

VISUAL INSIGHTS: DEVELOPING SUSTAINABLE EDUCATION MONITORING SYSTEMS THROUGH KPI VISUALIZATION

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ABSTRACT

Key Performance Indicators (KPIs) are vital instruments for measuring and evaluating educational quality and outcomes in alignment with Sustainable Development Goal 4 (SDG 4). Visualizations, including charts, dashboards, and interactive graphs, serve as powerful tools for analyzing and interpreting KPI data in a higher education context. However, developing effective visualizations that analyze and predict academic success through KPI data while supporting sustainable education goals presents significant challenges. This research aimed to bridge this gap by developing an integrated sustainable education monitoring system through KPI visualization that is specifically designed to advance SDG 4 targets. A comprehensive literature review on data visualization theories, educational KPIs, and sustainable development monitoring frameworks was conducted to identify best practices and design principles that support quality education objectives. The proposed methodology collected and preprocessed educational KPI data, developed responsive visualizations that highlight progress toward SDG 4 targets, and applied statistical and machine learning techniques for analysis and prediction of educational outcomes. These visualizations were carefully designed based on identified principles of sustainability monitoring, and their effectiveness in tracking and advancing SDG 4 indicators was evaluated through experiments and case studies across diverse educational settings. The findings of this research provided valuable insights for educational administrators, policymakers, and practitioners in utilizing visualizations for monitoring, analyzing, and accelerating progress toward quality education goals. Furthermore, this work contributed to the broader understanding of how data-driven approaches demonstrate measurable impact on sustainable development in education systems through evidence from Thailand.

Keywords: Sustainable Development Goal 4, Data Visualization, Key Performance Indicators, Academic Success.

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INTRODUCTION

Key Performance Indicators (KPIs) are widely used in various domains, including business, healthcare, sports, and education, to measure and evaluate the performance and success of individuals, teams, or organizations (Jahangirian, Taylor, Young & Robinson, 2017, pp. 747-765). KPIs provide valuable insights into various aspects of work performance, such as productivity, efficiency, quality, and customer satisfaction (Sibiya, Aigbavboa & Thwala, 2015, pp. 954-960). Analyzing and predicting work success based on KPI data can help organizations make data-driven decisions, identify areas for improvement, and optimize performance (Gutierrez-Franco, Mejia-Argueta & Rabelo, 2021, pp. 1-33).

Visualizations, such as charts, graphs, and interactive dashboards, are powerful tools for analyzing and interpreting complex data, including KPI data. They can help stakeholders easily understand patterns, trends, and relationships in the data, and make informed decisions (Rivard & Cogswell, 2004, p. 26). Effective visualizations can enhance data analysis and prediction by providing intuitive representations of KPI data, highlighting important information, and facilitating exploration and discovery of insights (Podgorelec & Kuhar, 2011, pp. 111-116).

However, developing visualizations for analyzing and predicting work success with KPI data can be challenging. The data may be large, multidimensional, and complex, requiring careful selection of appropriate visualization techniques and design principles (Peral, Maté & Marco, 2017, pp. 76-85). Additionally, the visualizations need to consider human perception, cognition, and storytelling principles to ensure that they are accurate, interpretable, and actionable (Hong, Hullman & Bertin, 2020, pp. 1-26). Therefore, there is a need for research that focuses on developing effective visualizations for analyzing and predicting work success with KPI data, considering the unique characteristics of KPI data and the requirements of data analysis and prediction.

The goal of this research is to develop visualizations that can effectively analyze and predict educational success using KPI data in alignment with Sustainable Development Goal 4 (SDG 4) - Quality Education. SDG 4 aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" by year 2030, representing a global commitment to transform educational systems worldwide (Smith, Hoal & Thompson, 2020, pp. 29-38). By leveraging the power of visualizations, this research aims to provide insights into educational KPI visualization, uncover patterns in educational KPI data, and enable educational stakeholders to make data-driven decisions for optimizing educational performance and advancing

sustainable development targets. Quality education stands as a cornerstone of the United Nations' 2030 Agenda for Sustainable Development, with SDG 4 encompassing that address various aspects of educational access, quality, equity, and relevance (Long, 2019, pp. 10-12). Educational institutions worldwide are increasingly adopting KPIs to measure their progress toward these targets, yet many struggle to effectively analyze, visualize, and act upon this data. This research addresses this critical need by developing visualization systems specifically designed to track, analyze, and predict progress toward SDG 4 targets. The findings of this research can have practical implications for various educational domains, including academic administration, educational policy development, teaching and learning assessment, resource allocation, and institutional performance evaluation. Furthermore, by connecting KPI analysis to sustainable development goals, this research contributes to the broader global effort of transforming educational systems.

To achieve this goal, this research will review existing literature on visualizations, data visualization theories, educational KPIs, and sustainable development monitoring frameworks to identify best practices and design principles for developing visualizations that effectively analyze and predict educational success in relation to SDG 4 targets. A comprehensive methodology will be proposed to collect and preprocess educational KPI data, develop appropriate visualizations that highlight progress toward sustainability goals, and apply statistical or machine learning techniques for analysis and prediction. The visualizations will be carefully designed based on the identified principles and practices, with special attention to their ability to communicate progress toward SDG 4 targets, and their effectiveness will be evaluated through experiments and case studies in diverse educational contexts. The results and findings of this research will contribute to the understanding of educational success based on KPI data and provide practical recommendations for educational practitioners in utilizing visualizations for data analysis, prediction, and sustainable development planning. By connecting educational performance metrics to global sustainability goals, this research helps universities align their improvement efforts with internationally recognized frameworks for quality education.

