

# IDENTIFYING AND QUANTIFYING INDUSTRY PERCEPTIONS OF ENGINEERING DRAWING SKILLS IN NOVICE MALAYSIAN ENGINEERS

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## ABSTRACT

To be effective, engineering drawings need to communicate information precisely and must ensure that a manufacturer can correctly interpret the presented information simply and unambiguously. As such, the manufacturer requires competent engineering staff when producing and interpreting engineering drawings. This paper reports on a survey completed to investigate the technical competencies of novice (graduate) engineers from the perspective of the manufacturing industry sector. The survey sought the views of engineering managers about both the competencies of current novice engineers and their expected competency for effectiveness within their workplace. The survey quantified anecdotal information provided by Malaysian colleagues. Survey questions were based on interviews with experienced Malaysian design and manufacturing engineers. 150 Malaysian industries were invited to participate in the online survey, of which 35 industries participated. The survey revealed that for all twelve issues investigated, there was a management perception that novice engineers have a lower competence than is management's expectation for the ability of current novice engineers. The survey participants identified the visualization of the three dimensional (3D) form of an object based on two dimensional (2D) drawing(s), and the interpretation of 2D drawings with interconnected parts as the competencies needing the most improvement in novice engineers.

*Keywords: Engineering drawing reading and visualization, Novice engineer competency, Malaysian manufacturing.*

## 1 INTRODUCTION

Engineering drawings are an important medium of communication in engineering. Of particular relevance to this paper is the quite common practice where a component or product is designed in one country, manufactured in a second country and possibly assembled in a third country. To avoid miscommunication among designers, manufacturers and assemblers, drawings must follow the rules set by national and international Standards and codes of practice. If a company is to effectively operate in a global product-manufacturing market, it will require expertise in the use of engineering drawings. In addition, different drawing preparation rules applied historically or geographically need to be identified and accommodated if costly errors are to be avoided. This is of critical importance for companies in developing countries such as Malaysia where manufacturing contracts are sought internationally.

The international Standard Organization (ISO) has an important role in setting worldwide rules for engineering drawings. Engineering drawings can be very complicated and there are many ISO standards to ensure that the information is transmitted correctly. The engineering drawing can also be considered a legal specification, where two companies can form a binding agreement based on a shared understanding of the component or product. The ISO standards are designed to be language-independent, so that a designer in one country can specify a product that can be successfully manufactured and assembled in another country without additional intervention by the designer.

National engineering (technical) drawing standards, including those from Britain (British Standards, including BS8888:2008); USA (ASME Y 14.5M) and Australia (AS1100:1992), are now mostly based on the ISO template but drawing rule variations remain (Figure 1).

The investigation reported in this paper was initiated by industry-based engineering colleagues in Malaysia who asserted (anecdotally) that graduate engineers had poor graphical communication skills. The authors completed an informal survey of experienced engineers and engineering managers in Malaysia to develop a deeper understanding of the specific issues of importance to them within the

broad discipline of engineering (technical) drawing. Information gathered from this informal survey was used to develop the questions asked in the formal survey of Malaysian engineering companies (See Appendix).

This paper reports on the perceptions of Malaysian engineering practitioners and managers about the relative importance of a range of engineering drawings skills, focusing on graduate engineers under their supervision.

The two-phase (informal, then formal) survey approach minimized the risk of important issues being neglected. The formal survey identified additional issues:

- Teaching undergraduate engineering students to have ongoing learning self-sufficiency is more important than teaching students specific technical drawing rules.
- It is vital to the development of a novice engineer that practical applications are incorporated throughout their undergraduate studies.

The outcomes of this paper form the basis of ongoing research into the efficient introduction of skills associated with reading and interpreting engineering drawings into existing undergraduate programs.

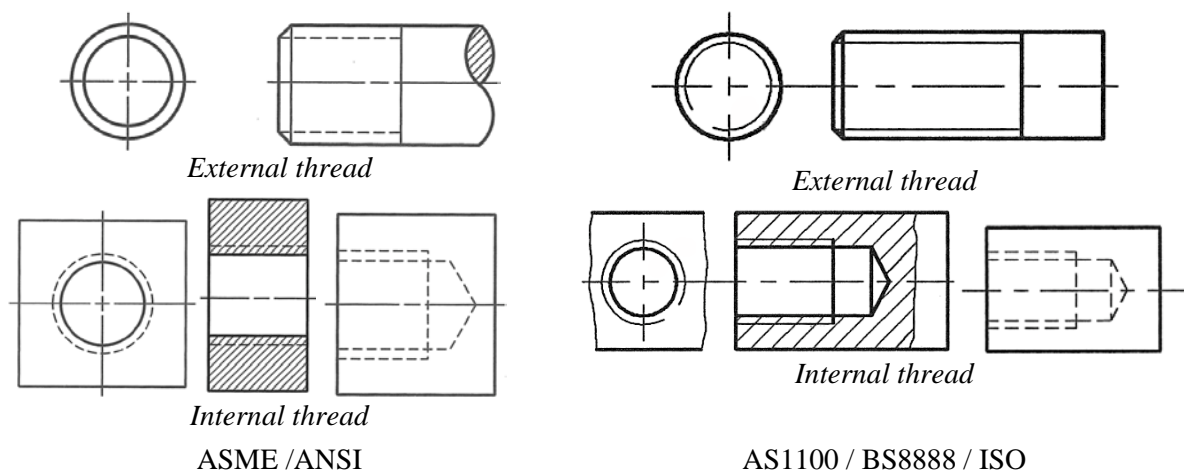


Figure 1. Subtle differences between standards – representation of threads.

