INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED23
24-28 JULY 2023, BORDEAUX, FRANCE

# THE T-SHAPED DESIGN ENGINEER – USING COHORTS TO EXPLORE HOW SKILLS PROFILES DIFFER THROUGH CAREER STAGES

**Dekoninck, Elies;**
**Bridge, Liam**

University of Bath

## ABSTRACT

The T-Shaped designer has previously been identified as a design engineer with the desirable set of skills for a successful career. Twelve design engineers ranging from novice to expert, were interviewed to gain an understanding of their skill set, how it has evolved and how it needs to evolve in order to be futureproofed. With the use of qualitative, quantitative data and the development of a novel engineering skills profiling method, this paper found that 75% of design engineers did not exhibit a T-shaped skill profile, but a skill shape that has been termed 'M-shaped' or 'Comb-shaped'. The majority of participants exhibited a great depth of specialist skills in multiple disciplines, not limited to their immediate field of work. All participants exhibited a wide knowledge of skills that allowed them to work across different disciplines, which included electronics, management or manufacturing, and so the wide vertical bar of the T-Shape design predicted by previous literature has been supported.

**Keywords**: Design education, Training, Teamwork

**Contact**:
Dekoninck, Elies
University of Bath
United Kingdom
e.a.dekoninck@bath.ac.uk

**Cite this article:** Dekoninck, E., Bridge, L. (2023) 'The T-Shaped Design Engineer – Using Cohorts to Explore How Skills Profiles Differ through Career Stages', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.354

## 1 INTRODUCTION

The aim of this research is to investigate the T-shape model to understand the skills and requirements of design engineers, how they evolve throughout a career, and how requirements for engineering design skills need to evolve to futureproof an engineering design career. In this research, design engineers are defined as those engineers in industry whose role focuses on the research and development of ideas for new products and systems, or the redesign of products and processes to improve their performance. The 'T' is the visual representation of the knowledge and skill that a design engineer arguably should possess to be desirable to today's companies. Companies such as IDEO, Google, Apple and Toyota (Hanson 2010; Tranquillo, 2013) have all previously identified this skill structure as desirable. It is important to understand how these skill sets evolve, whether this is the correct way of looking at these skill sets, and what can be done to aid the development of a desirable skill set. This paper reports on a research activity and semi-structured interviews with novices, intermediates, and experts within design engineering to understand the differences in the skill sets they possess and how these might typically evolve throughout a career in design engineering.

### 1.1 Introduction to the T-shape skills concept

In the T-shape model, the vertical bar represents the deep knowledge the designer holds in a certain field, whereas the horizontal bar represents the breadth and familiarity of other fields as well as 'soft skills' which allow the designer to collaborate in less familiar remits. One of the first mentions of the T-shape metaphor was in The Independent, where David Guest (1991) following Palmer's study (1990), wrote; "This type of rounded personality is also sought in other branches of the same theory, which prizes individuals known as T-shaped People". The new term was coined most evidently in design engineering by Tim Brown the CEO of design firm IDEO (Hansen, 2010). Brown refers to the T-shaped skill set as the most desirable for designers. A number of other high-profile companies have also publicly acknowledged the T-shaped designer as 'part of their DNA' as identified by Tranquillo (2013). Tranquillo's pedagogical research has directly tackled T-shaped skills within the education sector with the intention of initiating change to reflect the skill set in engineering. Tranquillo describes the ideal engineer's T-shape skill set as "technical depth (STEM) as well as cross-disciplinary breadth (TOP)". Robotham et al. (2013), identify two desirable t-shaped pathways for the education of design engineers.

It has also been debated in a number of industries whether a T-shape is fit for purpose. Various different alternative models have been proposed, such as I-shaped, A- or Pi-shaped along with M- or Comb-shaped models. Leonard-Barton (1995) argued that a Pi-shaped skill set would have technical expertise within two disciplines and able to converse between the two seamlessly. Others, such as Buxton (2009) have argued that the I-shape has seen the most success within a variety of industries and environments. Although previous authors have discussed the value of these models as a theoretical construct, we have not found any work which gathers data to populate practitioners' T-shapes. This study aims to test these models, apply data to these claims, and understand which model best fits the skill set of a design engineer.