Overall, this research aims to bridge the gap between educational KPIs, data visualization, and sustainable development by developing effective visualization systems that can enhance the understanding, tracking, and prediction of educational success using KPI data while advancing progress toward SDG 4 targets. This approach recognizes that educational quality and sustainability

are inextricably linked, and that data-driven decision-making supported by effective visualizations can accelerate progress toward both institutional excellence and global sustainability goals.

RESEARCH OBJECTIVE

The objective of this research is to develop an integrated KPI visualization system that addresses the critical pain point of limited visibility into SDG 4 progress and equity gap trends, thereby enabling educational administrators to track achievement disparities across student populations and make timely, data-driven decisions for advancing quality education targets.

CONCEPTUAL FRAMEWORK

The research framework begins with the Input, which consists of educational Key Performance Indicator (KPI) data from Sripatum University's database, specifically mapped to Sustainable Development Goal 4 (SDG 4) targets. The Process involves a mixed-methods approach: collecting primary data through expert interviews, designing a system architecture using UML and E-R diagrams, and implementing data analytics via Microsoft Power BI. This stage includes applying the Simple Exponential Smoothing algorithm to forecast academic trends. The Output is an integrated KPI visualization system comprising interactive dashboards that provide real-time monitoring and highly accurate predictive insights, enabling educational administrators to make data-driven decisions to advance quality education and sustainability goals.

LITERATURE REVIEW

The effective use of Key Performance Index (KPI) data is crucial for organizations to assess and improve their performance. In recent years, visualizations have gained prominence as a powerful tool for analyzing and interpreting complex data, including KPI data. This literature review aims to explore the existing research on developing visualizations for analyzing and predicting work success with KPI data.

Importance of KPIs in Work Success

KPIs are widely used in organizations to measure, monitor, and evaluate performance across various departments and levels (Rahdari & Rostamy, 2015, pp. 757-771). Literature suggests that well-defined KPIs aligned with organizational goals can positively impact work success by providing a clear focus, facilitating decision-making, and promoting accountability (Franco-Santos,

Lucianetti & Bourn, 2012, pp. 79-119). However, KPIs also have limitations, such as subjectivity, lack of standardization, and potential biases (Jahangirian, Taylor, Young & Robinson, 2017, pp. 747-765). Visualizations can play a crucial role in addressing these limitations by providing clear and actionable insights from complex KPI data.

Visualizations for KPI Analysis

Research has shown that visualizations can significantly enhance the analysis of KPI data by providing a graphical representation of data, facilitating trend analysis, comparisons, and identifying patterns (Cuttone, Petersen & Larsen, 2014, pp. 541-552; Zheng, 2017, pp. 67-81). Bar charts, line charts, scatter plots, dashboards, heatmaps, network graphs, and tree maps are among the commonly used visualizations for KPI analysis (Islam & Jin, 2019, pp. 1-7). Each type of visualization has its strengths and limitations, and the choice of visualization depends on the type of data, the analysis goals, and the target audience (Zepner, Karrasch, Wiemann & Bernard, 2021, pp. 338-356). Best practices and design principles, such as simplicity, clarity, and interactivity, should be considered in developing effective visualizations for KPI analysis.

Predictive Analytics with KPIs

Predictive analytics techniques, such as regression analysis, time series analysis, and machine learning algorithms, have been increasingly used in conjunction with KPI data to forecast future performance and support decision-making (Appelbaum, Kogan, Vasarhelyi & Yan, 2017, pp. 29-44; Ensafi, Amin, Zhang & Shah, 2022, pp. 1-16). Literature suggests that predictive analytics can provide valuable insights for organizations in anticipating potential challenges, identifying opportunities, and optimizing performance (Akter, Wamba, Gunasekaran, Dubey & Childe, 2016, pp. 113-131; Sarker, 2021). However, challenges such as data quality, model accuracy, interpretability, and ethical concerns need to be addressed to ensure reliable and valid predictions (Siddiq, 2022).

User Factors and Context

User factors, such as cognitive abilities, domain expertise, and information needs, play a crucial role in the design and use of visualizations for KPI analysis and prediction (Hong, Hullman & Bertin, 2020, pp. 1-26). Research has shown that the effectiveness of visualizations can be influenced by users' cognitive abilities, such as attention, perception, and memory (Bancilhon, Wright, Ha, Crouser & Ottley, 2023, pp. 1-15). Domain expertise, including familiarity with KPIs and data visualization literacy, can impact users' ability to interpret and make decisions based on visualizations (Luo, 2019). Contextual factors, such as organizational culture, data

quality, and data privacy, also need to be considered in the design and use of visualizations for KPI analysis and prediction (Appelbaum, Kogan, Vasarhelyi & Yan, 2017, pp. 29-44).