## 2 BACKGROUND

The design engineer's skills and talents are widely used, example, in civil engineering [1], software engineering [2], construction project management [3] and technical project managers [4]. Crain et al [5] categorized engineering design competencies as:

- Communication – reading, writing, speaking, listening, drawing, graphing
- Teamwork – structure, team interaction, commitment
- Process Improvement – define, manage, assess, improve processes used in design
- Information Gathering – sources, access, selection
- Problem Definition – goal statement, criteria, constraints
- Idea Generation – method selection, creativity, synthesis
- Evaluation and Decision Making – analysis, testing, methods for decisions
- Implementation – planning execution, completion of plan

Robinson et al [6] identified principal design engineer competencies as: role-specific technical; competencies associated with motivation; the use of intelligence to solve problems and make decisions; teamwork; management and leadership of others; communication; planning and management of projects and resources; innovation; and, strategic awareness of the wider business and customer context. Both categorizations recognize that the communication of technical concepts is highly important if the design engineer is to be effective.

The authors have completed an investigation into how well recently graduated (novice) engineers employed within the manufacturing sector in Malaysia are able to work with engineering drawings. The investigation focused on the needs of the sector itself by surveying engineering managers. The survey sought to discover managers' perceived skill level of novice engineers for a range of specific engineering drawing related skills. It also sought their expectation about how important each of the specific skills is within their organization. The survey findings are reported in this paper.

### 3 SPATIAL ENGINEERING SKILLS

Bertoline et al [7] state that many engineering curricula do not allocate time to the advancement of spatial ability, despite it being an essential for engineering skill. Engineering students are typically given little or no formal instruction in the use and development of spatial abilities. Mathewson [8] observed that educators do not teach visual-spatial thinking. Engineering texts frequently present static, orthogonal views of concepts, theories and ideas with little or no explanation of how to interpret the spatial information. In addition, paper-based technical materials rarely foster developmental growth of spatial abilities. Educators normally assume that the student will be able to make the mental leap, piecing together the spatial puzzle.

Engineering students have been shown to have difficulties comprehending engineering drawings [9]. Spatial skills also play a role in student responses to unstructured design problems [10], complex design problems [11], and the correct interpretation of machine design concepts [12]. Moreover, engineering students can struggle in design-based courses while excelling in technical or mathematical focused studies [13]. The reverse situation has also been observed where students with average technical skills excel in design-based courses [9]. This is perhaps because the brain's right hemisphere is required in design problem-solving, for example, to facilitate creativity, holistic problem solving, visualization and intuition [14].

Design requires synthesis skills, i.e. the capability to integrate knowledge from different domains such as mathematics, sciences and technologies, engineering disciplines and humanities [15]. However, the usual engineering pedagogical practice of teaching topics separately [13, 16, 17] does not support the development of these synthesis skills and rarely includes any discussion or exercise on how topics (domains) interrelate [13]. Field [14] concluded that a student's spatial skill and their comfort in making assumptions are important factors in predicting their design performance.

The importance of spatial visualization skills was highlighted in the commission report to the U.S. Departments of Labor and Education that identified "Seeing things in the mind's eye" as a foundation thinking skill [18], summarized in Table 1. The skill was needed to interpret pictorial representations, for example, "sees" a physical object or a system's operation from viewing an engineering drawing.

*Table 1. Secretary's Commission on Achieving Necessary Skills (SCANS), after [18].*

<b>SCANS</b>	<b>Foundation Thinking Skill description</b>
Level 5	Visualizes objects or processes from mathematical or scientific concepts and prepares a visual or verbal representation. From output data/information, visualizes processes or systems and identifies potential problems or malfunctions.
Level 4	Combines visual or verbal representations of an object or process obtained from different sources to create a three-dimensional mental picture. Visualizes yet-to-be-realized objects or processes and prepares a visual or verbal representation. Visualizes internal components and operations of machines or systems and predicts outcomes. Completes a mental picture from incomplete information.
Level 3	From a two-dimensional representation or a verbal description of an object or arrangement of objects, or a process or sequences of activities, creates a three dimensional mental picture. Mentally operates or manipulates components of an object. Visualizes exact details of a specific object to distinguish from others. Mentally coordinates objects in a space with regards to size, color, function, and visual presentation.
Level 2	From a two-dimensional representation of an object or arrangement of objects, creates a two-dimensional mental picture with regards to obvious features that distinguish objects from one another, and the spatial relationship between objects. Uses mental picture to recognize the exact object in the future or to create the spatial arrangement of the objects. Manipulates a mental picture two dimensionally to make alterations to the spatial relationship of objects.
Level 1	By seeing a basic or familiar object, create a two-dimensional mental picture of the object with regards to basic shape and color. Uses mental picture to recognize similar objects in the future.

