult to clarify where and how the acquisition happened.

This article examines an experiment to identify the causality between the techno-socio PBL contents and learning outcomes related to this Washington Accord 11 Graduate Attribute Profile (WA11GAP) by applying a text-mining technique. The results conclude that this methodology is useful not only for grasping the effectiveness of PBL program contents from a cause-effect perspective but is also applicable to other nonstandard teaching methods that cannot be quantitatively assessed with conventional exams.

1. Background and problem statement

1) Learning outcomes from techno-socio PBLs

Techno-socio Project-Based Learnings (PBLs), which are designed from the combination of social issues and technology-based solution developments through collaborations amongst public sectors, educational institutions, and industries, are a very effective teaching approach for nurturing engineering skillsets and mindsets for those who will become professional engineers in the future [1], [2]. These programs provide

participants with rich learning opportunities to identify, analyze, and solve real social issues through group work with teammates [3]. Such PBLs also create chances to conscientize the issues, which tend to be ignored in daily life [4]. Shibaura Institute of Technology (SIT), a Japanese leading engineering institution, Institut Teknologi Sepuluh Nopember (ITS), one of the top Indonesian universities, IHI Asia Pacific PTE. LTD. (IHIAP), a Japan-based multinational engineering conglomerate group, and Surabaya City Council, governing the second biggest city in Indonesia, have been organizing this program series for 3 years by creating a multi-national collaborative environment [5]. The years 2021 and 2022 were fully online due to the pandemic, and 2023 was a hybrid format, with the first half of the program featuring online lectures and the second half in-person at the Indonesian university's campus. This onsite component contained various out-of-the-classroom field research and extracurricular activities, such as an incinerator visit, several factory investigations, technical discussions with corporate engineers, and local cultural activities. The opportunity to communicate with local government officers about societal issues and discuss with industry professionals about possible technology applications from social and international perspectives results in a highly practical learning process [6].

Major expected learning outcomes include (1) knowledge about emerging technologies (in 2023, mainly traffic congestion, waste management and renewable energy), (2) problem-solving skills to apply technologies to environmental issues, (3) and awareness about the level of societal and industrial requirements in the real world [7]. In addition, as this is a multi-national program between Indonesia and Japan, the participants could also acquire (4) interpersonal communication skills under multi-ethnic circumstances. This program especially puts strong emphasis on the concept of "outside the classroom," namely field research activities that can supplement the limitations of in-class lectures. The students can absorb what they need through practice and together with teammates with different backgrounds.

2) Necessary attributes for global engineers based on Washington Accord

Generally speaking, PBL programs are also effective for acquiring Washington Accord 11 Graduate Attribute Profile (WA11GAP), which are essential requirements for future global engineers [8].

(1) Engineering Knowledge
(2) Problem Analysis
(3) Design/development of solutions
(4) Investigation
(5) Tool Usage
(6) The Engineer and the World
(7) Ethics
(8) Individual and Collaborative Team work
(9) Communication
(10) Project Management and Finance
(11) Lifelong learning

These 11 items comprise a comprehensive set of knowledge, skillsets, and mindsets. Because of the design flexibility, it is sufficient to incorporate these items into PBL course contents. In the case of this techno-socio PBL, this mode is quite suitable to embed the clues to enhance society-related factors, which can be difficult to encounter inside the ordinary classroom.

3) Issues of PBL Outcome assessment

While PBL is a highly effective teaching method, it also bears several issues. Firstly, there is no standard method of assessing students' learning outcomes. This is mainly because each PBL program is based on particular problems, issues, and/or themes and therefore the program contents are mostly tailor-made. Accordingly, there is no one-size-fits-all assessment [9].

Secondly, expected learning outcomes consist of both technical and non-technical skills, making it difficult to score these results. In terms of WA11GAP, other than (1) Engineering Knowledge and (5) Tool Usage, they are mostly non-technical skills or mindsets, and therefore quantitative measurement methods such as exams are unapplicable [10].

Thirdly, it is difficult to assess the participants' learning outcomes in a traditional classroom setting [11]. As PBL consists of various activities both inside and outside the classroom, it is difficult to identify causal relationships. While it is possible to recognize the learning outcomes, so far there is almost no method to determine when, where, and how participants have acquired them. In other words, if a methodology to find the causes behind acquisition of non-technical skills or mindsets is established, it will facilitate effective program design by embedding such causal mechanisms into particular activities.

2. Constructivism Learning Theory and Literature Review

From the theoretical perspective, Constructivism Learning Theory (CLT) is highly applicable to PBLs [12][13][14], [15]. The central idea of constructivism is that human learning constructs new knowledge upon the foundation of previous learning [16]. Accordingly, it is important to accumulate a wide range of learning experiences so that this construction will be built upon robust structures. Honebein [17] summarized the seven pedagogical goals of a constructivist learning environment, which include the knowledge construction process, experiences in and appreciation for multiple perspectives, learning in realistic contexts, student-centered learning, social experiences, multiple modes of representation, and awareness of the knowledge construction process with reflection. Most of these goals could be connected with the contents of this techno-socio PBL since it aims at solving societal issues provided by Surabaya City Council, and applying technologies researched and developed by IHIAP group.