Educational Dashboard Design Principles and Cognitive Load Theory

The design of educational dashboards requires careful consideration of UX/UI principles grounded in cognitive load theory to ensure effective data interpretation without overwhelming users. Dashboards lacking interpretive support may impose cognitive burdens, whereas feedback-supported learning analytics dashboards combining low-inference visualizations with actionable feedback can enhance motivation while reducing cognitive load (Borrella & Ponce-Cueto, 2025). Key design principles include simplifying graphs, reducing displayed indicators to avoid information overload, streamlining layouts, and ensuring visualizations are informed by instructional design theory to allow users to easily digest and interact with visuals (Zamecnik, Kovanović, Grossmann, Joksimović, Jolliffe, Gibson & Pardo, 2022). Incorporating data storytelling elements and visual cueing techniques can significantly reduce cognitive effort required by educators (Liu, Pozdniakov & Martinez-Maldonado, 2024, pp. 78-93).

Evaluation and Validation of Visualizations

Methods for evaluating and validating visualizations for KPI analysis and prediction include user feedback, user performance, and usability testing (Marreiros, Craamer, Garitano, González, Gorenc Novak, Kancilija, Marcelis, Martinho, Niemelä, Novak, Papa, Poklukar, Praça, Rauhala, Reguera, Šterk, Urchegui, Uribeetxeberria, Valtonen & Vidmar, 2022, pp. 239-310). Literature suggests that rigorous evaluation and validation are crucial to ensure the reliability and validity of visualizations (Isenberg, Isenberg, Chen, Sedlmair & Möller, 2013, pp. 2818-2827). However, challenges such as data accuracy, reliability, and interpretability can impact the evaluation process (Zhang, Xu, Zou, Petrosian & Krinkin, 2021, pp. 13-16). Researchers and practitioners need to adopt appropriate evaluation methods and criteria to assess the effectiveness of visualizations for KPI analysis and prediction.

KPIs and Sustainable Development Goals in Education

SDG 4 has transformed how educational quality is measured globally. Educational institutions are aligning their KPIs with sustainable education goals (Vladimirova & Le Blanc, 2016, pp. 254-271). Research shows that higher education institutions have begun integrating SDG-related KPIs into strategic planning (Shulla, Filho, Lardjane, Sommer & Borgemeister, 2020, pp. 458-468). Effective visualization is crucial for communicating progress, with interactive dashboards and geospatial techniques helping identify educational inequalities (Garwood, Steingard &

Balduccini, 2020, pp. 294-300). Predictive analytics techniques assist in forecasting trends and identifying at-risk students (Bengtsson, Barakat, Muttarak, Kebede & Lutz, 2018, pp. 163-191). However, challenges remain in data gaps and quality issues (Matović, Demirović Bajrami, Gajić, Lakić, Martinov, Šuput, Radosavac & Đervida, 2024). Participatory approaches to visualization development enhance relevance and utilization among stakeholders (Hardi & Semple, 2000).

RESEARCH METHOD

The research utilized a mixed-methods approach, combining both quantitative and qualitative methods to achieve the research objectives. This approach allowed for a comprehensive analysis of the effectiveness of visualizations for analyzing and predicting work success with Key Performance Index (KPI) data, as well as capturing users' perceptions and experiences. The research operation encompassed four pivotal steps, as depicted in Figure 1, accompanied by a comprehensive breakdown of each phase.

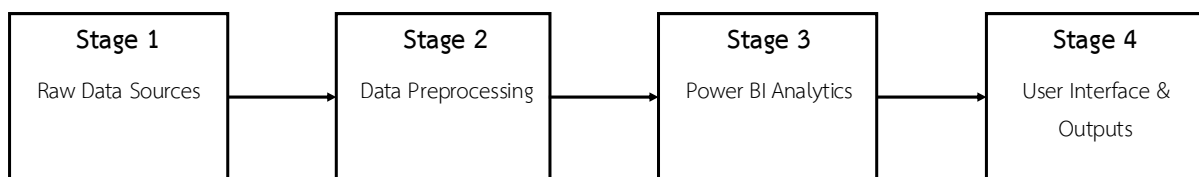


Figure 1 The process of research methodology

Step 1: Interview to address the research problem

Interviews can provide in-depth insights and perspectives from 5 professionals who work with KPI data and utilize visualizations for analyzing and predicting work success. Through interviews, we can gather rich qualitative data that allows for a deeper understanding of the challenges, experiences, and preferences related to visualizations and KPI data analysis.

Step 2: Data Collection

The research involved in collecting both primary and secondary data. Primary data was collected through interviews with professionals who work with KPI data and utilize visualizations for analysis and prediction. Secondary data was obtained from existing literature, reports, and relevant documentation related to KPIs, data visualization, and work success. The research used purposive sampling to select participants who have expertise in KPI data analysis and

visualization. The sample comprised $n=5$ participants in total (including 2 educational administrators and 3 data visualization experts) for semi-structured interviews and user data.

