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Creating a Competency Domain Index: Enhancing assessment for online programming and electronic design for lower secondary school

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Abstract
This study develops a Competency Domain Index (CDI) to enhance the assessment of online programming and electronic design for lower secondary schools in Malaysia. Conducted in two phases, the first identifies relevant competencies using the Nominal Group Technique (NGT), while the second develops the CDI with expert reviews. Results show over 70% expert consensus across all domains. The proposed CDI employs a spider web chart to visualise competencies, which are categorised according to Bloom's taxonomy of cognitive levels, using normalised scores. Future work will focus on validating the CDI in schools to ensure its effectiveness and applicability.

Keywords: Assessment; Competency; Education; Programming

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1.0 Introduction

In Malaysia, the subject of Design and Technology in lower secondary schools introduces students to the fields of basic electronics, simple programming, computer-aided design and project-based tasks (Sahaat & Mohd Nasri, 2020). This subject promotes students' creativity while developing their foundational skills, particularly problem-solving capabilities in design thinking and practical technology applications (Murugan & Abdullah, 2024). It helps prepare students for advanced studies and future careers in a technologically driven economy. The Curriculum and Assessment Document Standard (Dokumen Standard Kurikulum dan Pentaksiran or DSKP) for the subject of Design and Technology provides a structured framework to guide teaching, learning and assessment in this subject (Kementerian Pendidikan Malaysia, 2017). It aligns with the goals of the national curriculum, which emphasises equipping students with skills that are relevant to the 21st century, including critical thinking, collaboration and digital literacy.

The DSKP outlines specific learning standards and performance standards that can guide teachers on the expected competencies at each stage of learning. Assessment acts as one of the crucial parts in education and is one of the key elements in constructive alignment (Biggs, 1996). It serves as a tool for measuring students' achievements in learning outcomes. Information must be provided to educators and learners to know the effectiveness of the curriculum delivery while giving hints on continuous improvement (Kilag et al., 2024, Thornhill-Miller et al., 2023). In the DSKP, assessment is based on criteria that focus on competencies that reflect students'

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practical skills and conceptual understanding. Performance standards are often mapped across cognitive levels based on Bloom's taxonomy, thus encouraging teachers to assess not only factual recall but also higher-order skills.

This study seeks to address the gap in assessment standards for online programming and electronic design in lower secondary education. This study has two objectives. The first objective is to identify the competency domains and second objective is to develop a Competency Domain Index (CDI). Ambiguity in interpreting the assessment criteria (Ashby-King et al., 2022, Quinn, 2020) in the DSKP may lead to an inconsistent or biased evaluation of students' performance. Hence, this study proposes a CDI as a structured assessment framework. This index utilises a spider web chart with normalised scores to represent students' competencies visually, which are categorised according to Bloom's taxonomy of cognitive levels. These competencies are aligned with the DSKP for the Design and Technology subject. This study suggests a systematic and fair method of evaluating student skills by offering educators a tool to assess competencies accurately across various cognitive domains.

2.0 Literature Review

Classroom assessment has three distinct purposes: assessment for learning, assessment as learning and assessment of learning (Maki, 2023, Yusoff et al., 2023, Schellekens et al., 2021, Rini & Cahyanto, 2020). Every assessment has a unique role in supporting student development and guiding instructional practices. Assessment for learning is conducted throughout the learning process. Meanwhile, assessment as learning is the engagement of students in self-assessment. This type of self-monitoring helps students to know their strengths and areas for improvement. Assessment of learning stresses on assessing students at the end of the learning process, therefore providing a final overview of the students' achievement.

Mohamed Salleh et al. (2021) emphasized the importance of assessments in programming education that go beyond traditional exams to evaluate students' practical programming skills. In their study, a model for teaching and learning programming subjects was proposed. The model has several elements, including active learning, teacher training, resource availability and curriculum design. They proposed an integration of practical assessment, including assessment through projects, formative assessment and collaborative assessment to provide a real reflection of students' programming competencies. Buyrukoglu et al. (2019) on the other hand reported that students need personalised feedback to improve their programming skills. Using automated assessment tools has the advantage of reducing the burden of teachers in evaluating students' assignments. Furthermore, tools that are powered by artificial intelligence can provide tailored feedback that is specific to each student's assignments, this therefore being effective in enhancing students' competencies. Integrating human and artificial intelligence, particularly in assessments, demonstrates great potential to enrich the programming and learning experience of students.