## 4 ENGINEERING DRAWING

An engineering drawing is a document that provides an accurate description of an engineered artifact [19]. Baartmans and Sorby stated, “*a standard drawing layout typically includes the top, front, and right-side views of the object (from the viewer’s perspective, the right side is determined by looking at the front of the object), as well as an isometric or corner view of the object*” [20]. Engineering drawings provide essential information to manufacturing personnel: the precise dimensions, shape, and placement of each feature of a component. The American Design Drafting Association (ADDA) asserted that every object that is manufactured has an engineering (or technical) drawing that preceded it. An error in an engineering drawing can be very costly to an organization [19]. For example, defective product recalls waste materials, and machine, tooling and operator time.

Roorda [21] reports that there are two main kinds of engineering drawings, orthographic and pictorial. From the viewpoint of the designer or drafting technician, their creation can occur in two different ways: interpreting the pictorial drawing to make orthographic drawings, or interpreting the orthographic drawings to make a pictorial drawing. The latter process integrates a series of different views into a single spatial image. This task can be difficult, as integration of a series of different views into a single spatial image requires the correct interpretation of the views. Correct interpretation of a drawing involves visualizing the geometrical form (artifact) and the spatial layout of the object portrayed [21]. An engineering drawing must fully outline and illustrate the artifact to be constructed from it using as many views as needed to fully describe the artifact. Standard views describe how a construction seems from in front (elevation), above (plan), from the sides and possibly with additional auxiliary views. Tolerances ensure that manufacturing personnel are aware of the acceptable range of sizes, shapes and positions that a feature can take with reference to the underlying function specified by the designer.

## 5 SURVEY – METHOD

Malaysia has a strong interest in attracting multi-national manufacturing industries. As such, engineers with advanced abilities in reading and interpreting sophisticated engineering drawings are essential. A survey was initiated from anecdotal concerns from Malaysian colleagues about the reading and interpreting abilities of domestic graduate (novice) engineers.

Survey questions were based on the results of interviews completed with four experienced Malaysian design and manufacturing engineers. Interviewees were also engineering managers who had worked with or managed novice graduate engineers.

All interviews were audio recorded and fully transcribed. The transcripts were then analysed to elicit relevant indicators [22, 23]. At all stages within this analysis phase, similar indicators were clustered [24].

The interviews identified twelve issues that formed the basis of the main questionnaire that included twenty-four issue-based questions. A Likert scale was used for each of the questions where survey participants had five alternative choices for each question: “highly agree”, “agree”, “neutral”, “disagree” and “highly disagree”. The Cronbach coefficient ( $\alpha$ ) was used to measure internal consistency and the reliability score of the survey outcomes.

The survey sought the views of engineering managers about both the competencies of current novice engineers and their expected competency for effectiveness within their workplace. One hundred and fifty Malaysian industries were invited to participate in the survey online survey. A total of 35 completed questionnaires were returned for analysis.

## 6 SURVEY – INTERVIEW AND RESULTS

The results of the investigation to identify and quantify industry perceptions of engineering drawing skills in novice Malaysian engineers are reported in the following sections: interview and survey questionnaire results and analysis.

### 6.1 Interview results and analysis

This section contains a summary of the discussion and outcomes of interviews conducted with four experienced Malaysian design and manufacturing engineers who had also worked with novice engineers. All interviewees were adept in the use of engineering drawings. Typical expert comments are identified by italicized quotations. The clustering of various matters of interest resulted in twelve significant issues.

**Issue 1 “Understanding 1st angle projection” and issue 2 “Understanding 3rd angle projection”**

An orthogonal engineering drawing can be ambiguous if no projection is specified. In Figure 2, the reader would find it impossible to decide at which end of the cylinder a square hole and a circular hole are located, without additional information. Understanding the difference between first and third angle projection in orthogonal drawings would enable the ambiguity to be identified and an error prevented. Otherwise, an incorrect assumption could be easily made by a novice engineer.

One respondent said: “They don't really understand the 3rd angle and 1st angle projection, they just draw/design it regardless. But if they already used 3D software, they don't have to mind too much because the 3D software will do it for them.”

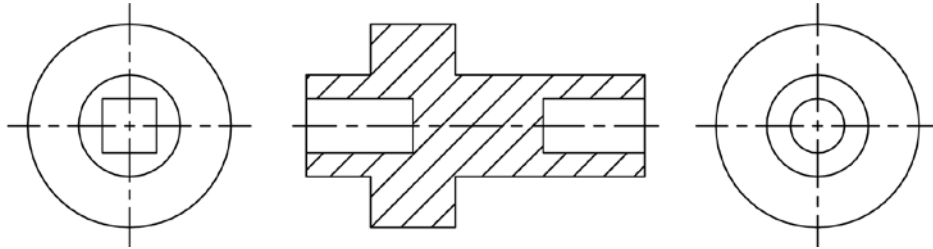


Figure 2. Example of issues 1 and 2. This orthogonal engineering drawing is ambiguous unless it is specified as being drawn using either first angle or third angle projection.

**Issue 3 “Interpreting two dimensional (2D) drawings with interconnected parts for example general assembly drawings”**

There is a perceived lack of ability in novice engineers to be able to identify and interpret the parts associated with 2D assembly drawings (Figure 3 shows an example image of this type). Industry-based engineers expect novice engineer to appreciate the three-dimensionality and associated function of a single-view assembly drawing. However, the authors postulate that novice engineer need to understand the technology or the functional relationship of the interacting parts before this is possible. For example, in Figure 3, the handle (part 4) rotates the integral cam to move the jaw (part 1) to the left. The compressive spring (part 10) resists this motion. The novice engineer requires experience with the functional components (i.e. handle, cam, jaw, spring) and their representation in an engineering drawing to be able to infer assembly function.

