XXVII-th International Scientific and Technical Conference Automation of Discrete Production

ADP - 2018

21-24 June 2018

Sozopol, Bulgaria.

An evaluation of technical drawings training needs for developing new training methods

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Abstract — In this research, the results of an international needs analysis study conducted to determine the requirements of teaching principle concepts used in manufacturing and assembly drawings are evaluated. Particularly, in order to form an infrastructure for new teaching methods, supported by VR / AR applications. Initially, the stakeholders were identified, parameters and methods were determined. An online survey with 320 participants was carried out by a team of researchers in Turkey, Bulgaria and UK. The survey addresses three different categories. The first category covers Perception of Technical Drawing Education, second category assesses Technical Drawing Knowledge and Ability, finally third category covers Expectations about Technical Drawing Education.

An important result of the study is that there is a significant deficit in all stakeholder groups that may not be possible to address by the traditional teaching methods of Technical Drawing Education.

Keywords*— Technical drawings, engineering drawings, technical training, need analyses*

1. Introduction

Technical Drawing (TD) describes the final state of a product's material, size, shape, tolerance and other dimensions, describing how the product will be manufactured, and so on. It can be described as the technical alphabet of the design in terms of providing easy, accurate way of communication between the designers and engineers. Concerns by higher education institutions McLaren (2008) and industry about the demise in standards of technical drawings produced by students, and workplace recruits due to a lack of understanding of basic geometric construction and the conventions of drafting skills that underpin this practices have challenged the traditional teaching strategies used during the last years. Meyers (2000) states that technıcal drawings have evolved significantly as a result of the introduction and broadening of 3D tools as a key teaching component in the design process. Azevado (2009) identifies the need to develop instruments to make qualifications comparable and help skills be better recognised, studying the European Qualification Framework (EQF) and the Accreditation Board for Engineering and Technology (ABET).

Torres et al., (2015) categorised the theories of drawing as disturbing, passionate, philosophical and technical in which some utilise on the methods, others are based on systematic, pedagogical and psychological experiences. Instructors can choose among the wide range of methods that have been proposed to match the particularities of their subjects. However, less attention has been paid to the opinion of the students on the effectiveness of each methodology, although it is a key element in identifying which methods are more effective to achieve the goal of deep learning (Vidal et al., 2017). Deficiencies of technical reading skills are often covered through theory-based educational programs at Vocational or Engineering Schools. However, for technical drawing lessons, theory should be integrated with practical experience as TD has proven especially important in the production phase, and as the nature of skills required are strongly dependant on the manufacturing requirements. In this context, educational institutions in collaboration with manufacturing partners should develop joint educational programs for innovative new teaching methods; not only relying on a lecturer's ability to engage student participation, but on different strategies aimed at fostering deep learning through the active involvement of the students to use correct TD practices. Field (2004) proposes that the basic TD foundations cannot be replaced, and that its teaching should include the development of the necessary level of spatial reasoning. This is supported by the work of Leopold, Gorska and Sorby (2001) that suggest that the physical nature of the drafting experience develops a deeper understanding of the meaning of lines and symbols on a page and helps to develop the ability to make mental conversions into 3D realities.

The integration of new technologies and strategies such as VR/AR applications into the 3D Design phase of product development is becoming widespread to meet demands for faster and efficient new product development together with social encouragement. Kaufmann and Dünser (2007) investigated the use of an educational augmented reality application. They summarise three evaluations of an educational AR application for geometry. Repeated formative evaluations with more than 100 students guided the redesign of the application and its user interface throughout the years. The research discusses the usability, issues with VR sickness by providing guidelines on designing augmented reality applications with head-mounted displays. Arslan and Uzaslan (2017) stated that some firms have applied different in-house TD training models to keep up with new technological innovations in their specific fields. They investigated how a target-oriented in-house TD training programme should be developed and evaluated for effectiveness. The aim of their study was to develop, implement and evaluate a competency-based and target-oriented TD training programme with the cooperation of both the academic and the automotive industrial sectors. An important result of this study, according to performance analyses, 26% of the participants had improved their performance relative to an untrained cohort when a target orientated TD training programme was implemented.

In this study, the results of an international needs analysis of TD training requirements conducted to determine the subject areas lacking in teaching the concepts of basic and advanced standards and principles used in manufacturing and installation of TD drawings are evaluated. The team includes multidisciplinary international researchers from academic and commercial engineers, designers, software developers. As stated by Kleinsmann and Dong (2007), interdisciplinary research is key for successfully delivering innovative solutions where efficient communications between the team members bring a shared understanding about the content. Therefore, communication and interaction among interdisciplinary members during new teaching strategy development content can be enhanced by having a common understanding in the use of representations as stated by Pei et al., (2011).