Salleh et al. (2021) aimed on searching for the most effective way of measuring students' competency in programming courses. They reported that students' achievement in the final examination and additional practical or hands-on assessments, such as challenging projects and assignments, have positive correlation with the students' programming competency. Their study investigated various types of assessments, including quizzes, assignments, projects and exams, for programming courses before reaching a conclusion on the most accurate reflection of students' competencies. They recommended incorporating a balanced mix of assessment types. This approach ensures a comprehensive view of students' abilities while offering ideas for educators to improve curriculum design. Qureshi (2023) investigated the use of ChatGPT as a tool for learning and assessment in the undergraduate computer science curriculum. A comparison of two groups of students via a programming challenge demonstrated that the group using ChatGPT generally outperformed the group using traditional resources, such as textbooks. However, the solutions using ChatGPT had inconsistencies and errors. The study revealed the immense of ChatGPT in improving learning outcomes in programming.

Vagueness in assessment is not a new concept. It emerges because of various limitations, including individual differences and vagueness in criteria (Kwon & Ko, 2024, Behforouz, 2022, Finstad et al., 2022, Verheyen & Storms, 2018). Marshall (2008) discussed the disadvantages of vagueness in assessment, including unreliability of judgement. Therefore, this study aims to address the current gap in assessment standards for online programming as well as electronic design in lower secondary education in Malaysia. This work identifies the key competency domains in programming based on experts' consensus followed by the development of the CDI. The newly developed index is expected to reflect students' performance in programming. This study is important because it offers valuable insights into improving assessment practices specifically for online programming and electronic design. By clarifying these competency domains, policymakers and educators are supported by accurate evaluation methods and gain insights when proposing strategies to foster programming education.

3.0 Methodology

Two phases are involved in developing the CDI for the assessment of online programming and electronic design in lower secondary schools. The first phase is about identifying the competency domains using the Nominal Group Technique (NGT). After identifying the competency domains in the first phase, the second phase develops the CDI based on expert feedback and reviews.

This study employed the NGT as the primary research methodology in the first phase. The technique was first developed in the 1970s as a consensus method (Atherton, 2016, Delbecq & Van de Ven, 1971). It is a structured approach that has been commonly used for solving problems, creating ideas and determining priorities (Shegaram et al., 2024, Kamarudin, et al., 2024, Mahmood, Zain & Zakaria, 2023). The NGT has of five steps. The process starts with the introduction of the NGT to the group and the delivery of the nominal question. Then, based on participants' independent thoughts, a process on the silent generation of ideas is conducted. Next, ideas are shared in a round-robin fashion without discussion. When the group exhausts new ideas, the participants start to clarify their ideas before further grouping similar concepts. Each participant votes to select the top-priority ideas using a ranking sheet. Finally, the scores for each idea are computed for further discussion to reach a final consensus. The NGT session was performed online. The session spanned approximately two hours and fifteen minutes and involved nine experts. The sample size in this study aligns with the recommendations of previous studies: Ven and Delbecq (1971) suggested 5–9 participants, Abdullah and Islam (2011) recommended 7–10 participants, and Harvey and Holmes (2012) proposed 5–9 participants. Four panel experts had a background in educational and curriculum development and held a doctorate degree. Three panel experts had a background in electrical and electronic engineering and also held a doctorate degree. Meanwhile, one panel expert had a background in computer science and a doctorate degree. Another industry expert had a master's degree. All the panel experts had more than five years of working experience.

After reaching a consensus, the study proceeded to the second phase: the development of the CDI. Based on expert discussions and reviews, this study proposed a process for calculating the CDI. Student performance should be visualised using a spider web chart to illustrate strengths and weaknesses clearly, thus enabling strategic planning for targeted improvements.

4.0 Findings

Findings from the analysis showed that all the domains achieved an optimal range with over 70% expert consensus. The domains were ranked and prioritised based on the total score of the voting by nine experts using a Likert scale with the following scores: 1 for extremely unimportant, 2 for unimportant, 3 for uncertain, 4 for important and 5 for extremely important. The summary of findings from the NGT is demonstrated in Table 1. Meanwhile, the individual vote is shown in Table 2.