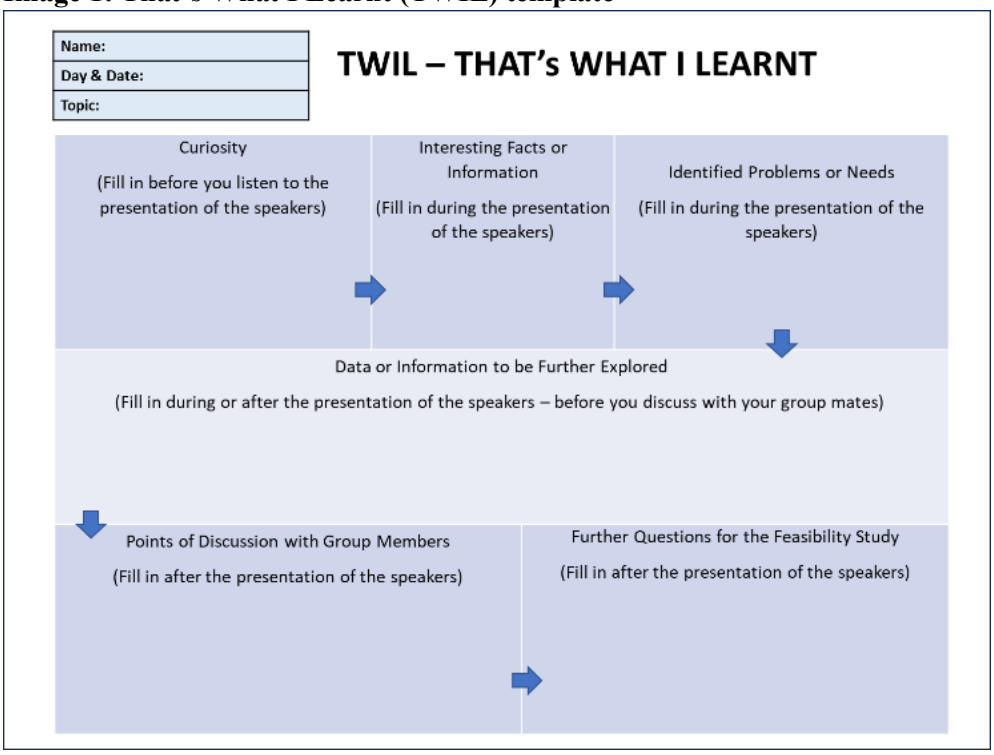
Basic characteristics of CLT and its learning environment are: knowledge sharing between teachers and students, sharing of authority between teachers and students, the teacher's role as a facilitator or a guide, and small-sized heterogeneous learning groups [12]. Thus, the teachers' role for designing PBL contents and the setting environment is crucial. Meanwhile, Olusegun [18] concluded that teachers need to reflect on their practice in order to apply these ideas to their work, and constructivist teachers encourage students to constantly assess how the activity is helping them gain understanding [19]. Hence, PBL method is effective to facilitate students' cognition between the learning outcomes and the causes for making them happen.

3. New development of analysis method using text-mining technique

1) Participant text data output using "That's What I Learnt" (TWIL) template and presentation output

Through this techno-socio PBL, participants are asked to fill out a template called TWIL (Image 1) at the end of daily classes and/or major activities. This was invented by ITS for navigating the students' input summarization and idea creation. This process was also meant to be a self-reflection for stabilizing what they absorbed. It is also expected to enhance their English writing skills. TWIL is initially for individual records to streamline each participant's thought flow. Then, each team is to compile individual TWILs into a Group TWIL, discuss their key findings, and then summarize them as a final presentation file. Through these processes, they verbalize what they have done, felt, and considered as text data, occasionally with visuals such as pictures or graphics. Hence, there is substantial intermediate data made throughout this PBL.

Image 1: That's What I Learnt (TWIL) template



2) Idea of applying a text-mining methodology to the effectiveness of learning experiences

Through informal inter-department discussions among professors of environmental systems, data science, and interdisciplinary education, the text-mining methodology came to light by considering how to reuse this TWIL for improving this PBL series. The hypothetical idea then was that this method has the potential for multiple benefits such as the investigation of cause-and-effect relationships between particular contents and specific learning outcomes, improvement of learning effectiveness by encouraging learners to write more documents, and effective reflection of their learning experiences by giving immediate feedback at the end of the program, etc. To examine this hypothesis, the first version prototype was made for experimental analysis. Based on the results, the approach to establishing this analytical method will be discussed. Image 2 describes the outline of this process.