2. Materials and Methods

A rigorous stake holder analysis from internal and external partners has been carried out in order to develop an understanding of the needs and opportunities for influencing within the given context. Stakeholder analysis of the internal and external partners of the subject has been carried out in terms of the needs analysis. Stakeholder analysis is the process of the assessing a decision's impact on relevant parties where the information is used to assess how the interests of those stakeholders should be addressed in a project plan, policy, program in this case development of the AR/VR contents. The analysis helped identify issues of TD teaching and learning in educational environments.

2.1. Stakeholder analysis

Stakeholder analysis has been carried out to determine requirements of the content and strategies to be developed within the scope of the study for all parties involved with TD. The following questions were used to determine the stakeholder's requirements:

- Who are the operators and directors of TD?
- Who gets benefits from the TD education offered by the institutions?
- Who are affected by the TD education provided by the institutions and who influence their activities?

Table 1. Stakeholders and distribution by priority

Stakeholders	**Status**	**Reason**	**Priority**
Students	Customer	Main TD user	1.
Instructors	I.S.	TD provider and developer	2.
Universities	E.S.	TD provider and developer	3.
Vocational Colleges	E.S.	TD provider	4.
Related sector representatives	E.S.	Strategic partner	5.
Workers	E.S.	TD user	6.
Public representatives	E.S.	Main partner	7.
NGO	E.S.	TD user and strategic partner	8.

I.S.: Interior Stakeholder
E.S.: External Stakeholder

Stakeholders were determined by literature review, interviews with industry and NGO (Non-Government Organisation) representatives, and a mini-workshop jointly organised by the third-stage program development committee with lecturers, teachers, and trainers in the sector. Stakeholders identified for this study (shown in Table 1) were categorised according to their functions and priorities. The most important group among the stakeholders is undoubtedly the main service group, i.e. students. Subsequently, the second largest group of stakeholders consisted of a group of TD instructors, which is compatible with the literature (Ashford 2017; Crawley et al 2007; Besterfield et al 2014).

2.2. Needs analysis

A needs analysis is a process to be followed to demonstrate the difference between the current and the desired situation for the training program and material development. A needs analysis of TD education consists of four stages: preparation, information collecting, analysis and reporting. "The Difference Approach" was used in the analysis of the information. This reveals the difference between observed and expected success levels. For this approach need is the difference between the expected skill level and the current skills. This difference shows the characteristics of the program that must be earned by TD user.

2.3. Statistical Analysis

For needs analysis, information are collected, analysed and evaluated for material and content development subjects. In the needs analysis there are 25 five-point Likert-type scale and 5 open ended questions. With the first 5 of these questions, questionnaires were formed to measure participants' TD perception, next 20 to measure knowledge and skill levels and the last 5 questions to measure the expectations of TD education. Questionnaire which does not contain judgments in its content, is directed to all parties determined by the stakeholder analysis through the Google survey application. These question groups make different evaluations during the analysis, and are primarily concerned with the level of education and knowledge skills, competences of education levels, differences between institutions and countries.

Within the scope of the study, a survey was conducted with 320 people in different education and sectoral positions in three different countries. In this survey, 252 from Turkey, 58 from Bulgaria and 10 from the UK people participated. The sectoral distribution of respondents is given in Figure 1.