Table 1. Suggested Domains with Prior Rank

No.	Items/ Domains	Total Item Score	Percentage (%)	Voter Consensus	Rank Priority
1	Understanding of electronic components	45	100.00	Accepted	1
2	Understanding of programming concepts	45	100.00	Accepted	1
3	Knowledge and understanding of circuit design concepts	45	100.00	Accepted	1
4	Application of circuit design skills	40	88.89	Accepted	3
5	Application of programming skills	45	100.00	Accepted	1
6	Ability to analyse basic electronic circuits	40	88.89	Accepted	3
7	Ability to evaluate the effectiveness of design solutions	38	84.44	Accepted	4
8	Ability to manage electronic design projects from conception to completion	41	91.11	Accepted	2

Table 2. NGT Voting Result

No.	Items/ Domains	Voter								
		1	2	3	4	5	6	7	8	9
1	Understanding of electronic components	5	5	5	5	5	5	5	5	5
2	Understanding of programming concepts	5	5	5	5	5	5	5	5	5
3	Knowledge and understanding of circuit design concepts	5	5	5	5	5	5	5	5	5
4	Application of circuit design skills	5	5	5	5	4	5	5	5	1
5	Application of programming skills	5	5	5	5	5	5	5	5	5
6	Ability to analyse basic electronic circuits	5	5	5	5	5	5	4	5	1
7	Ability to evaluate the effectiveness of design solutions	4	4	5	5	5	5	4	5	1
8	Ability to manage electronic design projects from conception to completion	4	4	5	5	4	5	4	5	5

Using the voting results from the previous step, the experts discussed and agreed with the CDI development process. The process involved several steps as follows. The first step involved arranging the competency domain based on the revised Bloom's taxonomy of cognitive levels. This arrangement was derived from the consensus of experts in the first phase. The domain was also closely related to the highlighted learning outcomes in the DSKP. The competency domains are shown in Table 3.

Table 3. Competency Domain with Cognitive Levels

Cognitive Level	Competency Domain
1: Remembering	Understanding of Electronic Components
2: Understanding	Understanding of Programming Concepts
2: Understanding	Knowledge and Understanding of Circuit Design Concepts
3: Applying	Application of Circuit Design Skills
3: Applying	Application of Programming Skills
4: Analysing	Ability to Analyse Basic Electronic Circuits
5: Evaluating	Ability to Evaluate the Effectiveness of Design Solutions
6: Creating	Ability to Manage Electronic Design Projects

Then, the second step involved assigning weights based on the cognitive level. The experts agreed with the proposed weights as shown in Table 4 but also suggested that the weights could be adjusted based on the specific needs of institutions. For example, high weights could be assigned to high cognitive levels because these weights reflect an advanced mastery of the topics. Tables 3 and 4 indicate that teachers can evaluate competencies within each domain using a scaled system. For instance, a scale from 0 to 4 can be used, where 0 represents no evidence, 1 indicates minimal evidence, 2 represents sufficient evidence, 3 signifies strong evidence and

4 represents advanced evidence. The fourth step involved calculating the weighted scores by multiplying each score by its corresponding weight.

Table 4. Suggested Weights for Different Cognitive Levels

Cognitive Level	Weight
1: Remembering	1
2: Understanding	1
2: Understanding	1
3: Applying	1
3: Applying	1
4: Analysing	1
5: Evaluating	1
6: Creating	1

Next, the weighted scores were normalised to a scale of 0 to 100, thus allowing for equal comparison across different competencies in the spider web chart. The formulas for calculating the normalised scores are provided in Eq. (1) and more specifically in Eq. (2).

$$Normalized\ Score = \left[\frac{Weighted\ Score}{Maximum\ Possible\ Weighted\ Score}\right] \times Normalization\ Factor \quad (1)$$

$$Normalized\ Score = \left[\frac{Weighted\ Score}{4}\right] \times 100 \quad (2)$$

where the maximum possible score for each domain is 4 points multiple with weight.

The next step was the computation of the CDI, which is a single but consolidated metric that represents the students' overall competency level. This index is the average of all normalised scores or the weighted average depending on whether all competencies are equally significant. In other words, the CDI provides a clear snapshot of the students' proficiency across domains.

Finally, the last step involved creating the spider web chart. In the spider web chart, each competency domain was represented by a different axis where the normalised scores from zero to 100 were plotted along each axis. The chart can provide a clear visualisation of students' performance across different competency domains. The strengths and weaknesses of the students are revealed, thus providing areas for improvement at different cognitive levels.