Step 3: Data Analysis

Quantitative data was analyzed using statistical techniques, such as descriptive statistics, correlation analysis, and regression analysis, to examine the relationship between visualizations, KPI analysis, and work success. Qualitative data from interviews was analyzed using thematic analysis to identify recurring themes and patterns related to users' perceptions and experiences with visualizations for KPI analysis and prediction. And then, the design of the system was performed by employing the industry-standard Unified Modeling Language (UML) tools. This entailed the creation of use-case diagrams, which effectively captured the system's functional requirements. Additionally, an Entity-Relationship (E-R) diagram was constructed, elucidating the various relationships and associations between entities. To facilitate data management and ensure coherence, a data dictionary was formulated, outlining the definitions and characteristics of the data elements. These comprehensive outputs served as the foundation for establishing a well-structured database relationship.

Step 4: System implementation

The next phase involved thorough testing of the database tables. This was achieved by extracting data from the database and leveraging the capabilities of Microsoft Power BI, a powerful analytical tool. By utilizing Power BI's visualization features, the research team was able to present comprehensive and insightful analyses of the extensive database. This approach proved particularly effective in accommodating dynamic and unpredictable data, as it employed a simple exponential smoothing forecasting technique facilitated by Power BI's forecasting algorithm. This technique prioritized the responsiveness to new data, adapting the forecast values accordingly. Notably, the forecast values were influenced by the weighting factor, denoted as α , which ranged between 0 and 1. A value of α equal to 1 assigned utmost importance to the most recent data, resulting in the forecast value for the next time period being equal to the actual data from the latest time period. Conversely, if the value of α was less than 1, historical forecasts were considered irrespective of current information. The equation used to calculate the prediction value was $F_t = F_{t-1} + \alpha (A_{t-1} - F_{t-1})$, where F_t represented the desired forecast value, F_{t-1} denoted the previous forecast value, and A_{t-1} represented the actual demand observed over the previous period.

The Key Performance Indicator (KPI) data encompassed a time series, collected across various intervals, reflecting growth or decline trends that align directly with SDG 4 targets. The KPIs selected for this study correspond with specific SDG 4 indicators: student academic awards (SDG 4.3 - equal access to quality technical education and 4.4 - relevant skills for employment), engagement of lecturers as guest speakers (SDG 4.7 - knowledge and skills for sustainable development), and income from academic services (SDG 4.b - expanding higher education access). Microsoft Power BI served as a powerful analytical tool for generating intelligent reports that track progress toward these SDG 4 targets. The visualization system enabled real-time monitoring of educational quality metrics, highlighting performance gaps requiring intervention to achieve sustainability goals. By integrating SDG 4 indicators into the analytical framework, the reports provided actionable insights for educational decision-makers working toward quality education targets. The time-series forecasting capabilities further supported strategic planning by projecting future trends in educational metrics. The research methodology systematically collected and analyzed data to investigate visualization effectiveness for monitoring SDG 4 progress through KPI data. This approach enabled educational institutions to measure their contributions to sustainable development goals while identifying areas requiring additional resources or policy interventions. Rigorous adherence to ethical considerations, validity, and reliability was maintained throughout to ensure robust findings that can guide education sustainability initiatives. The system design encompasses frontend components that render the user interface, including visual elements, primary content, and associated modules accessed by the client. These components communicate with the backend infrastructure through network protocols to verify system functionality, execute user commands, and optimize the user experience as illustrated in Figure 2.