The steps of data processing are as follows:

(1) Sentences were extracted from the following parts of the global PBL TWIL documents (PDF/Word files).
   - Identified problems or needs
   - Data or information to be further explored

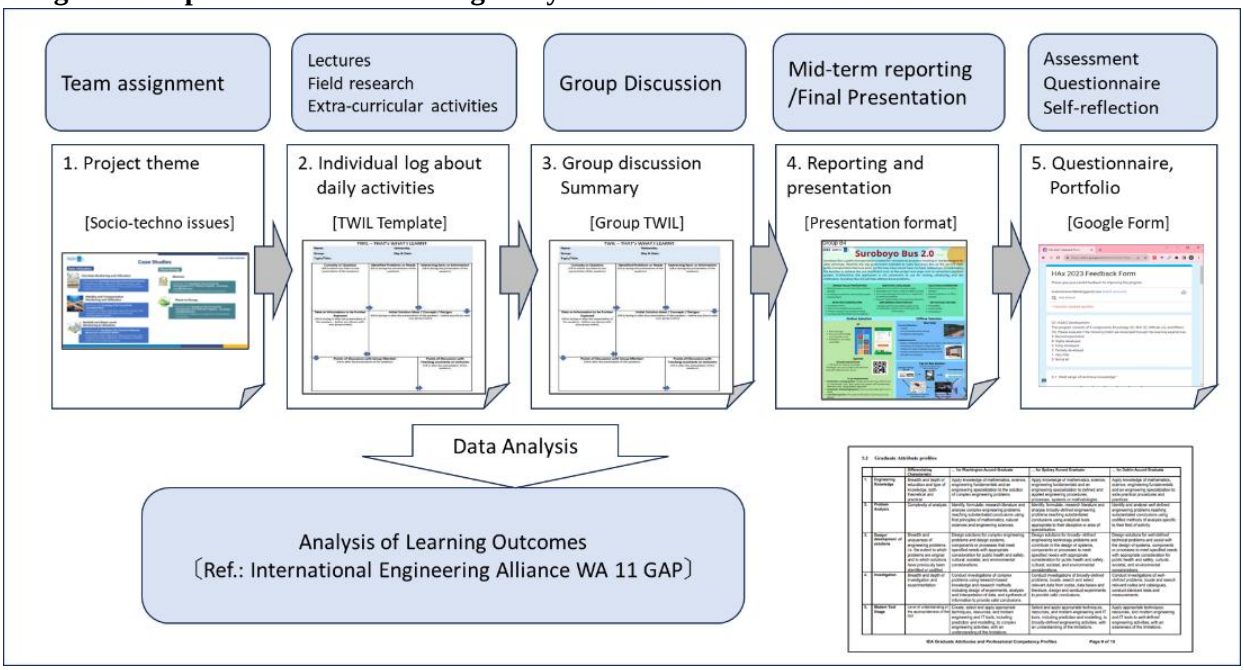
(2) Tokens (words) were extracted from the sentences and were mapped to embedding vectors, whose directions express the meaning of the tokens. The Word2Vec method was used to obtain the embedding vectors by use of the library, gensim, and its pretrained model, "word3vec-google-news-300," disclosed at Hugging face.

(3) Principal Component Analysis (PCA) / t-SNE were applied to the obtained embedding vectors for dimensionality reduction.

(4) A clustering method, Optics, was applied to the obtained vectors in Step 3. For the application of Optics, cosine similarity was used for the "metric" and the minimum sample number set depending on the distribution of tokens in the target description data.

(5) The two-dimensional vectors with colors corresponding to cluster labels were placed in the two-dimensional scattering graph.

Image 2: PBL process and text-mining analysis



4. Research objectives and research questions

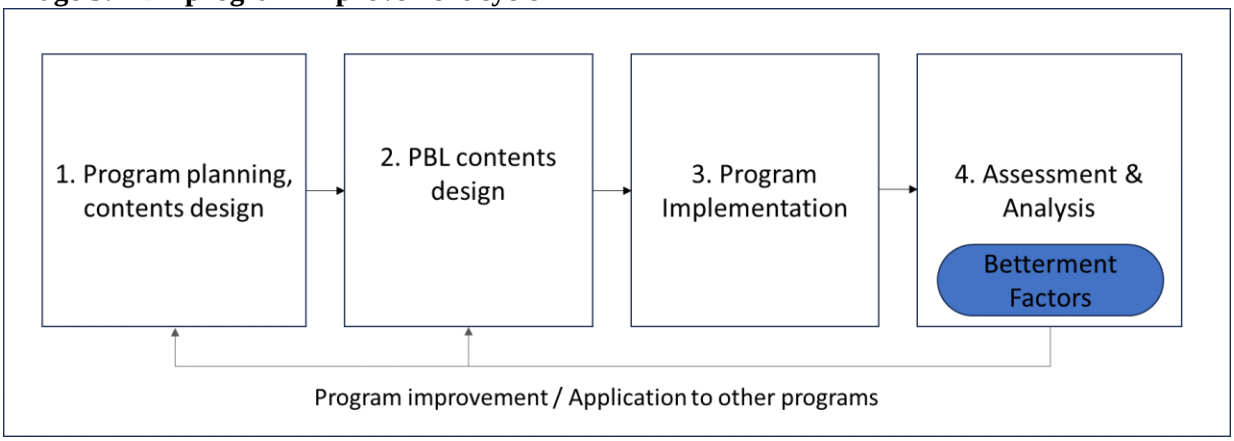
1) Major research objectives and creation of an improvement cycle

The first objective is to evaluate the effectiveness of this techno-social PBL for developing capable global-level engineers with high-level skillsets and mindsets. In particular, which WA11GAP participants felt they could acquire these skillsets and mindsets through various activities of this program?