“To interpret drawing.... this is a common problem to these people, especially for a complicated drawing. They might take hours to understand, this time, the imagination must be very high. If it's low, they will interpret the drawing wrongly, which will become a problem also. The imagination that I meant was, to visualize the object from the existing drawing”.

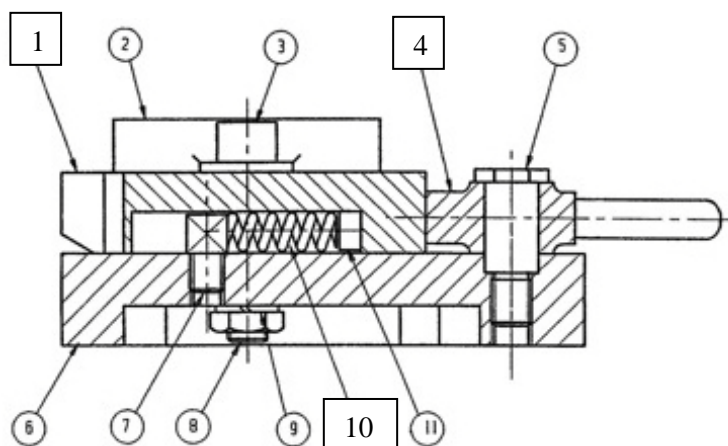


Figure 3. Example of issue 3. A sample assembly drawing with only one view.

**Issue 4 “Visualizing the three dimensional (3D) form of an object based on a two dimensional (2D) drawing.”**

Experienced Malaysian design and manufacturing engineers thought graduates found it difficult to visualize and interpret a physical object when only provided with a 2D image: “...problem with how

far this part goes. What move in respect to what? Or what should be assembled first?. Simple assembly drawing they probably can interpret easily (this is normally example during study ) ... but when come to a real situation ... assembly design may consist a lot of parts and much more complicated....”

Figure 4 is part of a sample test that has been used to measure a subject’s ability to interpret in 3D.

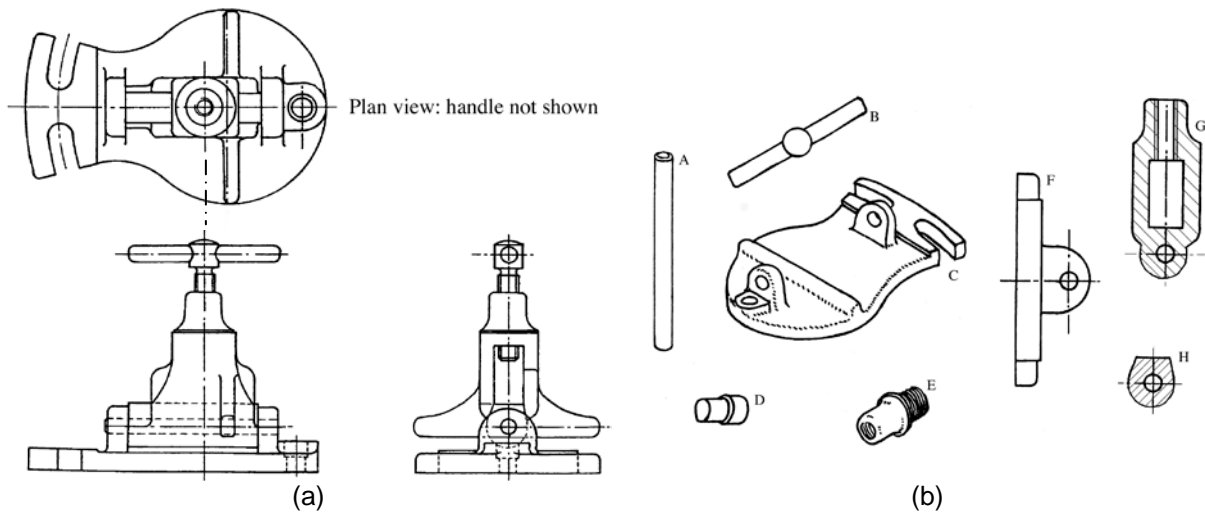


Figure 4. Example of issue 4. A sample test to determine whether subjects can perceive the three dimensionality of 2D images. Figure 4a (left) shows an assembly drawing of a clamp in third angle projection. Figure 4b (right) shows eight sketches of a range of labeled components. The subject is asked whether each of the sketches represents a valid view or section of a clamp component.

**Issue 5 “Fully understanding the symbols in engineering drawings related to Geometric Dimensioning and Tolerancing (GDT), for example, angularity, flatness, cylindricity”.**

Graduate engineers were found to have difficulties with geometrical dimensional tolerance symbols, in particular, those with a similar appearance but different meanings (examples in Figure 5). “The symbols in [a] drawing, what people call geometric tolerance and dimensioning, this is a bit more difficult, but very important, like the symbols of position, co-planarity, all must be understood.”