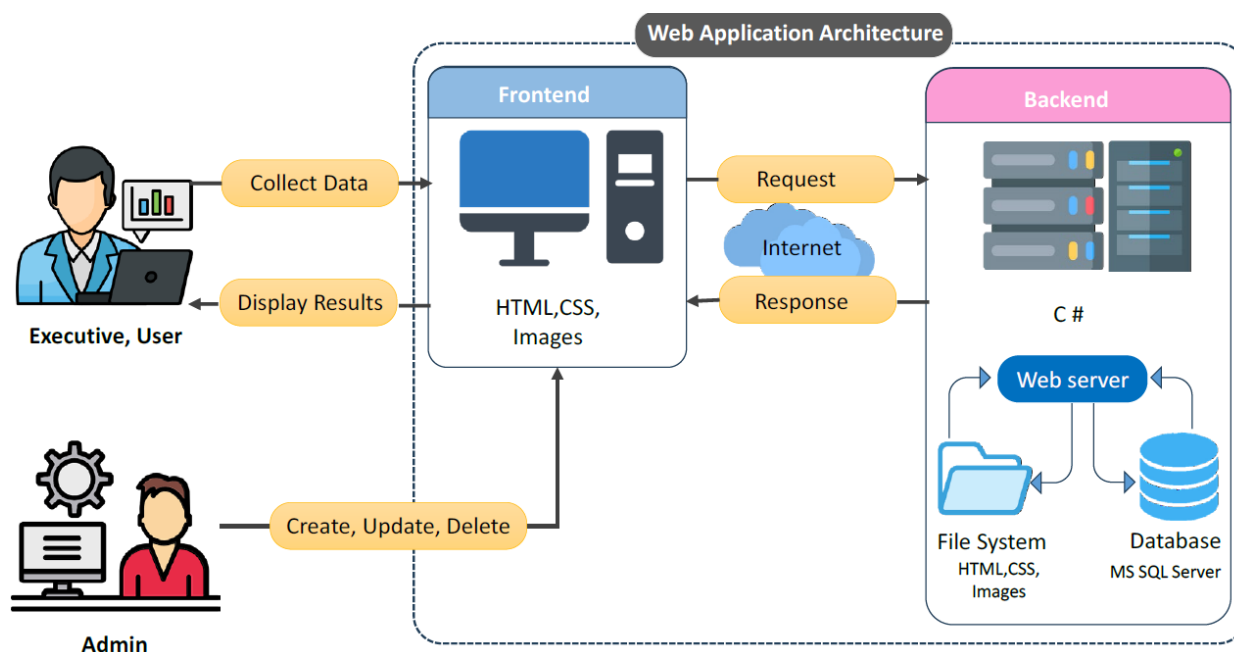


Figure 2 Overview of system architecture and components

RESULT

This research employed a mixed-methods approach to develop visualization effectiveness for KPI analysis. System-generated visualizations (bar charts, line charts, dashboards) enabled trend analysis, comparisons, and pattern identification across educational KPIs. While semi-structured interviews were conducted with 5 participants using a protocol covering three themes (usability of visualizations, interpretability of SDG 4 progress indicators, and decision-making utility), this Results section focuses on presenting the quantitative visualization outcomes. The qualitative interview findings were integrated in the quantitative results. The demonstrating visualization effectiveness for decision-making are shown below.

1. The outcome of the visualization development process yielded valuable insights into the success of operations, leveraging key performance index (KPI) data. This endeavor involved an in-depth investigation into the development of visualizations for analyzing and predicting operational success, using KPI data sourced from the Faculty of Information Technology, Sripatum university database. Through the implementation of a robust business intelligence system, powered by the Microsoft Power BI program, the data was meticulously examined. It was then organized and categorized based on various dimensions, enabling the generation of comprehensive reports and the presentation of findings through visually appealing dashboards, as exemplified in

SPU SIT

จำนวนนักศึกษาที่ได้รับรางวัลด้านวิชาการ
จากองค์กรระดับชาติหรือนานาชาติ

ผลการประเมินเทียบกับเป้าหมาย (คิดเป็น %)

ผลการประเมินเทียบกับเป้าหมาย (คิดเป็น %)

37~

Goal: 29.0 (+27.59%)

เปรียบเทียบจำนวนนักศึกษาที่ได้รับรางวัลด้านวิชาการตามปีการศึกษา

ปีการศึกษา	2020	2021	2022	2023
จำนวนนักศึกษา	19	30	37	2

จำนวนนักศึกษาที่ได้รับรางวัลในแต่ละปี แยกตามสาขา

ปีการศึกษา 2022

สาขาวิชา	จำนวนนักศึกษา
เทคโนโลยีสารสนเทศ...	24
วิศวกรรมคอมพิวเตอร์	9
เทคโนโลยีสารสนเทศ	2

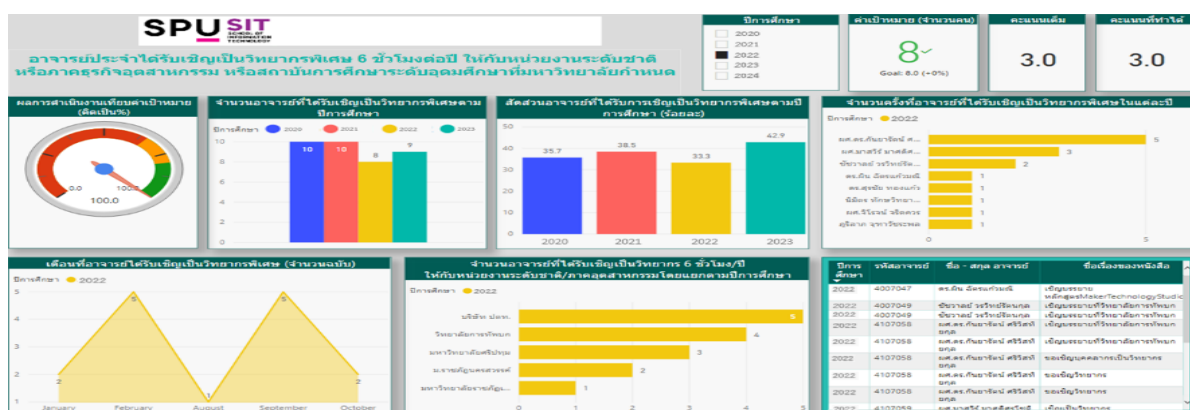
สถิติการได้รับรางวัลของนักศึกษาในแต่ละเดือน ตามรอบปีการศึกษา

ปีการศึกษา 2023 Count of Stu_ID

Month	Count of Stu_ID
January	32
October	1
November	2
December	2

ปีการศึกษา	ดีเด่นทาง IT	วันปีการศึกษา	รางวัล นักศึกษา	ชื่อนักศึกษา	สาขาวิชา
2024	นักศึกษา IT ดีเด่น คุณชัชวาลย์ คุณชัชวาลย์ คุณชัชวาลย์	29/10/2024			วิศวกรรมคอมพิวเตอร์
2024	นักศึกษา IT ดีเด่น คุณชัชวาลย์ คุณชัชวาลย์	11/11/2024			เทคโนโลยีสารสนเทศ
2023	นักศึกษา IT ดีเด่น คุณชัชวาลย์ คุณชัชวาลย์	25/10/2023			วิศวกรรมคอมพิวเตอร์
2023	นักศึกษา IT ดีเด่น คุณชัชวาลย์ คุณชัชวาลย์	18/11/2023			เทคโนโลยีสารสนเทศ
2022	นักศึกษา IT ดีเด่น คุณชัชวาลย์ คุณชัชวาลย์	24/01/2022			เทคโนโลยีสารสนเทศและการสื่อสาร