The second objective is to establish a methodology to analyze PBL learning outcomes with this newly developed text-mining prototype by applying it to this techno-socio PBL as an experimental testbed. Based on the results, the validity of this method for analyzing the causality between the PBL contents and the students' learning outcomes will be discussed.

The final goal is to create a cycle for improving the next PBL to be held in 2024, as well as apply it to other non-standardized programs for which assessing learning outcomes is difficult. Image 3 illustrates the feedback cycle of the lessons learned from the past program to the next one.

Image 3: PBL program improvement cycle



2) Research questions (RQs):

RQ1: According to the participants, which aspects of WA11GAP are produced in this "techno-socio PBL" instruction method?
Conventional grading typically relies on factors such as the quality of the final group presentations and participation in class/team activities, thus overlooking items like "(6) The Engineer and the World", "(7) Ethics", and "(11) Lifelong learning" that do not directly correlate with assignment creation or outputs. Therefore, the effectiveness of techno-socio PBL has not been measured. Additionally, learners may find it difficult to focus on items that are not included in the grading criteria. Thus, deliberate highlighting of such items and extracting the learning effects of non-evaluative elements can be considered to enhance the content of future iterations of this PBL series and other social issue-centric PBLs.
RQ2: In the current situation, where there is little standardized evaluation and few analysis methods for customized programs like PBL, can these text-mining technology-based tools offer widely applicable analytical methods? Can they extract learning elements that contribute to the achievement of learning outcomes and reveal causal relationships? Or can they discover the potential to do so?
It is meaningful both technically and conceptually to identify the causal relationships between learning outcomes and the items that caused them by collectively analyzing the intermediate documents that participating students produce in large quantities throughout their learning process using this enabling technology. Furthermore, this technology strongly encourages participating students to write their daily learning more extensively, leading to an increase in the amount of writing they produce. The text-mining prototype in this trial is a first version, and through this trial, it sets the direction for establishing this method.
RQ3: Based on the analysis and lessons learned from this trial implementation of text-mining applications (or based on the content of RQ1 and RQ2), how can future experiential learning programs be designed and implemented to enhance their learning effectiveness?
This PBL series will be conducted again in August-September 2024, so reflecting on the lessons learned from this trial will contribute to improving its content. Furthermore, since SIT and ITS are also conducting other PBLs, considering their application will enhance the scalability of this text-mining method.

5. Research methodologies

1) Participant's self-evaluation of WA11GPA

After the program, a Likert-scale questionnaire was conducted for self-evaluation of skill or awareness enhancement about WA11GAP. While this is subjective, it is still meaningful to recognize their awareness of these factors. It is also beneficial for making assumptions about the effectiveness of the program components. This time 15 responses were collected through a Google Form.

2) Post-program interviews with participants

Interviews with 9 participants were conducted to record their initial objectives for attending this program, expectations, what they experienced, and lessons learned. This process is also informative for revealing their candid opinions, which are useful for supplementing other quantitative data.

3) Text mining of students' TWIL and presentation output using the prototype tool

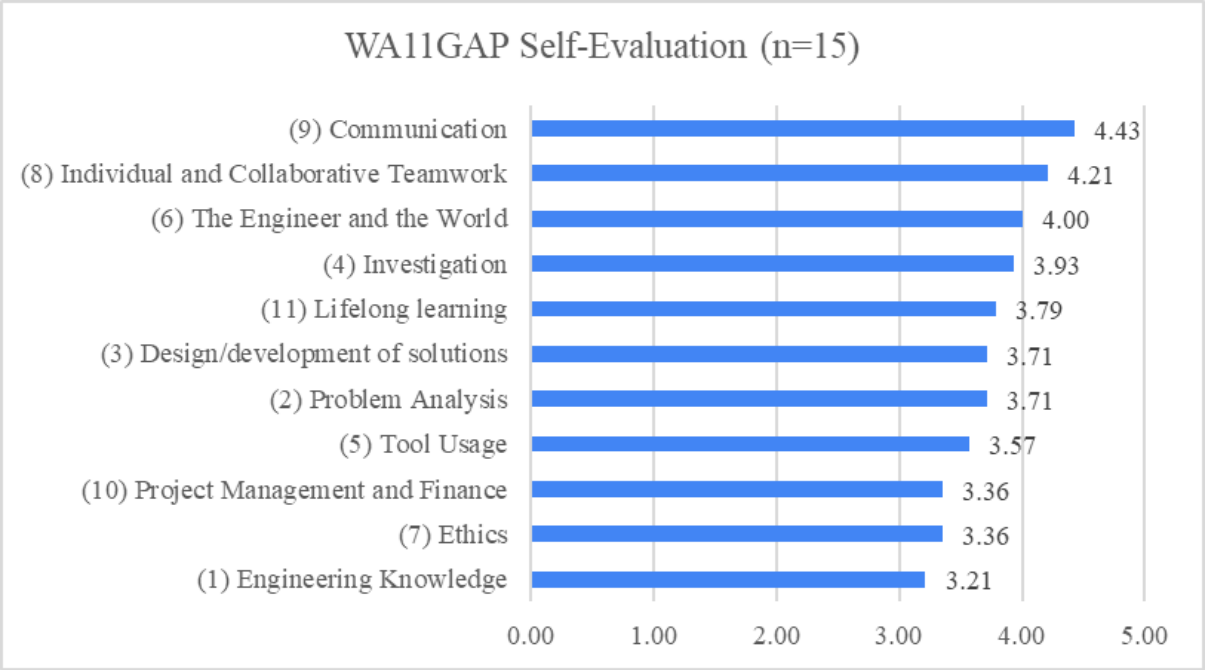
Groups of frequently appearing words and their synonyms are found as clusters. The interpretation of the obtained clusters gives the categories of words used in the descriptions. The text data in TWILs and final presentations were applied to the analysis using a newly developed tool.