Type of tolerance	Characteristics to be tolerated	Symbol	Datum needed	Applications
Form	Roundness		No	The periphery of a circle. Cross-section of a bore, cylinder, cone or sphere.
	Cylindricity		No	The combination of circularity, straightness and parallelism of cylindrical surfaces. Mating bores and plungers.
	Profile of a line		No	The profile of a straight or irregular line.
	Profile of a surface		No	The profile of a straight or irregular surface.

Figure 5. Example of issue 5. Samples of abstract symbols for GDT with similar appearances.

**Issue 6 “Visualizing three dimensional (3D) lines, such as in design work involving drawings that represent a complex piping system.”**

Visualizing a 3D interconnected network (specifically from interview, the design of piping networks, such as in Figure 6) with reference to only a 2D layout drawing was identified as a significant issue.

“In the design work involving piping, I watch my student previously; it’s really difficult to imagine 3D lines, like if you look at it from the top, front, and side views ... I’ve done a project before with a Japanese chap; this chap has an excellent imagination skill/energy/intuition even though he hasn’t draw it using the software, he can imagine how the pipe goes through, without hitting other parts (e.g. piping in air condition box outside the house).”



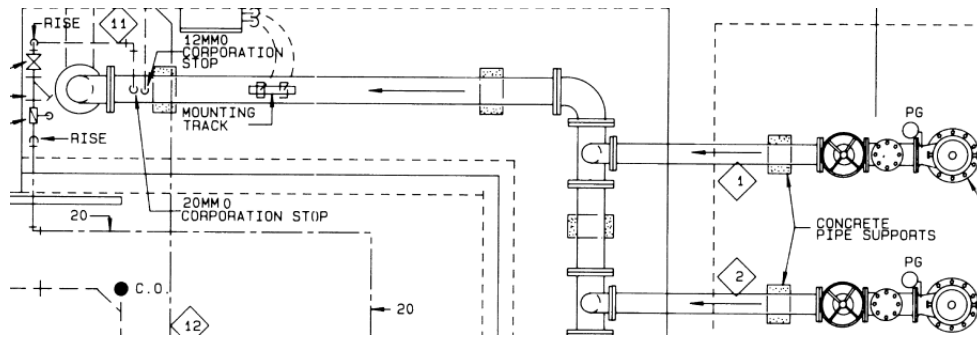


Figure 6. Example of issue 6, showing part of a piping layout drawing.

**Issue 7 “Understanding the concept of hidden lines, and their function in engineering drawings.”**

Hidden lines are not banned but discouraged in the Australian drawing standard where it is recommended that appropriate sectioned views be used to avoid need for hidden lines in orthogonal drawing. Hidden lines can introduce ambiguities, where for example in Figure 7, the features being identified by the (dashed) hidden lines could be readily misinterpreted. In addition, the dashed internal thread representation in the ASME standard (Figure 1) could readily be misinterpreted as a hidden shoulder feature. “Problem on reading hidden lines is also the same, when they read the drawing wrongly, then finally the object they want to build will be wrong.”

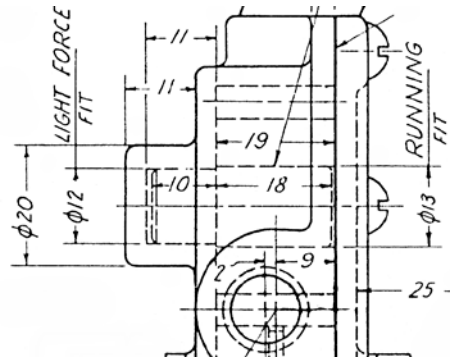


Figure 7. Example of issue 7, showing how ambiguity can arise from the use of hidden lines.

**Issue 8 “Understanding drawing scale and using it appropriately.”**

The scaling of physical objects enables their representation in engineering drawings. An inability by novice engineers to use scaling correctly (whether in creating a drawing or attempting to interpret information) was reported by the interviewed engineering managers. “Another one is the drawing scale in especially when drawing 2D especially they just ignorantly putting the dimensions without following the scales, so the drawing itself become wrong.”

Figure 8 shows a simple example where the combination of a dimension (cylindrical diameter of 10 mm) combined with a scale factor of 1:5 can result in the erroneous interpretations, such as represented in Figure 8(c) and 8(e).

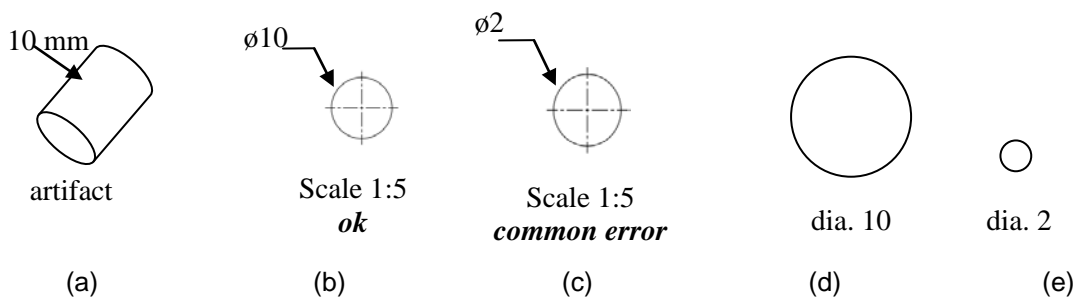


Figure 8. Example of issue 8, where (d) represents the intended interpretation from (b) and (e) represents an incorrect interpretation associated with (c)

**Issue 9 “Identifying design faults by checking the drawing, for example, by completing an interference check.”**

Interviewed engineers thought that novice engineers lack the ability to identify design faults associated with part manufacture and design assembly through inspection of engineering drawings (for example, Figure 9). “Not doing drawing check, especially during assembly, when they assemble thousands of components, sometimes we can’t see that the design got stacked among themselves, so before we approve any design, we have to do interference check first, so that there’s no problem of unable to be assemble when we produce it later.”