Figure 1. Distribution of groups participating in the survey

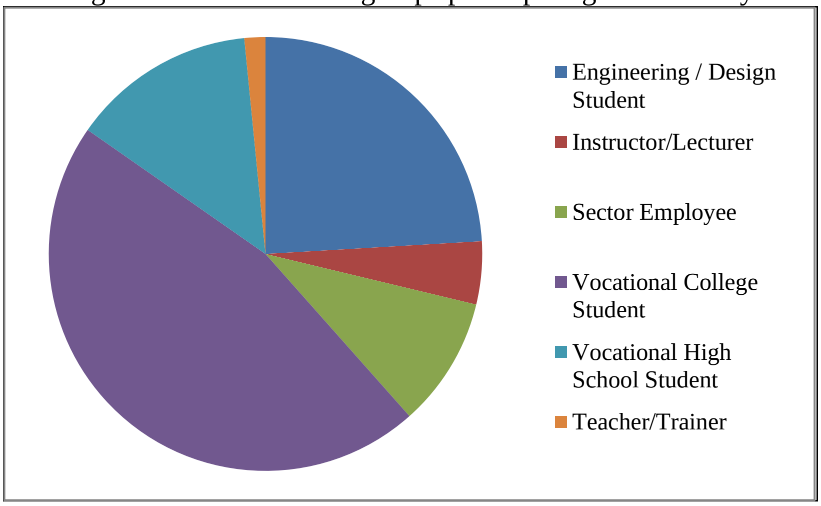

Figure 1 shows that vocational student constitutes an important weight in the distribution of the surveyed groups, the second is the engineering students and the third is the vocational high school students. The graph can be interpreted as a meaningful distribution in terms of the representation of the situation in the sector of the individuals who are trained in Technical Drawings.
The evaluation of the survey results was carried out in the form of analyses of three different sub-question groups and open-ended questions. Figure 2 gives a graph of the average of the questions asked by the five Likert scale.

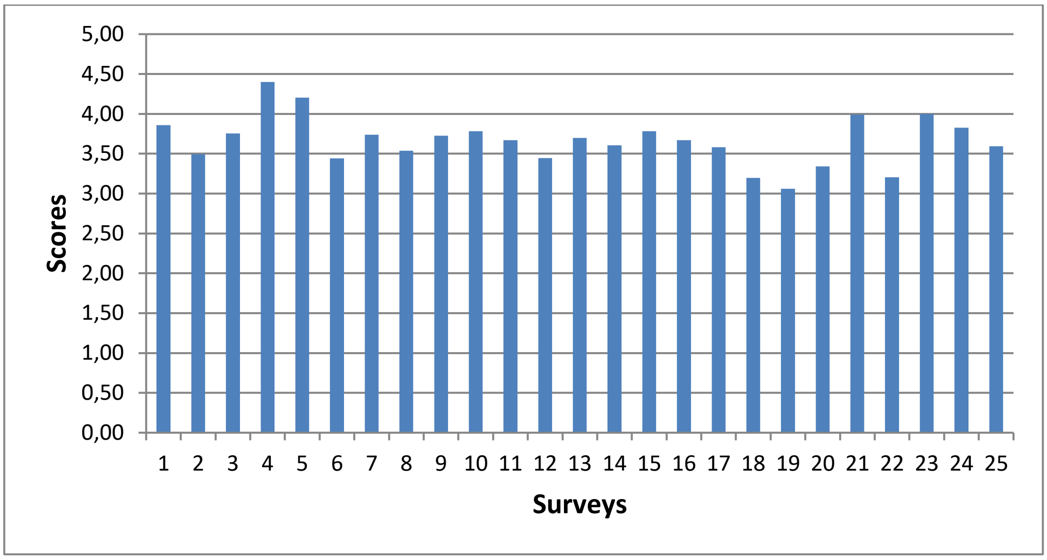

Figure 2. General average by question

From the first 5 given questions and through assessing the measurement of the Technical Drawings perception of the persons evaluated (Figure 2) the following comments can be drafted:

1. 76% of the answers given to the judiciary in the question "*You have efficient the Technical Drawing knowledge and skills required by your profession*" find themselves able enough with Technical Drawing.
2. 70% of the answers given to the question "*you are using a common language in technical drawing and awareness of standards such as BS, ASME, ISO, DIN*" find themselves confident.
3. 73% of the answers given to the question "You *have practical skills to support your theoretical technique knowledge*." Find themselves having good skills.
4. 88% of answers given to the question "*You think the technical drawing reading skills is vital for a technical staff*" think this is vital (12% do not attend this question)
5. Answers to the question "You *think that technical drawing reading mistakes cause discarded or low quality product*" show that 84% of participants are sufficiently informed about awareness of discarded product and its importance (16% do not participate in this question).

Figure 3 shows the answers to the following 20 questions which are the reference source, the technical information and skills of the technical persons surveyed. Here the main subject headings correspond to technical issues that are missing.