6. Key findings and analysis

1) Participants' self-evaluation of WA11GAPs

Chart 1 shows results of the post-program survey using a Google Form, asking participants to "Please evaluate how much you could learn about the following attributes through this PBL." Most participants considered this program effective for improving "Communication (4.33)" and "Individual and Collaborative Team work (4.21)." Other attributes, namely "The Engineer and the World (4.00)" and "Lifelong learning (3.79)," also obtained relatively higher scores than "Engineering Knowledge (3.21)." It is reasonable that "The Engineer and the World (4.00)" is high since this was a techno-socio PBL. It is assumed that "Investigation (3.93)" skills were enhanced through significant field research and interactions with industrial experts and local authorities. An interesting consequence is a high ranking for "Lifelong learning (3.79)," even though this was not clearly mentioned throughout this PBL. It implies that the participants raised awareness through the stimulus from professional engineers since they keep seeking new technologies and applications.

Chart 1: WA11GAP self-evaluation



2) Summary of the interview with select participants

The following are extracts from select participant feedback. One participant noted, "This PBL was quite different from ordinary studies because of its comprehensive process of recognizing societal issues, creating solutions, summarizing various ideas, and presenting it all as group output." Participants were almost unanimously agreed that they improved their communication and teamwork skills through a setting with a mixed team of Japanese and Indonesian participants communicating in English, which contributed to optimizing team performance and shared achievements. Several Japanese students confessed that they were not accustomed to proactive thinking and collaboration, and therefore this approach itself was quite challenging for them. They also mentioned the hospitality of Indonesian students and academic staff was far more than what they initially assumed. This was quite an eye-opening experience for them. On the other hand, Indonesian participants, who played the role of hosts, mentioned that the interaction with foreigners had extended their views through the cultural exchange. In terms of

communication in English as a second language, when oral interaction was not smooth, they supplemented the gap using pictures, drawings, and/or sharing of search results. The process of finding alternatives gave them confidence in solving issues.

3) Text-mining analysis of individual/group TWILs

Computer science technology has made the analysis of high-volume text data possible [20]. In this study, we standardized keywords in our target documents by grouping synonyms such as “these words/expressions could be replaced with this keyword” and “these clusters could be wholly interpreted into this keyword” by use of a deep learning-based natural language processing method. This method enabled contextual investigations such as cause-and-effect relationships. Thus, the analysis of correlation among multiple keywords has now become available by controlling for the fluctuation of human expression. Table 1 shows the word-level clusters.

Table 1: The obtained clusters for words found in the descriptions for “Identified problems or needs” in TWIL template

Cluster	Interpretation	#	Words in the clusters
0	Level	16	'Low', 'low', 'low', 'high', 'high', 'high', 'Low', 'high', 'low', 'high', 'low', 'high', 'low', 'low', 'low', 'low'
1	Action / Movement	25	'go', 'come', 'come', 'fly', 'begin', 'settle', 'return', 'come', 'take', 'get', 'disperse', 'collect', 'find', 'occur', 'compete', 'happen', 'go', 'observe', 'give', 'declare', 'participate', 'occur', 'go', 'emerge', 'leave'
2	Sense	16	'real', 'like', 'anymore', 'sort', 'think', 'sort', 'type', 'lack', 'sense', 'say', 'like', 'smell', 'know', 'feel', 'count', 'kind'
3	Time	18	'place', 'period', 'routine', 'time', 'year', 'match', 'period', 'year', 'Rice', 'year', 'night', 'place', 'point', 'week', 'half', 'half', 'night', 'regular'
4	Business	21	'chain', 'chain', 'business', 'chain', 'industrial', 'commercial', 'economic', 'company', 'company', 'global', 'company', 'company', 'company', 'company', 'market', 'company', 'industrial', 'globally', 'financial', 'credit', 'enterprise'
5	Water	16	'water', 'water', 'drainage', 'water', 'ash', 'riverbank', 'water', 'drainage', 'water', 'water', 'water', 'water', 'water', 'water', 'wastewater', 'sludge'
6	Management	17	'management', 'management', 'management', 'mitigation', 'optimization', 'mitigation', 'maintenance', 'management', 'management', 'Management', 'management', 'Solutions', 'management', 'management', 'maintenance', 'management', 'management'
7	System	21	'system', 'system', 'system', 'system', 'system', 'system', 'system', 'system', 'system', 'system', 'System', 'system', 'system', 'system', 'system', 'system', 'system', 'system', 'system', 'system', 'system'
8	Necessity	19	'need', 'able', 'need', 'need', 'try', 'want', 'try', 'need', 'tend', 'need', 'need', 'need', 'Determined', 'want', 'able', 'able', 'want', 'want', 'opportunity'