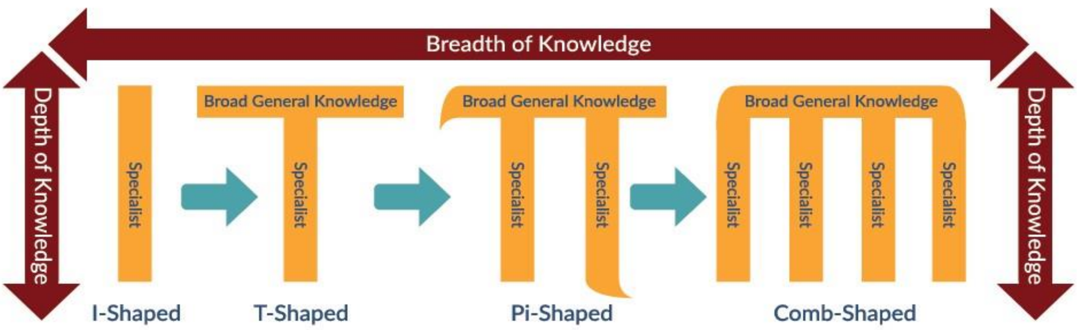


*Figure 1 - DevOps Institute. From I-Shaped to T-Shaped – Why DevOps Professionals Need to be Multi-Skilled (https://devopsinstitute.com/2017/11/15/from-i-shaped-to-t-shaped-why-devops-professionals-need-tobe-multi-skilled/).*



https://doi.org/10.1017/pds.2023.354 Published online by Cambridge University Press

## 1.2 Novice vs Expert

Although there has been little research into the T-shaped design engineer and the development of such skill sets, there has been extensive coverage of expertise in design and the transition from novice to expert, notably by Nigel Cross (2007; 2011) and Cross et al. (1994).

This research builds on the current understanding of expert and novice design engineers' skill sets and investigates if they can be linked with the T-shaped model. Previous literature has not developed an understanding of how the cross-disciplinary attributes of design engineers - such as skills in manufacturing, materials, electronics, software, business and supply chain - change through a career. Whilst we do know that having knowledge beyond a specialist area of expertise can aid design activities. In the longer term, the research aims to bring together previous knowledge and new cross-discipline understanding to model the desirable shape for a design engineer's skill set, whilst concurrently understanding how novices can best gain this skill set.

# 2 RESEARCH METHODS

Data was collected from three cohorts, novice (N), intermediate (I) and expert (E). Given that a large amount of research indicates that expertise in a certain field is gained through 10 years of dedicated work within that field (Kaufman & Kaufman, 2007; Syed, 2010) this definition was used to define the cohort of experts in this research. Novices are defined as students from the University of Bath studying Integrated Design Engineering or Mechanical Engineering, have chosen specialist design modules in their final year of study, and have experienced one year of work in industry. The intermediate cohort was comprised of those professional design engineers with less than 10 years' experience in industry. Table 1 briefly summarises those interviewed. More than 12 hours of interview audio was fully transcribed, creating over 90,000 words of transcribed text. Interviews lasted an average of 1.05 hours and included on average 584 data entries in the thematic analysis stage.

*Table 1 - Anonymised description of research participants.*

| ***Participant*** | ***Years' Experience*** | ***Level of Education*** | ***Job Description*** |
|---|---|---|---|
| *N1* | 1.5 | 5th Year Mech Eng UG | Previous experience in medical devices FMCG for a product design consultancy as well as automotive parts. |
| *N2* | 1 | 5th Year IDE UG | Previous experience with medical device development. |
| *N4* | 1 | 5th Year IDE UG | Previous experience in medical devices, FMCG and sports products product design consultancy. |
| *N5* | 1.5 | 5th Year Mech Eng UG | Previous product design experience for an automotive manufacturer. |
| *I1* | 6 | MEng | Currently Design Manager for a small company in the construction and agriculture industry. Previous design and testing experience at larger company. |
| *I2* | 9 | MEng | Self-employed design engineer with previous experience with medical devices in product design consultancy. |
| *I3* | 5 | MEng | Senior Engineer & Associate at product design consultancy focusing on medical and consumer products. |
| *I4* | 4.5 | MEng | Senior Mechanical Engineer at product design consultancy focusing on medical and FMCG products. Previous experience in the automotive industry |
| *E1* | 31 | PhD Engineering | Principle Mechanical Engineer in the medical sector and Associate Professor in Higher Education doing research and teaching |
| *E2* | 25 | MA Engineering | Engineering Manager International R&D in the furniture design and manufacture industry |
| *E3* | 12 | MEng | Project Engineer supplying systems and equipment to the automotive industry. |
| *E4* | 18 | MEng | Head of Systems Engineering in the defence and security industry with previous experience in medical and consumer devices, aerospace design and simulation. |



https://doi.org/10.1017/pds.2023.354 Published online by Cambridge University Press

The initial semi-structured interview questions were designed to gain a greater understanding of the level of expertise of the participant within engineering design. Information gathered from these questions allowed comparison of how a design engineer's experience or the position within the company/business may affect their results, as well as allowing comparison between different stages in their career or with differing experiences within engineering design.