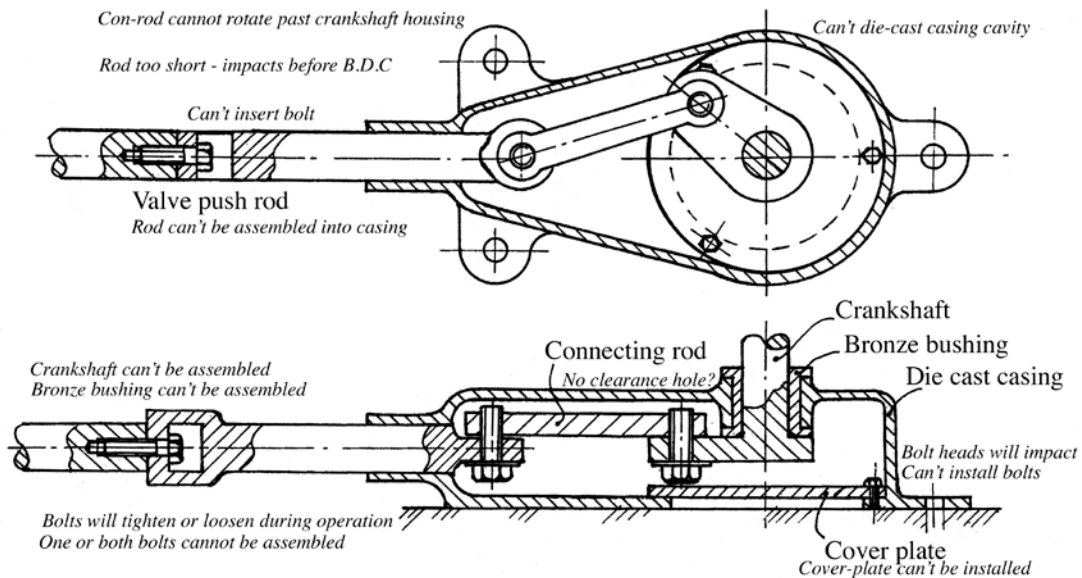


Figure 9. Example of issue 9, showing an assembly drawing of a machine that is impossible to manufacture and assemble, and will not function as required (*italicized text*).

**Issue 10 “Identifying drawing errors by checking the drawing, for example, by identifying missing lines or missing dimensions.”**

Care is needed when constructing 2D orthogonal drawings. Otherwise, gross manufacturing errors can result from seemingly minor drawing errors. For example, Figure 10 shows two 3D images of alternative parts that in their 2D representations differ by only one line segment. There is also the risk of ambiguity or confusion associated with drawing symbols. For example, it would be easy for a naïve person to misinterpret the centre-line in Figure 10(a) as corresponding to a fully revolute 3D object – Figure 10(b) – and not a cylinder with two planar surfaces – Figure 10(c). Experienced engineers were concerned about the novice engineer’s ability to recognize subtle differences between drawing representations.

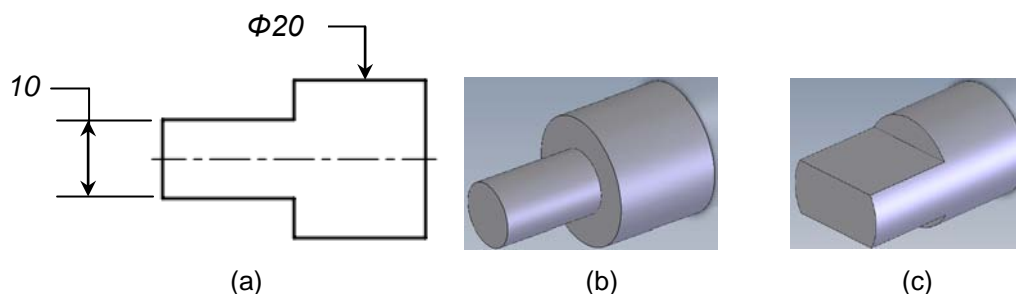


Figure 10. Example of issue 10, where (a) can be misinterpreted as (b) when it is actually (c).

**Issue 11 “Creating 3D CAD models” and issue 12 “Assembling 3D CAD models”**

Graduate engineers were found to have difficulties when using Computer Aided Design (CAD) to create complex parts and assemblies.

Comments from the interviewed engineers included: “Another critical one is in [CAD] assembly time, if they do machine design, the part is quite simple, like plate, but it has many holes, but when they want to assemble it they have a problem”, “people will give drawing in 2D ... that’s usual



...everywhere it is all 2D drawings ... then we will visualize and draw 3D ... but the problem [is that] in [the] 2D drawing there will be many layers ... imagine if there are 1000+ component to assemble, even though the parts are simple ... like plate design with same holes... if they don't know how to interpret the drawing which are on stacked (overlaps) they will assemble wrongly, then there will be design interference ... or hole which is supposed to align (to assemble the screw) ... but not aligned."