9	Environment	26	'sustainability', 'environment', 'pollution', 'pollution', 'Pollution', 'sustainable', 'sustainable', 'sustainable', 'conservation', 'environmental', 'sustainability', 'pollution', 'sustainably', 'sustainable', 'Environment', 'environment', 'environmentally', 'environmental', 'sustainable', 'Conservation', 'Environment', 'environment', 'environment', 'pollution', 'environmental', 'sustainability'
10	Facility	15	'plant', 'plant', 'plant', 'plant', 'plant', 'plant', 'facility', 'plant', 'facility', 'facility', 'plant', 'site', 'site', 'facility', 'facility'
11	Cost	17	'cost', 'cost', 'cost', 'cost', 'price', 'cost', 'price', 'expensive', 'cost', 'Cost', 'cost', 'price', 'cost', 'cost', 'price', 'affordable', 'price'
12	Fuel	27	'LNG', 'Gas', 'Gas', 'gasoline', 'diesel', 'oil', 'coal', 'gasoline', 'fuel', 'oil', 'coal', 'coal', 'gas', 'oil', 'oil', 'fuel', 'coal', 'fuel', 'oil', 'fuel', 'gas', 'gas', 'gasoline', 'diesel', 'oil', 'coal', 'gas'
13	Renewable energy	40	'Renewable', 'renewable', 'biomass', 'biomass', 'biomass', 'biomass', 'renewable', 'biomass', 'renewable', 'biomass', 'Biomass', 'renewable', 'biomass', 'biomass', 'Biomass', 'Biomass', 'bioethanol', 'biodiesel', 'bioethanol', 'biomass', 'biomass', 'gasification', 'biorefinery', 'biomass', 'Biofuel', 'renewable', 'biomass', 'Biomass', 'biomass', 'bioenergy', 'bioenergy', 'Biomass', 'biomass', 'biomass', 'biomass', 'biodiesel', 'biodiesel', 'biodiesel', 'biodiesel', 'renewable'
14	Energy	47	'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'Energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'Energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'energy', 'solar', 'energy', 'energy', 'energy', 'energy', 'solar', 'solar', 'energy', 'solar'
15	Change of amount	18	'maximize', 'minimize', 'reduce', 'mitigate', 'reduce', 'maximize', 'reduce', 'reduce', 'enhance', 'reduce', 'reduce', 'reduce', 'reduce', 'reduce', 'reduce', 'reduce', 'reduce', 'reduce'
16	Emission	22	'Emission', 'emission', 'Emission', 'emission', 'Emissions', 'GHG', 'emission', 'Emission', 'Emission', 'emission', 'emission', 'Emission', 'emission', 'emission', 'emission', 'emission', 'emission', 'emission', 'emission', 'emission', 'emission', 'emission'
17	Waste	44	'waste', 'waste', 'waste', 'waste', 'waste', 'garbage', 'trash', 'waste', 'waste', 'waste', 'waste', 'incineration', 'incineration', 'Waste', 'waste', 'waste', 'bin', 'waste', 'waste', 'waste', 'waste', 'waste', 'waste', 'waste', 'littering', 'waste', 'waste', 'garbage', 'litter', 'waste', 'waste', 'Waste', 'waste', 'waste', 'waste', 'waste', 'waste', 'incinerator', 'waste', 'waste', 'waste', 'Waste', 'garbage', 'garbage'
18	Process	19	'method', 'method', 'method', 'process', 'process', 'process', 'process', 'process', 'process', 'process', 'process', 'process', 'process', 'method', 'method', 'process', 'process', 'process', 'process'

19	Electric power	21	'electricity', 'electricity', 'power', 'hydro', 'power', 'power', 'power', 'power', 'power', 'TWh', 'power', 'electricity', 'power', 'power', 'power', 'power', 'electricity', 'electrical', 'power', 'power', 'power'
20	Indonesia	23	'Indonesia', 'Indonesia'

The tokens are supposed to be controlled by the TWIL format with the sequence of (1) curiosity - (2) Interesting facts or information – (3) Identified problems or needs – (4) Data or information to be further explored – (5) Points of discussion with group members – (6) Further questions. It is reasonable to find that the tokens related to project themes frequently appeared, such as “fuel”, “energy”, “environment”, “waste”, etc. Simultaneously, business-related tokens are also mentioned such as “business” (21 times), “management” (17 times), “need/necessity” (19 times), “system” (21 times), “cost” (17 times), and “process” (19 times).” Thus, it is assumed that participants mainly considered and discussed environmental solutions from business perspectives.