The participants were then handed 47 randomly organised cards, each of which had a skill printed on one face. The skills collection on the cards was compiled using the UKSPEC (Engineering Council, 2013) as an underlying framework, and UK universities' engineering course content was used to create the complete collection. The framework and the skills can be seen in Table 2. After selecting these skills, the participant was asked if there were any additional skills, they wanted to add. They were informed that they could add any skill, no matter how specialist or broad.  Using the skills that the participant chose from this part of the interview, the participant was asked to do the following for each skill:

- give the skill a score from 1 to 10 as to how proficient they are at the skill they selected (a 1 represents a very basic, systems-level understanding of the skill, and 10 is an 'industry leading' understanding of the skill or area);
- describe how often the skill is utilised by themselves;
- give a brief example as to when they have used the skill in their engineering design work.

The participant was then asked to sort the skills they had in their set into two categories; specialist (skills that they believed that they had specialised in over their career) and multi-disciplinary (more general skills that could be utilised across any engineering design discipline or project). Finally, there was a stage of further questioning and reflection on highly-scored skills in order to verify an adjust their initial selection, identification and scoring.

*Table 2 - Table of engineering, design and interpersonal skills - developed from UKSPEC and UK Universities' taught skills.*

| | | | | | | |
|---|---|---|---|---|---|---|
| **Fundamental Engineering Design Skills** | Mechanical Design | Systems Design | Structural Design | | | |
| **Specialist Sector Specific Design Skills** | Automotive Design | Robotics Design | Medical Design | Aerospace Design | | |
| **Specialist Design Skills** | UI Design | UX Design | Sustainable Design | Control Systems Design | Material Design | Electronic Design |
| **Dynamic / Fluid Analysis** | Fluid Flow Analysis | Aerodynamic Analysis | CFD | Thermal Analysis | Vibrations / Noise Analysis | |
| **Static / Structural Analysis** | FEA | Structural Analysis | Mechanical Analysis | Material Analysis | | |
| **Practical / Manufacturing Skills** | Practical / Workshop Skills | Manufacturing | Rapid Prototyping | | | |
| **Design Communication Skills** | CAD | Communication | Technical Drawing | Presentation Skills | Report Writing | |
| **Creative Skills** | Problem Solving | Creative thinking | Concept / Sketching | | | |
| **Software Skills** | Coding | Programming | Software Development | | | |
| **Interpersonal/Personal Skills** | Teamwork | Individual Work | Responsibility | | | |
| **Management Skills/Leadership** | Negotiation | Leadership | Conflict Management | Management | Time Management | |
| **Business Skills** | Economic Analysis | Business Analysis | | | | |
| **Mathematics** | Mathematics | | | | | |

The aim was to use the data collected to build individual skills profiles. Figure 2 shows how the specialist skills would be represented on the lower bars of the illustration and multi-disciplinary skills would be represented by the uppermost bars. The skill scores would be used to determine the 'depth' of specialist skills and the 'height' of the multi-disciplinary skills. The related specialisms would be clustered together to enable the exploration of whether Pi-, M- or Comb-shaped profiles might emerge.



https://doi.org/10.1017/pds.2023.354 Published online by Cambridge University Press

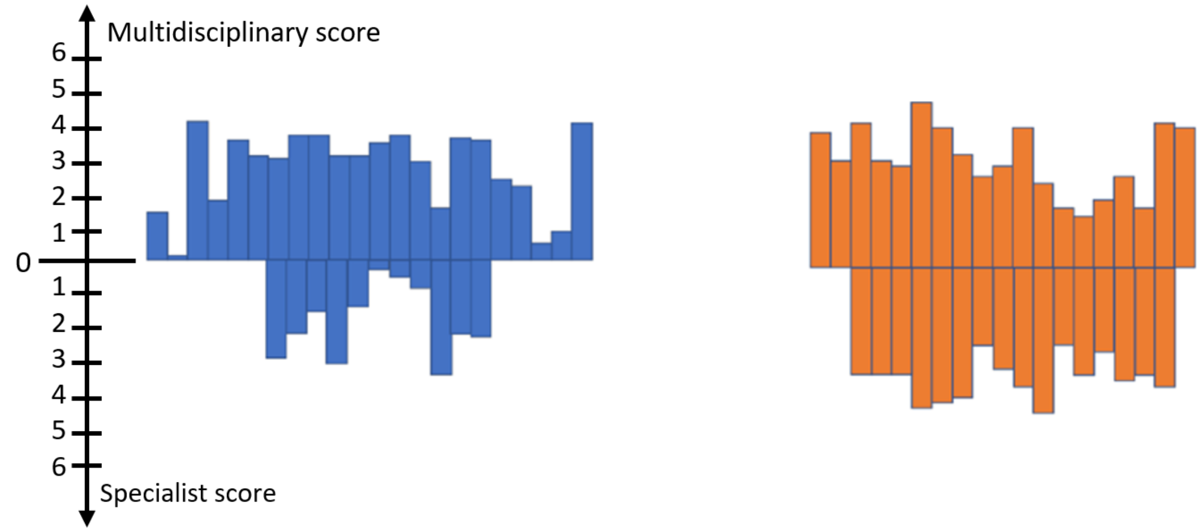


*Figure 2 - Representation for the individual profiles developed during a pilot stage (results from 2 pilot participants shown).*