### Summary of Issues identified from interviews

The preceding sections have identified the twelve principal issues associated with reading and interpreting engineering drawings that were forthcoming from interviews conducted with experienced Malaysian engineers.

## 6.2 Online survey results and analysis

The twelve issues were used as a basis for twenty-four of the twenty-eight questions in the subsequent online survey seeking the opinions of Malaysian industries about the relevant competencies of current novice engineers and their expected competency for effectiveness within their workplace. The survey questions are included in the Appendix, where each issue being questioned is identified numerically in the third column, and the corresponding SCANS levels [18] in the fourth column. Issue-based questions also include an alpha-code: "P" corresponds to a question seeking the perception of the responder, and "E" corresponds to a question seeking the expectation of the responder. One hundred and fifty Malaysian industries were invited to participate in the online survey, of which 35 responded. All respondents had supervised graduate engineers. The distribution of supervisory experience of the respondents was: 9% for less than 1 year, 26% for 1-3 years, 24% for 3-5 years, and 41% for more than 5 years.

A sample of the survey structure is shown in Figure 11, where participants choose one of five options between "Highly Disagree" and "Highly Agree". Questions 1 to 3 enabled the authors to assess whether the survey responder was within our sought population. Question 28 sought insights from the responder, especially issues that had been omitted from the survey.

Figure 12 shows the mean perceptions and mean expectations. For all 12 issues, the differences between all the expectations and their corresponding perceptions were positive, indicating that survey responders consider novice (graduate) engineers need to be more proficient at reading and interpreting engineering drawings. The survey demonstrates a need within the Malaysian manufacturing sector for improved educational outcomes for engineering students in graphical communication.

**4. My graduate engineers understand the concept of third angle projection.**

1   2   3   4   5

Highly Disagree      Highly Agree

**5. I require my graduate engineers to understand the concept of third angle projection.**

1   2   3   4   5

Highly Disagree      Highly Agree

Figure 11. Sample questions from the online survey.

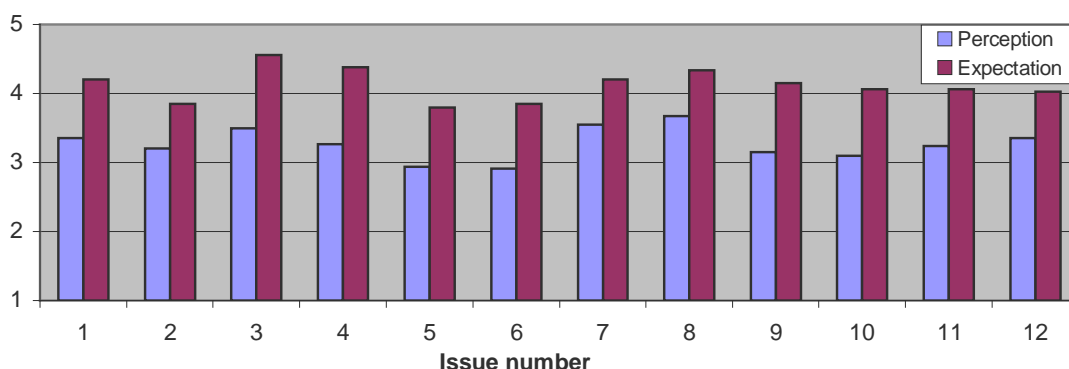


Figure 12. Mean survey responder perception and expectation scores for each of the twelve issues.

The mean difference between expectation and perception scores, a measure of the deficiency of novice engineer ability (Figure 13), was highest for issue 4 (Visualizing the 3D form of an object based on a 2D drawing) and lowest for issue 2 (Understanding third angle projection). None of the issues resulted in a negative difference, (representing an abundance of novice engineers' ability!). The non-sequential ranking of issues in Figure 13 offers a strong indication that survey participants were attentive and identified issues of important to them.

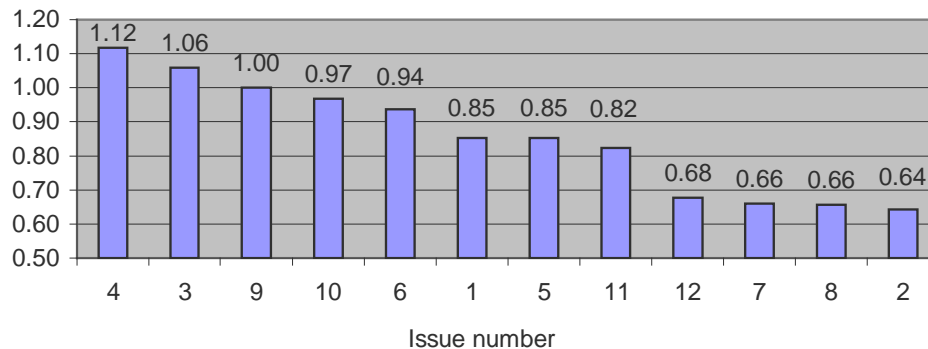


Figure 13. Pareto chart of mean difference between scores of Expectation and Perception for each issue.

Question 28 of the survey invited participants to comment on their experiences in supervising graduate engineers in relation to working with engineering drawings (Appendix). Most respondents' comments were related to one or more of the issues identified in section 6.1.