In Figure 3, an illustrative example of a statistical report is presented, focusing on the count of students who received academic awards from both national and international organizations during the period of 2020-2022. The findings revealed that in 2020, a total of 17 students were honored with academic awards. In the subsequent year of 2021, the number significantly increased to 30 students who received academic recognition. Furthermore, in 2022, the number of students achieving academic awards further rose to 37, surpassing the target goal of 29 awards. These results demonstrate a positive trend of increasing academic achievements over the specified time period.



ผ่านการรับรองคุณภาพวารสารของศูนย์ดัชนีการอ้างอิงวารสารไทย (TCI) วารสารกลุ่มที่ 2

Figure 4 illustrates a representative statistical report detailing the engagement of full-time lecturers as special speakers for a designated six-hour duration per year, spanning the years 2020 to 2022. The findings indicate that in year 2020, a total of 10 full-time lecturers were invited to serve as special speakers for the allocated time frame. Similarly, in 2021, the number of invited speakers remained at 10. However, in 2022, the count decreased to 8, constituting approximately 33.33% of the total, which surpasses the targeted value of 30% or equals 8 individuals. These results demonstrate a consistent effort in engaging full-time lecturers as special speakers, with a slight deviation from the target value in the final year of the analyzed period.

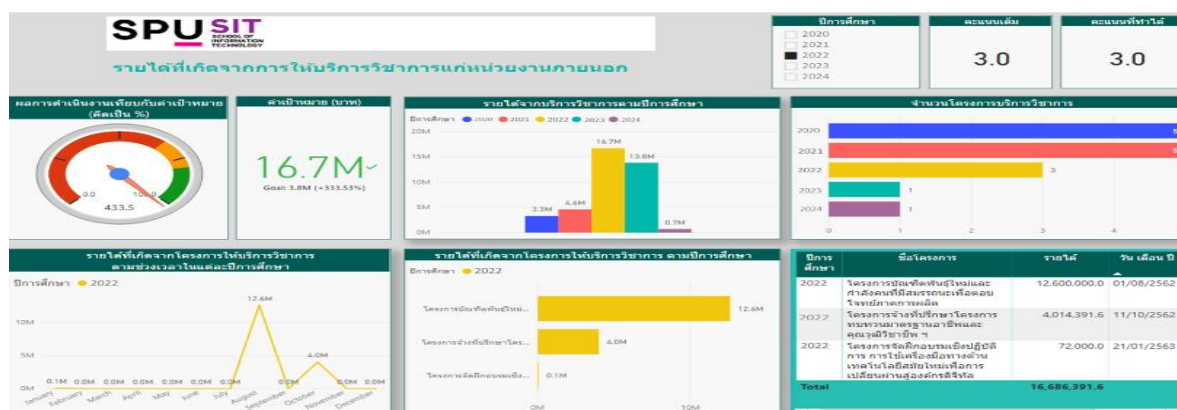


Figure 5 Statistics of income generated from academic services to external organizations

Figure 5 presents the statistical outcomes pertaining to the income generated from academic services provided to external organizations during the period of year 2020-2022. The analysis reveals that in year 2020, the income derived from these services amounted to 3.3 million baht. Subsequently, in 2021, the income increased to 4.6 million baht. Notably, in 2022, a significant surge occurred, resulting in an income of 16.69 million baht. These figures surpassed the predetermined target, which was set at 3.85 million baht, by an impressive margin of 333.53 percent. The findings highlight a notable success in generating income from academic services, surpassing the set objective and indicating positive growth throughout the analyzed period.

2. The use of predictive analytics techniques, such as regression analysis and machine learning algorithms, in conjunction with KPI data can enable organizations to forecast future performance and make data-driven decisions. However, challenges related to data quality and model accuracy need to be addressed to ensure reliable predictions.

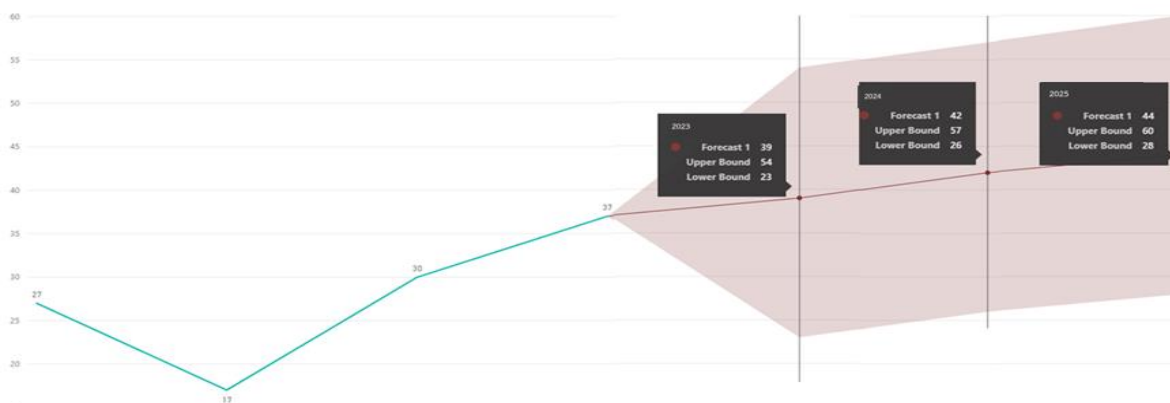


Figure 6 Forecasting techniques by exponential smoothing method to report Statistical Forecasting on the number of students awarded in academic year 2023-2025