During the test period, it became apparent that individuals would often score two skills identically. However, when asked how often they utilised the skills, this would differ. It was decided that these skills should not have an identical score. Therefore, a utilisation adjustment was designed to allow for this. Depending on the wording they used: a score was given, from 1 to 5 dependent on how often they used the skill. An example for a skill being scored 5 would be for a skill being used on a daily basis.

The second adjustment to the scores given by participants was for self-assessment bias. Four skills were identified that had been chosen by all of the twelve participants. These also included a significant depth of information from each participant, and would therefore be suitable to carry out a comparison (moderation) of skills scores between participants. The four skills used for this were: CAD, Mechanical Design, Rapid Prototyping and Responsibility. Objective mark schemes, using Choulier and Weite, (2011) as a framework, were compiled to moderate the variance of participants self-reported skill levels. This self-assessment bias scoring adjustment was subject to an interobserver reliability check with 2 additional researchers, which scored >90% agreement across each of these 4 skills score adjustments.

Using the utilisation and bias adjustments described above, the size (i.e. the height or the depth) of each of the skill bars for each of the participants was calculated using the following:

$$\lambda = \alpha - \left(\frac{5-\beta}{\alpha}\right) - \eta$$

$\alpha$ = Proficiency Score
$\beta$ = Utilisation Score
$\eta$ = Self-Assessment Bias
$\mu$ = Weighted Score
$\lambda$ = Final Skill Competency Score

# 3 RESULTS

This section presents the results of the engineering skills profiling across our three cohorts. The thematic analysis of the interviews, which was carried out separately in NVivo as part of the research, is not presented in this paper, but was used to give context for the results.

## 3.1 T-shaped models - skills scoring results

Table 3 collects the initial data findings which show how the participants' years of experience increase the average number of skills chosen from the pack of cards in the interview procedure (novices 30.75, intermediates 34.50 and experts 38.25). Table 3 also identifies the number of 'additional skills' added by each participant and the percentage of skills that the participants classified as specialist. As expected, the percentage of skills typically labelled as specialist also increased with experience (novices 34.52%, intermediates 37.13% and experts 41.68%)



https://doi.org/10.1017/pds.2023.354 Published online by Cambridge University Press

*Table 3 - Participant interview data - skills chosen.*

| Participant | Years of Exp. | Skills Chosen | Specialist Skills | % Specialist | Additional Skills Added |
|---|---|---|---|---|---|
| **E1** | 31 | 41 | 13 | 31.71% | 4 |
| **E2** | 25 | 40 | 15 | 37.50% | 4 |
| **E3** | 12 | 35 | 19 | 54.29% | 4 |
| **E4** | 18 | 37 | 16 | 43.24% | 1 |
| **Average** | | **38.25** | **15.75** | **41.68%** | **3.25** |
| **I1** | 6 | 31 | 9 | 29.03% | 2 |
| **I2** | 9 | 37 | 14 | 37.84% | 2 |
| **I3** | 5 | 40 | 14 | 35.00% | 3 |
| **I4** | 4.5 | 30 | 14 | 46.67% | 1 |
| **Average** | | **34.50** | **12.75** | **37.13%** | **2.00** |
| **N1** | 1.5 | 35 | 8 | 22.86% | 2 |
| **N2** | 1 | 30 | 14 | 46.67% | 0 |
| **N4** | 1 | 30 | 12 | 40.00% | 0 |
| **N5** | 1.5 | 28 | 8 | 28.57% | 2 |
| **Average** | | **30.75** | **10.50** | **34.52%** | **1.00** |

Using the engineering skills profiling method described in section 2, the data from the twelve participants were input and each individual's profile was created and studied. The full collection of the skills profiles is shown in figure 3.