7. Discussion

Participants, both Indonesians and Japanese, expressed that they had the most learning effectiveness in non-technical areas such as “Communication (4.43)” and “Individual and Collaborative Team work (4.21)”. This suggests that interactive methods such as group work on real-world challenges were more effective compared to traditional passive learning in classrooms or laboratories. Additionally, scores related to consciousness aspects such as “The Engineer and the World (4.00)”, and “Lifelong learning (3.79)” were high. Thus, this PBL led to increased awareness related to its social aspects.

On the other hand, despite most participants being engineering students and the program containing many technical factors, the self-assessment scores for “Engineering Knowledge” were low, at 3.21. Nevertheless, during the online portion in the first half of the program, time was allocated to explaining technical aspects, and the final presentations included sufficient technical elements based on each theme. This indicates that adequate technical idea creation was conducted. Therefore, this is likely due to an accumulation of existing knowledge, contrasting with the novelty in non-technical areas, resulting in a lower rate of increase.

Regarding the text mining of TWIL, many industry-related terms such as business, management, need/necessity, system, process, and cost were frequently mentioned, indicating that they were learned. In contrast, the self-evaluation scores for “Project Management and Finance” were low, at 3.36. This suggests that the learned items were not linked to conscious awareness. To improve this, in the format of the final presentation in the next PBL, participants could be instructed to design and develop their solutions, and make items such as implementation process, cost, financial forecasting, etc., mandatory, thus using learned items as outputs.

Hence, by incorporating socio and techno factors into the learning method of PBL, it seems possible to achieve more holistic engineering education blending both technical and non-technical skills. Reflections after the program will be crucial for enhancing its effectiveness. Many items in WA11GAP cannot be quantified, leading to subjective grading based on rubrics. Furthermore, items about awareness or mindsets such as The Engineer and the World”, “Ethics”, and “Lifelong learning” are not subject to grading, making them of lower priority in learners' ordinary minds. Therefore, increasing awareness of such items and conducting reflections through feedback on achievements that have not been graded but

have been acquired by participants in post-program feedback are expected to contribute to the qualitative improvement of engineering education.

Regarding the applicability of the text-mining method, this approach is suitable for arranging information contained in writing at various levels, such as letters, words, and sentences. This prototype has adopted word-level text mining for identifying keywords inside the participant's reports. The challenge of existing keyword extraction lies in the way that keywords with similar meanings can be treated as different types even though they are quite similar. (In the case of technical sentences like those found in this PBL, the ambiguities of keywords with multiple meanings won't be an issue.) The conventional text-mining method is based on a manually created dictionary and converts synonyms to one specific word. However, this encounters difficulties if the volume of text data increases because of not only handling large amounts of data but also more ambiguities. (The codebook approach is considered to be this approach.)

For these reasons, Word2Vec, one of the natural language processing methodologies to convert the specific word in the sentence to the numeric vector and perceive its meaning, was selected to assign the group of synonyms to one word. Clustering methodologies enable the automatic summary of similar vectors. Through this trial, the cluster of expressions with quantitative changes such as "maximize," "minimize," "reduce" and "mitigate" was obtained. This is considered meaningful to compare with WA11GAPs. Though WA's definition of GAPs does not mention the quantification of knowledge and skills, this approach demonstrated that the participants are doing their learning activities with the perspective of quantitative change.

Since clustering generally has difficulty handling high-dimensional data, it requires the application of dimensional reduction. This research examined the usage of the "t-SNE" method for dimensional reduction to two-dimensional space. For the next step, aiming at analyzing participants' descriptions with sentence level rather than word level analysis, the categorization of participants' thought processes is experimented with by disassembling participants' writings into sentences and applying deep-learning models such as Bidirectional Auto-Regressive Transformers (BART).

Based on these discussions, each RQ could be answered as follows below.

Answer to RQ1: In this PBL, non-technical skills based on sociological factors improved significantly. Such learning experiences, which are often not encountered in traditional engineering education, offer highly interactive learning opportunities where practical exposure to such topics is possible. Particularly in interpersonal and multinational team interactions, improvements in interpersonal skills such as "Communication" and "Individual and Collaborative Team work" are expected. Moreover, paying attention to these learning outcomes that are not subject to grading is important for both educators and participating learners.

Answer to RQ2: In the text mining conducted on TWIL, a discrepancy was discovered between what learners recorded as "learned" and their own recognition in self-evaluation. This time, the analysis did not progress to the point of comparing the daily learning content with the TWIL description items due to the limited data volume. In the next trial, participants will be notified of the use of this analysis method during the PBL implementation period and write as much as possible. They will also be provided with several keywords related to WA11GAP in the orientation and encouraged to actively fill them in, with the expectation that this would lead to a clearer understanding of the causal relationship between learning objectives and outcomes in future analyses.