5.0 Discussion

Assessment has an essential role in the field of education because it evaluates the achievement of learning objectives and offers guidance for future improvements. In general, assessments have two types, namely, formative and summative assessments (Salleh et al., 2021). Formative assessments are performed during the learning process because it focuses on monitoring the learning progress, Meanwhile, summative assessments are usually conducted at the end of the learning period to evaluate the overall learning outcomes. Both types significantly influence the learning journey. However, several challenges, such as vague or subjective evaluation criteria and biases from assessors (Kwon & Ko, 2024), can hinder the fairness of evaluations, thus leading to results that do not accurately reflect students' actual performance. This study addresses these issues by proposing the development of a measurement tool called the CDI to improve the assessment of online programming.

During the first phase of the study, the brainstorming session resulted in eight domains for voting. For experts, the most important aspect is for lower secondary school students to master foundational domains, such as understanding electronic components, grasping programming concepts and having knowledge of circuit design principles as well as applying programming skills. The highest-ranked domains are all at a lower cognitive level, which may reflect the belief that mastering the basics is crucial at this stage. The ability to manage electronic design projects from start to finish ranks second and is followed by the application of circuit design skills and the ability to analyse basic electronic circuits. Among the eight domains, the ability to evaluate the effectiveness of design solutions received the fewest votes. When the students are young, this higher-level skill is less important than the foundational, lower-cognitive-level domains mentioned earlier.

The second phase focused on discussing the development of the CDI. Based on the consensus on the competency domains and reference to DSKP, the experts established a formula for calculating scores, which should be supported by evidence from students' work, such as assignments or tests. Furthermore, they suggested assigning different weights to cognitive levels. While the experts agreed that these weights could be adjusted to meet school requirements, they initially proposed equal weights for all cognitive levels. The experts believed that mastering each cognitive level at the lower secondary level was more crucial than excelling in higher cognitive levels even if the outcomes indicate strong subject mastery. The experts proposed using a spider web chart to provide an enhanced view of students' overall performance and their achievement for every competency domain. This chart offers a clear visualisation effect that can effectively highlight students' strengths and weaknesses. It also shows the areas for further improvement across the domains, thereby assisting teachers in planning targeted interventions for every student.

CDI can be computed in two ways. The first way computes the mean of all normalised scores, while the second way employs the weighted average depending on the relative importance assigned to each competency. All competencies are treated equally in the computation of the mean value, hence reflecting a balanced approach where every domain contributes equally to the final score. Meanwhile, the weighted average approach assigns greater significance to specific competencies that are deemed more important than others. This method ensures that the CDI aligns with the priorities of the curriculum or the desired learning outcomes. The CDI can be seen as a comprehensive indicator of a student's overall competency by synthesising data from multiple domains. The computed value offers educators and stakeholders with a concise snapshot of a student's proficiency across various domains. This structured approach not only supports fair assessment but also facilitates targeted feedback while highlighting areas of strength and further improvement. Hence, it fosters effective learning and student development.

The findings of this study offer valuable recommendations on the assessment guidelines or standards to improve current practices in evaluating online programming and electronic design. The proposed CDI is expected to improve the accuracy and comprehensiveness of the representation of students' competency levels. The improved visualisation using a spider web chart helps to support educators in several aspects, such as refining assessment practices, promoting consistency and ensuring fair evaluation standards for students.

6.0 Conclusion & Recommendations

This study gathered the consensus of field experts to develop a CDI to assess online programming and electronic design for lower secondary schools in Malaysia. By employing the NGT together with expert reviews, this work collected valuable feedback that highlighted ways to create a fair and effective assessment approach. The CDI uses a spider web chart to represent competencies visually. These competencies are arranged according to Bloom's taxonomy of cognitive levels using normalised scores for clarity.

However, the study has certain limitations. The findings are based on a small group of experts, which can introduce potential bias because of personal perspectives. Additionally, the NGT was conducted online instead of face to face because of the varied schedules and geographical locations of the experts. Despite these limitations, the NGT proved effective in gathering and summarising expert consensus to support the development of the CDI for online programming assessments.

Further study will focus on the validation of the CDI because a detailed evaluation of the CDI's validity and reliability has not yet been conducted. This examination will require a blend of qualitative and quantitative approaches to assess the CDI's robustness thoroughly. Future research can evaluate the CDI through various methods, such as piloting it with students, analysing correlations between CDI scores and those from other established assessments and using reliability measures, such as Cronbach's alpha. These steps will contribute to a comprehensive validation of the CDI, thus ultimately enhancing the effectiveness of the index as an assessment tool.

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Paper Contribution to Related Field of Study

The findings of this study aim to offer educators valuable recommendations that can serve as assessment guidelines or standards for evaluating online programming in lower secondary education. The proposed Competency Domain Index can provide an effective representation of students' competency levels.

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