The initial analysis highlighted that there are different types of profiles evident within the cohorts. It showed that Expert 1 (E1) did not have the same skill profile as the other experts, as the specialist design skills are much smaller in comparison. The same can be argued for Intermediate 1 (I1) compared to other intermediates. Their specialist skills may be smaller than peers, but their multi-disciplinary skills on average scored higher and they also had more of those skills in number. From the full interview it was clear that this was due to their positions and practise within their engineering design industries. E1 played a large managerial role within their company, is also working in the educational sector and has almost 10 more years experience than the expert cohort average. I1 has a similar managerial position for a much smaller company. During their interviews, E1 and I1 spoke a lot more about the management of projects and business, as opposed to the direct engineering applications and skills. Therefore, these two participants could be argued to possess a more managerial skill set which would explain the acquisition of more multi-disciplinary skills. The same findings could be made about Novice 1, for the skill set exhibited by this participant is very similar to that of E1 and I1, but with less depth. The structure is however dissimilar to other novice results with respect to the depth of specialist skills identified. These three have been placed to the right side of figure 3 to show them as a unique type of design engineer. For the numerical results shown in Table 4, E1 was omitted (as being a strong outlier) from the results but N1 and I1 were retained within their respective groups.

A similar observation from this data, was that Intermediate 2 (I2), with 9 years of experience within engineering design has a skill set similar to that of the experts. The depth of specialist and multi-disciplinary skills is greater than that of other intermediates, and are of similar value and composition to the experts. This is potentially due to the significantly larger number of years' experience of I2 compared to those of other intermediates interviewed who had very similar years of experience (4.5, 5 and 6 years). This participant is also very close to the 10-year threshold to be placed in the 'expert' cohort. Previous literature has argued that the acquisition of expertise after 10 years is an average and therefore can be achieved in less time than this (Kaufman & Kaufman, 2007; Syed, 2010). For the purpose of exploring the differences between cohorts, and with 9 years of experience, it was decided it was better to include I2 in the expert cohort.



https://doi.org/10.1017/pds.2023.354 Published online by Cambridge University Press