However, some interesting issues were mentioned that had not been raised in the earlier interview phase. Four comments related to three issues not identified in section 6.1 were:

- Teaching undergraduate engineering students to have ongoing learning self-sufficiency may well be more important than teaching students specific technical drawing rules.  
*“Not teach them all the skills...they must learn and do research to acquire the skills”*
- It may well be especially important in the development of a novice engineer that practical applications, with associated engineering drawings, are incorporated throughout their undergraduate studies. .  
*“I think they lack of exposure on real application of the engineering drawing. They learn the engineering drawing since in the first year, but, they unable to apply what they learn for the following years.”* More exposure to both reading and producing engineering drawings is the apparent recommendation of a second responder: *“They are pretty good but the need more practice. Train them and train them hard. :)”*
- Engineering training should also lead to some expertise in 2D CAD.  
*“My roles basically require my subordinate to be able to prepare 2D drawings in MS Visio. No details as CAD software able to produce [what] is really required.”*

## 7 CONCLUDING REMARKS

This paper demonstrates that there are perceived deficits in the training of graduate engineers in Malaysia with respect to reading and interpreting engineering drawings. Malaysia is one of many economically developing countries that receives much direct foreign investment by multinational companies such as Honda, Proton (Mitsubishi), Perodua (Daihatsu), Naza (Kia), Modenas (Kawasaki), Shell, Esso, Sharp, Samsung and Dell. The globalization of manufacture requires that engineers in Malaysia be able read engineering drawings created elsewhere in the world. Malaysian undergraduate engineering programs follow fairly conventional international procedures, but because Malaysian engineering graduates may need to interact with an unusually wide range of standards it is valid to ask the question: “should there be something special about the way that engineers are educated in Malaysia?” This question was the basis for undertaking the research. The outcomes reported in this paper have initiated a research a program to investigate the effect of frequent exposure to students of engineering drawings in an analytical course, to explore the possible learning benefit that this exposure might create, without extending or otherwise altering the overall undergraduate program.

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## APPENDIX: Survey of supervisors of novice engineers

#	Question	Issue	SCANS level
1.	Have you ever worked in a job where you supervise engineers and these engineers have to read and interpret engineering drawings?		
2.	If yes, how many years have you worked in the supervisory position?		
3.	Briefly explain your subordinate's duties. E.g. creating and modeling engineering objects, checking engineering drawings, creating manufacturing preparation layout or process planning, operating or maintaining machines, overseeing assembly operations, selling (i.e. sales engineer).		
4.	My graduate engineers understand the concept of third angle projection.	1P	2,3
5.	I require my graduate engineers to understand the concept of third angle projection.	1E	2,3
6.	My graduate engineers understand the concept of first angle projection.	2P	2,3
7.	I require my graduate engineers to understand the concept of first angle projection.	2E	2,3
8.	My graduate engineers can easily interpret two dimensional (2D) drawings with interconnected parts e.g. general assembly drawings.	3P	3
9.	I require my graduate engineers to interpret two dimensional (2D) drawings with interconnected parts e.g. general assembly drawings.	3E	3
10.	My graduate engineers can easily visualize the three dimensional (3D) form of an object based on a two dimensional (2D) drawing.	4P	3
11.	I require my graduate engineers to visualize the three dimensional (3D) form of an object based on a two dimensional (2D) drawing.	4E	3
12.	My graduate engineers fully understand the symbols in engineering drawings related to Geometric Dimensioning and Tolerancing (GDT), e.g. angularity, flatness, cylindricity.	5P	4
13.	I require my graduate engineers to fully understand the symbols in engineering drawing related to Geometric Dimensioning and Tolerancing (GDT), e.g. angularity, flatness, cylindricity.	5E	4
14.	My graduate engineers can easily visualize three dimensional (3D) lines, such as in design work involving drawings that represent a complex piping system, such as inside an air conditioning box.	6P	4
15.	I require my graduate engineers to visualize three dimensional (3D) lines, e.g. in design work involving drawings that represent a complex piping system, such as inside an air conditioning box.	6E	4
16.	My graduate engineers fully understand the concept of hidden lines, and their function in engineering drawings.	7P	2
17.	I require my graduate engineers to understand the concept of hidden lines, and their function in engineering drawings.	7E	2
18.	My graduate engineers fully understand drawing scale and use it appropriately.	8P	2
19.	I require my graduate engineers to understand drawing scale and use it appropriately.	8E	2
20.	My graduate engineers can identify design faults by checking the drawing, e.g. by doing an interference check.	9P	5
21.	I require my graduate engineers to be able to see design faults.	9E	5
22.	My graduate engineers can identify drawing errors by checking the drawing, e.g. identify missing lines or missing dimensions.	10P	
23.	I require my graduate engineers to be able to identify drawing errors.	10E	
24.	My graduate engineers can easily create 3D models of parts in a CAD system.	11P	4
25.	I require my graduate engineers to be able to create 3D models of parts in a CAD system.	11E	4
26.	My graduate engineers can easily assemble CAD models of parts they draw or receive from other sources.	12P	5
27.	I require my graduate engineers to be able to easily assemble CAD models of parts they draw or receive from other sources.	12E	5
28.	Do you have any relevant comments about your experience of supervising graduate engineers in relation to working with engineering drawings?		

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