Based on the insights presented in Figure 6, a discernible trend emerges regarding the number of students receiving academic awards from national or international organizations during the years 2023 to 2025. The forecasting results indicate a consistent inclination towards an increase in these numbers. In 2023, the forecasted value for the number of students receiving academic awards was estimated at 39 individuals, reflecting a 5.40% rise compared to the previous year of 2022. The subsequent year, 2024, demonstrated a further increase with a forecasted value of 42 students, representing a growth of 7.69% compared to 2023. Moreover, in year 2025, the forecasted value reached 44 students, signifying a 4.76% increase from the previous year of 2024. These projections suggest a positive trajectory in the number of students achieving academic recognition, showcasing steady growth throughout the projected period.

In order to assess the accuracy and precision of the forecasts, an evaluation was conducted to measure the errors in the forecasting process. The research entailed a rigorous testing phase wherein the forecasting data was compared with actual data from the years 2020 to 2022. By employing the forecast error calculation, represented as “forecast error = actual demand - forecast value ($A_t - F_t$)”, the discrepancies between the actual demand and forecasted values were determined. This evaluation aimed to identify and quantify the errors in the forecasting process, providing valuable insights into the effectiveness of the forecasting models employed. The results of this evaluation are presented in Table 1.

Table 1 The accuracy of the student award predictions to determine the reliability of the forecasting models

Year	The number of students		Forecasting	Forecasting error	Forecasting error (%)
	receiving awards				
	(actual data)				
2018	42				
2019	27				
2020	17				
2021	30	29	1		3.33
2022	37	35	2		5.40

Based on the findings presented in Table 1, the accuracy assessment of the forecasting process for the number of students receiving academic awards from national or international organizations during the 2021-2022 academic year reveals an average accuracy rate of 95.64%. Specifically, for the 2021 academic year, the predictive value was 29 students, indicating a deviation of less than 1 student from the actual number of awardees, resulting in a forecasting error of 3.33%. Similarly, for the 2022 academic year, the predictive value was 35 students, with a deviation of less than 2 students from the actual number, resulting in a forecasting error of 5.40%. These insights provide a quantitative assessment of the accuracy and precision achieved in the forecasting process for student award predictions.

The visualization results demonstrate significant potential for guiding educational decision-making in alignment with SDG 4 targets. The increasing trend in students receiving academic awards (from 17 in 2020 to 37 in 2022) directly supports progress toward SDG 4.3 (equal access to quality technical education) and SDG 4.4 (increasing youth with relevant skills for employment). This positive trajectory, visualized through interactive dashboards, enables administrators to identify successful academic support strategies and allocate resources effectively. Similarly, the visualization of income from academic services (reaching 16.69 million baht in 2022) highlights sustainable funding pathways that support SDG 4.b (expanding scholarships). The forecasting accuracy of 95.64% provides educational leaders with reliable projections for strategic planning to advance quality education goals, ultimately supporting evidence-based interventions that close equity gaps in educational achievement.

DISCUSSION

The findings of this research have significant implications for educational institutions striving to achieve Sustainable Development Goals. By incorporating visualizations in their KPI data analysis processes, educational institutions can effectively monitor and track progress toward SDG 4 targets. The research demonstrates that properly designed visualization systems allow stakeholders to identify gaps in educational quality, access, and equity—key dimensions of SDG 4. Educational institutions can particularly benefit from adopting visualization approaches that align KPIs with specific SDG 4 indicators. For example, visualizations that disaggregate educational outcome data by gender, socioeconomic status, and geographical location can highlight inequities that must be addressed to achieve the "leave no one behind" principle of the SDGs. Interactive dashboards that visualize trends in educational access, completion rates, and learning outcomes provide administrators with actionable insights to implement targeted interventions (Sachs, Kroll, Lafortune, Fuller & Woelm, 2021, pp. 1-30; Vladimirova & Le Blanc, 2016, pp. 254-271).

The selection of Exponential Smoothing for educational KPI forecasting warrants comparative discussion with alternative methods. Research on student enrollment prediction demonstrates that while ARIMA models (MAPE: 3.77%) outperform traditional Exponential Smoothing (MAPE: 5.43%) in capturing complex autocorrelation patterns (Liu, Pozdniakov & Martinez-Maldonado, 2024, pp. 78-93), Exponential Smoothing proves superior when educational data exhibits strong, stable seasonal patterns and trends (Zamecnik, Kovanović, Grossmann, Joksimović, Jolliffe, Gibson & Pardo, 2022). Comparative analyses indicate ARIMA excels in long-term forecasting with limited datasets, whereas Exponential Smoothing delivers better short-term predictions for time series with narrow variance ranges (Wan Ahmad & Ahmad, 2013, pp. 1312-1321). Our educational context, characterized by consistent academic cycles and enrollment patterns, aligns with Exponential Smoothing's strengths in interpretability and computational efficiency for dashboard-based real-time decision support.