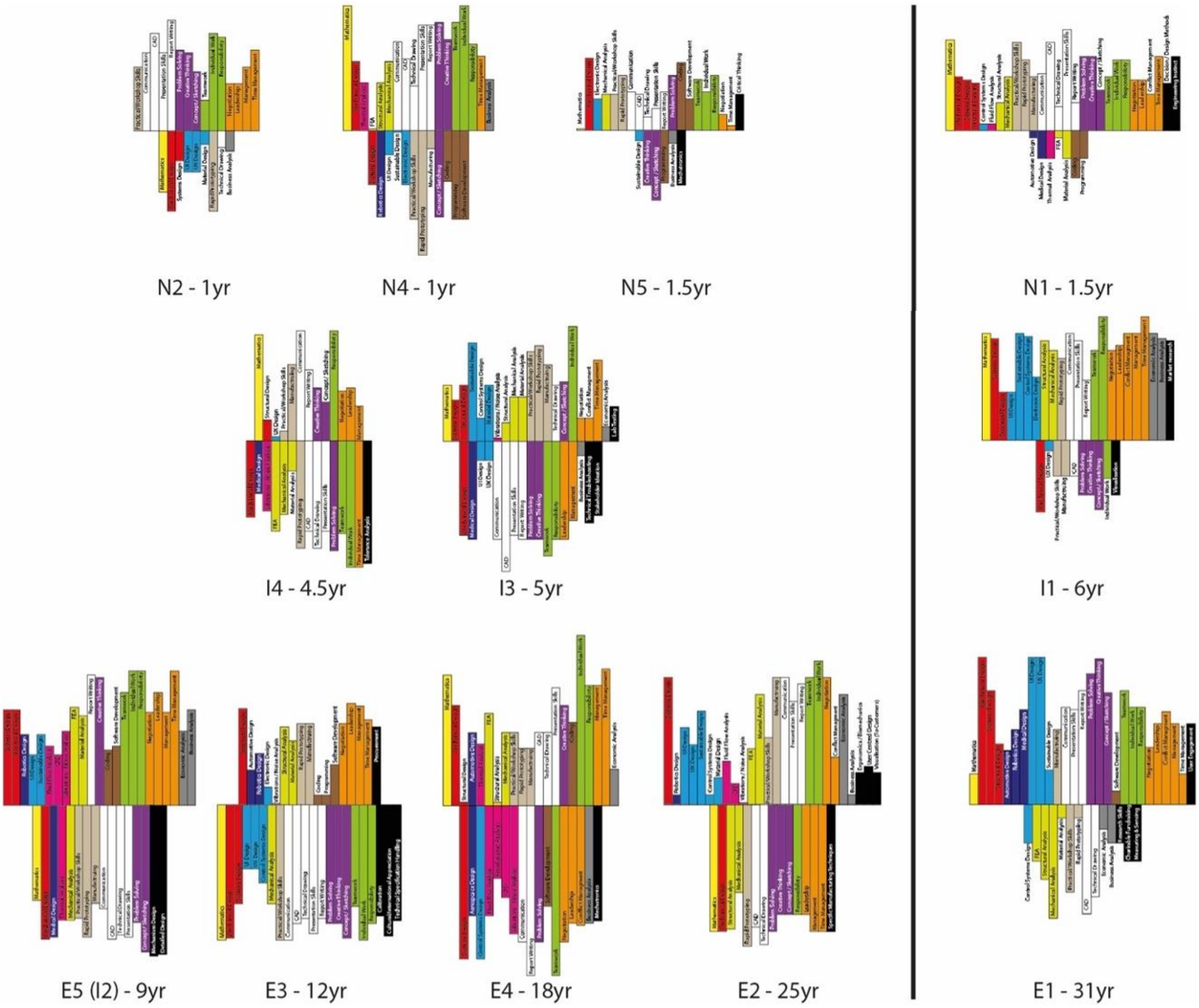


*Figure 3 - Visual overview of design engineering skill profiles following the initial analysis of the cohorts.*

These small adjustments in the layout of the data set are shown in figure 3 in order to explore the development of a T-shaped skill set between career stages. Firstly, the significant difference in the size of the profiles between the three groups is identified (both in terms of the numbers of skills they selected and the length of the bars indicating the skill competency score. The increase in size of skills between the novice cohort and the other two groups is noticeably greater than the difference between intermediate and expert groups. The variation in the skill types within the novices' sets is greater, when compared to those in industry (intermediates and experts). This could in part be attributed to the complex and large variation in students identified by Adams et al. (2003).

The scoring data also helps to characterise the evolution of both specialist and multi-disciplinary skills as years of engineering design experience increases. Table 4 illustrates the increase of average specialist and multi-disciplinary scores, from 2.6 to 6.21 and 3.66 to 4.66 respectively, from novice to expert. This increase in specialist skills follows previous conjecture that an increased depth of specialist skills is a component of a desirable design engineer (Hanson, 2010). However, due to this being an average of all specialist skills, it is not possible to draw a conclusion as to whether this indicates a specialism in one or more areas, therefore this data on its own cannot support the claim for a T-shaped designer.



https://doi.org/10.1017/pds.2023.354 Published online by Cambridge University Press

*Table 4 - Average multi-disciplinary and specialist scores of the re-arranged cohorts.*

| Participant | No. MD | No. Spec | Avg MD Score | Avg Spec Score |
|---|---|---|---|---|
| N1 | 28 | 7 | 3.34 | 1.48 |
| N2 | 15 | 9 | 4.40 | 2.56 |
| N4 | 18 | 12 | 4.71 | 3.82 |
| N5 | 20 | 6 | 2.19 | 2.55 |
| | **20.25** | **8.5** | **3.66** | **2.60** |
| I1 | 23 | 10 | 5.61 | 6.72 |
| I3 | 22 | 16 | 2.86 | 5.48 |
| I4 | 13 | 15 | 3.38 | 5.46 |
| | **19.33** | **13.67** | **3.95** | **5.89** |
| E1 | 27 | 14 | 5.35 | 3.49 |
| E2 | 26 | 16 | 4.25 | 7.27 |
| E3 | 17 | 22 | 3.56 | 6.80 |
| E5 (I2) | 23 | 17 | 5.48 | 7.27 |
| | **23.25** | **17.25** | **4.66** | **6.21** |

Intuitively, the longer you have been in engineering design, the more you have used the skill, have been exposed to different situations where the skill is utilised and therefore it is unsurprising that the level of skills in intermediates is much higher than that of novices. In addition to this, the average number of specialist skills chosen by participants also significantly increased with experience, from 8.5 to 13.67 and then to 17.25 for experts. This increase in specialist skills chosen, supports the argument that an design engineer develops a 'comb' or 'M-shaped' model, not T-shaped. In the transcripts, the experts also identified themselves as having a deeper and specialist knowledge in a wider range of areas which would be considered multiple 'stems' as identified by Tranquillo (2013).

Using the average score for specialist skills we can show the typical evolution of the depth of specialist knowledge and skill acquisition between novices and those who are practising in industry (Figure 4). This plot shows the sharp increase in specialist skills knowledge during the first years that a design engineer works in industry, and how these skills scores flatten off in the experienced cohort.