RQ3: Improvements in learning effectiveness in PBL engineering education through the utilization of these methods is planned for the next program in 2024. Application of this methodology to the course design phase could improve the comprehensive PBL learning process. At the planning stage, the instructors will incorporate the possible opportunities for acquiring WA11GPA skills into the contents,

and convey these items to participants without mentioning where they are embedded. Participants are suggested to use these clustering keywords when they write intermediate works like TWILs, mid-term reports, final outputs, and even e-mails or in text chat tools such as Learning Management System (LMS), WhatsApp, or Slack. After completing all program contents, the text-mining analysis results are disclosed to them and used for individual and group reflection. This post-program feedback process will enhance their cognition about their actual learning outcomes as reflections, and consequentially build their confidence to be a global engineer. Per Image 3 PBL Program improvement cycle, the following will be reflected to the "1. Program planning, contents design" phase.

Table 2: Sample of keyword clusters related to WA11GAP

No.	WA Graduate Attribute Profile	Clustering keyword samples
1	Engineering Knowledge (1) Generic terms	Knowledge, technology, engineering, science
	(2) Technical terms	data monitoring, data processing, data analysis, data utilization, transportation, mobility, monitoring, biomass, energy, waste-to-energy, low carbon,
2	Problem Analysis	problem problematic, issue, analyse, analytical analysis
3	Desing/development of solution	Solution, solving, solve, design, create, develop, development
4	Investigation	Investigate, investigation, research, inspect, inspection, identify,
5	Tool Usage (1) Generic terms	tool, software, app
	(2) Specifc tool name	CANVA, MatLab,
6	The engineer and the World	society, social, societal, local, community, (kampong)
7	Ethics	Ethics, ethical
8	Individual and Collaborative Team work	team work, group work, group activities, cooperate, cooperation, work together, collaborate, collaboration,
9	Communication	Communication, discussion, communicate, discuss, discussion, debate, presentation, present, English
10	Project Management and Finance	Plan, planning, profit, profitability, accounting, revenue, income, finance, financial, business
11	Lifelong learning	life-long, continuing education, keep learning

- To explain WA11GAP to the participants at the program orientation, and convey that it includes both technical and non-technical skills, and raise their awareness to absorb them outside the classroom.
- To articulate the contents of individual learning processes using process-based recording templates like TWIL, thereby encouraging them to write more using the sample keywords (Table 2) so that they can also improve their writing techniques.
- To provide them with feedback on what learning outcomes are likely using quick analysis from text mining, and thereby enhance participants' learning effectiveness through reflection.

8. Conclusion

Washington Accord is a standard referenced by major countries worldwide, and degree accreditation adheres to this standard. Moreover, in terms of substance, it is important for engineers who can thrive globally to possess both technical and non-technical skillsets and mindsets as outlined in WA11GAP. Programs that comprehensively experience such skills through experiential learning, such as socio-techno PBLs, are effective. Particularly in this case focusing on societal issues in the Surabaya local community

in Indonesia, it appears that there was effectiveness in learning the non-technical skills based on socio factors.

On the other hand, the comparison between self-evaluation and text mining suggests that there may be discrepancies between actual learning outcomes and self-awareness. Therefore, adding reflection linking these aspects in the post-program phase is expected to enhance the absorption effectiveness of the program content.

Regarding text mining, it was experimentally conducted using a newly developed prototype in this case. If it becomes possible to increase the intermediate data created by participants during the program, it is believed that specific learning content contributing to each WA11GAP learning outcome can be identified. Additionally, participants articulating their daily learning more frequently can also lead to improvement in English writing skills, which is beneficial in itself. Therefore, implementing such improvements in future PBLs and establishing the method of text mining are important steps for enhancing WA11GAP acquisition going forward.

Combining practical educational content rooted in social issues with text mining as an enabling technology for analyzing new learning content, and focusing on learning outcomes that are not subject to grading and providing feedback to learners, contributes to the development of globally competent engineers capable of acquiring experientially rooted skills.

9. Future efforts

Based on these results, the improvement of PBL design methods that lead to the comprehensive acquisition of WA11GAP will be continued. Specifically, in the next PBL to be conducted in September 2024, it will be reaffirmed whether emphasizing social issues will yield learning outcomes in non-technical factors such as communication and teamwork. In addition to this, an instructional design prompting output for business-related items will be implemented to test whether self-evaluation in “Project Management and Finance” improves.

Furthermore, in 2024, another type of PBL using Kaggle competitions is planned. In this PBL, emphasis will be placed on workshops focusing on “Tool Usage” and the “Design/development of solutions”. This analysis method will be conducted, and a survey will be carried out to investigate whether participants describe items related to this in their learning process records and whether they are reflected in participant self-evaluation.

In these PBLs, participants will be instructed to describe their records of intermediate tasks more thoroughly, enabling more stage-specific text mining. This will enhance the functionality of this prototype and method to more clearly measure the causal relationship between learning content and actual outcomes.

Acknowledgements:

The authors gratefully wish to thank all of the professors and academic staff who contributed to the implementation of this techno-socio PBL series. We also appreciate all participants in this ambitious program. Last but not least, we thank Dr. Rongal Watson, Associate Professor of Beloit College, for adding insights for fine-tuning this article.

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