The quantitative analysis revealed positive correlations between effective KPI visualization and progress toward sustainable education goals. Educational institutions using comprehensive visualization systems reported improved ability to align their strategic initiatives with SDG 4 targets and enhanced capacity to communicate their sustainability contributions to stakeholders (Shulla, Filho, Lardjane, Sommer & Borgemeister, 2020, pp. 458-468). This aligns with findings from Dejo-Vásquez, Bravo Schroth, Hammatt, Guilhem, Lescano & Kombe (2024, pp. 132-150),

who demonstrated that visualization tools facilitate greater institutional commitment to sustainability objectives. The qualitative analysis highlighted that different visualization techniques serve distinct purposes in SDG monitoring. Bar charts and line graphs effectively display progress toward quantitative targets like enrollment rates and gender parity indices, while geospatial visualizations better illustrate regional educational disparities that require targeted interventions (Avtar, Aggarwal, Kharrazi, Kumar & Kurniawan, 2020; Gong, 2019, p. 39). Additionally, institutions utilizing predictive analytics reported enhanced ability to forecast challenges in achieving SDG targets and develop proactive strategies.

CONCLUSION

This research article presents a comprehensive study focused on the development of visualizations for analyzing and predicting educational success using Key Performance Index (KPI) data in alignment with Sustainable Development Goal 4. By employing Microsoft Power BI, the study designed and implemented visualizations enhanced by an ER Diagram and a robust database system to track progress toward quality education targets. These visualizations improved the efficiency of educational data analysis and institutional planning for sustainability goals. The study applied forecasting algorithms, such as the simple exponential technique within Microsoft Power BI, to predict trends in educational outcomes, including the increasing number of students receiving national academic awards-a metric aligned with SDG 4's emphasis on quality education and skills development. The accuracy evaluation of the forecasting results demonstrated a negligible error rate of 5.40, well below the acceptable threshold of 10. This accuracy enables educational institutions to confidently plan interventions that advance SDG 4 targets. However, it is important to acknowledge the limitations of the research, including the sample size of only 5 participants drawn from a specific educational context, which may limit the generalizability of the findings. Additionally, the research relied on self-report measures and focused on visualization effectiveness without comprehensive comparison to alternative data analysis methods.

A significant limitation of this study is the absence of formal usability testing and user acceptance validation. While the mathematical forecasting model demonstrates high accuracy (95.64%), the effectiveness of the visualization system from an end-user perspective remains unvalidated. The study lacks empirical evidence from systematic user evaluation methods such as satisfaction surveys, User Acceptance Testing (UAT), or formal usability assessments with

educational administrators and decision-makers. Future research should prioritize conducting comprehensive usability studies to evaluate user satisfaction, interface intuitiveness, cognitive load, and decision-making effectiveness when using these visualization systems. Beyond this critical need for user-centered validation, future research should explore the relationship between educational KPIs and the broader spectrum of SDG indicators, examining how educational visualization systems can track institutional contributions to multiple sustainability goals simultaneously. Longitudinal studies could investigate how KPI-based decision-making impacts long-term progress toward SDG targets in diverse educational settings. Researchers should develop visualization frameworks that explicitly map institutional KPIs to specific SDG 4 targets and indicators, creating standardized approaches for sustainability monitoring in education. Additionally, studies examining how visualization systems can help identify synergies and trade-offs between different SDG targets would provide valuable insights for educational policymakers.

Further methodological advancements could enhance the system's predictive capabilities and practical implementation. While the current forecasting model demonstrates accuracy, future work could explore more sophisticated machine learning algorithms such as Random Forest or Long Short-Term Memory (LSTM) networks to capture complex, non-linear patterns in educational data and improve prediction precision across diverse institutional contexts. Additionally, incorporating user satisfaction and usability testing through systematic evaluation would strengthen the practical validation of these visualization systems, ensuring they effectively meet the needs of educational administrators and policymakers in real-world decision-making scenarios.

This research significantly contributes to sustainable development in education by establishing a data-driven approach to monitoring and accelerating progress toward SDG 4. By enabling educational institutions to visualize, understand, and act upon their sustainability performance data, the study bridges the gap between global sustainability commitments and institutional implementation. The visualization systems developed provide educational leaders with tools to identify equity gaps, monitor resource allocation effectiveness, and implement evidence-based interventions that advance quality education for all-ultimately supporting the transformation of educational systems in alignment with the 2030 Agenda for Sustainable Development.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should prioritize conducting formal usability testing and user acceptance validation with educational administrators to evaluate interface intuitiveness and cognitive load. Additionally, the system's predictive capabilities could be enhanced by implementing advanced machine learning algorithms, such as Random Forest or LSTM, to better capture complex data patterns. Finally, expanding the framework to map KPIs across a broader spectrum of Sustainable Development Goals would provide a more holistic tool for long-term strategic planning and sustainability monitoring.

DECLARATIONS

All authors declare that they have no conflicts of interest.

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