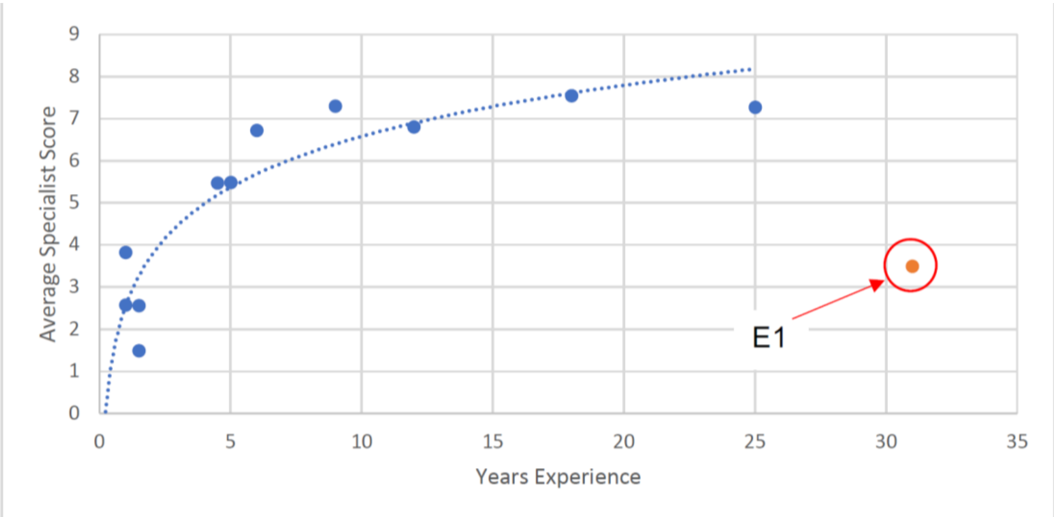


*Figure 4 - Average specialist skill score against years of experience.*

Figure 5 shows the proportion of skills within each skill group that were selected by each cohort. A skill group is defined by the first column in Table 2 and is also reflected in the colour of the bars used in profiles in figure 3. The graphic does not represent the score given to that skill, only that the skill was chosen by the participants. For example, the top brown line shows that all cohorts selected all of


https://doi.org/10.1017/pds.2023.354 Published online by Cambridge University Press

the Interpersonal/Personal skills cards as part of their interview (Teamwork, Individual Work and Responsibility).

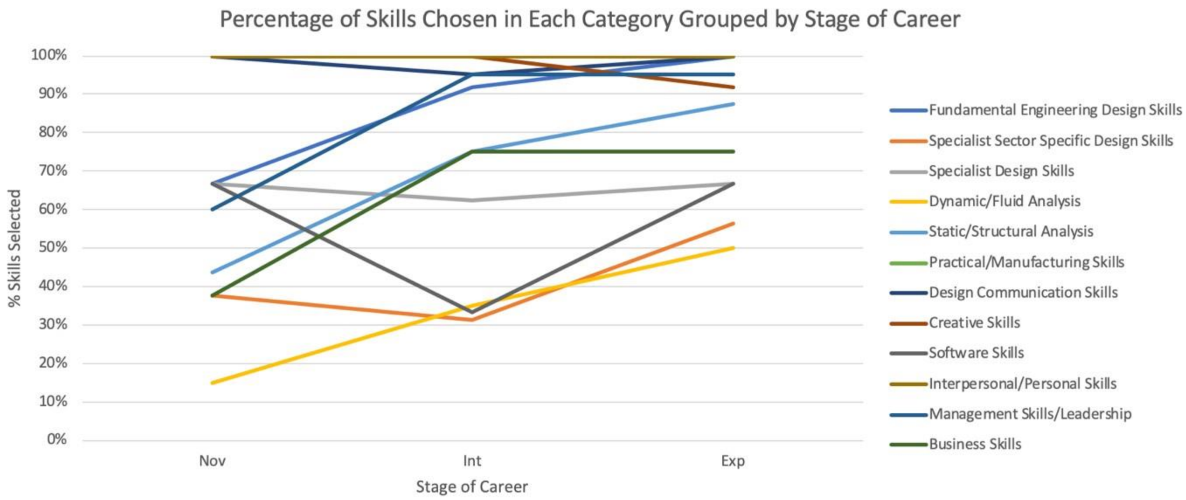


*Figure 5 - Graphical illustration of the selection of different skill groups with experience.*

The graph may help to identify skill groups that are improved throughout the career of a design engineer. This includes 'Fundamental Design Engineering Skills' which increased on average from 60% to 100% selected. Other skill sets that follow this increasing trend are 'Management & Leadership Skills', 'Static/Structural Analysis', 'Dynamic & Fluid Analysis' and 'Business Skills'. Further analysis of this data highlights that there are a group of skills that can be identified as the core skills acquired by expert design engineers, where 90% of them were selected by the expert cohort. These include the following: Interpersonal / Personal Skills; Design Communication Skills; Fundamental Engineering Skills; Creative Skills; and Management / Leadership Skills.

## 4 CONCLUSIONS

This paper aimed to explore the differences in the skill sets between novices, intermediates, and experts, and how these might typically evolve throughout a career in design engineering. Theoretically, the T-shaped skill profile would emerge in practice through working across multiple disciplines within engineering design. However, the findings from this study show that this is not the most common skill structure in design engineering. The most common skill structure is M-shaped, having multiple deep specialisms and also a broad familiarity of other skills that can be used across multiple disciplines. This allows design engineers to work in multiple specialist areas closely related to their role, but also allows them to fluently communicate with other disciplines outside of their remit. The use of the profiling method produced insightful data which showed that the level of understanding of knowledge and skills increases with experience. It is also useful to identify the ways in which design engineers perceive their specialist skills, as they evolve throughout their career. As an engineer's experience increases, design communication skills along with personal, interpersonal and management skills all become more specialist and grow significantly in depth.

### 4.1 The limitations and reflections

It must be noted that due to the number of participants used, these are initial findings and further work is being done to challenge these claims using a much larger sample group. A more accurate study of the evolution of a design engineer would be to follow individuals and carry out the same profiling technique over a large time period. In other words, a large-sample longitudinal study would be needed. Taking into consideration the time limitations in this research, this cohort-based method was chosen and developed to at least be able to explore skills profiles in different career stages. How closely it was able to mimic data from a longitudinal study will have to be seen by conducting a longitudinal study and making comparisons.



https://doi.org/10.1017/pds.2023.354 Published online by Cambridge University Press

Full thematic analysis was conducted on the extensive interview transcripts. This data is very insightful, but still needs to be reported formally. Initial promising findings include:

- the size of the business and the types of industries (sectors) the design engineers were exposed to also affected their skills profiles, with those in smaller companies and working across multiple industries exhibiting a more T-shaped skills profile;
- the futureproofing of engineering design skills was found to be just as important in experts as it is in novices.

The final reflection worth mentioning is that multiple participants found that taking part in the research activity was very useful because it helped them understand their own skills better. One participant even suggested that the research activity could be used as a tool for the purposes of the participants' career development. It may be possible, to construct a study where peers assess each other's skills to create accurate profiles.

## REFERENCES


Adams, R.S., Turns, J. and Atman, C.J. (2003), “Educating effective engineering designers: The role of reflective practice.” *Design studies*, 24(3), pp.275-294. http://doi.org/10.1016/S0142-694X(02)00056-X

Buxton, B. (2009) Innovation Calls for I-Shaped People.” *Business Week*. Insight Section.

Choulier D., Weite P. A. (2011), “A Coherent and Discriminating Skills Standard for Innovative Design.” Laboratoire M3M, University of Technology Belfort Montbeliard, France. *International Conference on Engineering Design, ICED11*.

Cross, N (2007), “From a Design Science to a Design Discipline: Understanding Designerly Ways of Knowing.” *Design Research Now* (Essays and Selected Projects) pg. 28-41.

Cross, N, Christiaans, and H, Dorst, K. (1994) “Design Expertise Amongst Student Designers.” *Journal of Art & Design Education*. Volume 13, No.1. Pg. 39-56

Cross N. (2011), *Design Thinking, Understanding How Designers Think and Work,* Oxford: Berg.

Engineering Council (2013) *UK STANDARD FOR PROFESSIONAL ENGINEERING COMPETENCE: Engineering Technician, Incorporated Engineer and Chartered Engineer Standard*.

Guest, D. (1991), “The hunt is on for the Renaissance Man of computing”. *The Independent*.

Hansen, M T. (2010) “IDEO CEO Tim Brown: T-Shaped Stars: The Backbone of IDEO’s Collaborative Culture.” Found at: https://chiefexecutive.net/ideo-ceo-timbrown-t-shaped-stars-the-backbone-of-ideoaes-collaborative-culture__trashed/ (First Accessed 7/11/18)

Kaufman S., Kaufman J. (2007), “Ten Years to Expertise, Many More to Greatness: An Investigation of Modern Writers. *Journal of Creative Behavior*.” Learning Research Institute, California State University at San Bernardino, Department of Psychology

Leonard-Barton, D. (1995), “Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation.” Harvard Business School Press.

Palmer, C. (1990), “‘Hybrids’ — a critical force in the application of information technology in the nineties”, *Journal of Information Technology*, Volume 5.

Robotham, A.J., Raine, J.K., Nates, R.J. and White, D.E., (2013), “Reflections on the challenge of developing professional engineering designers and engineering design technologists - A New Zealand perspective.” In *International Conference on Engineering Design - ICED13*.

Syed, M. (2010), *Bounce, The Myth of Talent and The Power of Practise*. HarperCollins UK, http://doi.org/10.1123/iscj.2014-0066

Tranquillo, J. (2013), “The T-shaped Engineer: Connecting the STEM to the TOP.” Bucknell University. *120th ASEE Annual Conference & Exposition*. June 23-26.





https://doi.org/10.1017/pds.2023.354 Published online by Cambridge University Press