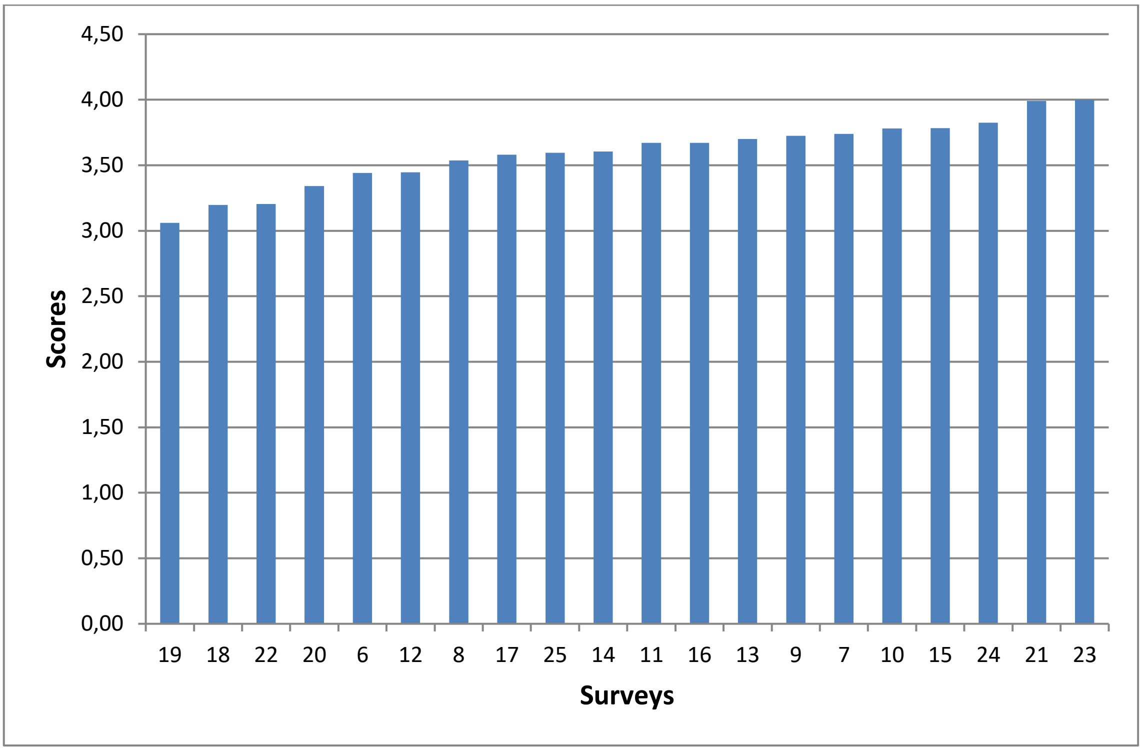

Figure 3. Sequential ordering of questions measuring technical drawings skill

When the results of needs analysis were examined, grouping similar subjects from the resulting table was possible. Geometric measurement and tolerance (GMDT), one of the most difficult subjects, emerged as the most improvement needed. Answers to this question group were given very close results to each other. Therefore, the ranking made up to 40% of this analysis from the first question felt needing 20% to the last question felt like Table 3, except for minor variations. There is an example of small differentiation, one of which is the answer in the third row, "*You think that technical drawing training is enough to read the drawing used in the sector*", not a GMDT but a judgment belonging to the Technical Drawings. This is not interpreted as a differentiation that will affect the analysis because it must be considered independently of the technical content. When the general judgments are also excluded from the answers given as a result, the content stream in Table 2 can be sorted according to the need. Table 3 shows the main topic headings emerging in the analysis result.

Table 2. Sequential technical topics according to need after needs analysis

1	19. You know the difference between circular runout and total runout.
2	18. You know the details of true position tolerance and maximum material application.
3	20. You know the Surface roughness concept, signs and Ra, Rz, Rmax. standards of the symbols.
4	12. You know the critical details of the absolute and auxiliary measure.
5	8. You know the projection methods and you can read these methods from the symbols on the title blocks.
6	17. Recognize geometric dimensioning and tolerancing symbols and know the meanings on the drawing.
7	14. You can read the corner chamfer tolerances.
8	11. You can read dimension tolerances in manufacturing drawings
9	16. You know the difference and importance of geometric dimensioning and tolerancing in manufacturing.

10	13. You can read the symbols for shaft and hole tolerances and find the fitting tolerances on the tables.
11	9. You know the types of sectioning and you can distinguish between full and stepped sectioning.
12	7. You know the details on the drawing title block and read the general tolerances on the title block
13	10. You know perspective methods and visualize perspective drawings in your head..
14	15. You can easily distinguish manufacturing and assembly drawings.

Table 3. Subject headings for material development

1	Geometric Dimensioning and Tolerancing
2	Surface roughness
3	Measurement
4	Projection methods
5	Corner chamfer tolerances
6	Dimension tolerances
7	Shaft and hole tolerances
8	Sectioning
9	Perspective
10	Manufacturing and assembly drawings

In addition to the general evaluations, the Figure 4 shows similar results in terms of both question-based and general education in Turkey and other countries. This demonstrates that the title of the perceived need to be the same in UK, Turkey and Bulgaria which is an important finding in scientific terms.

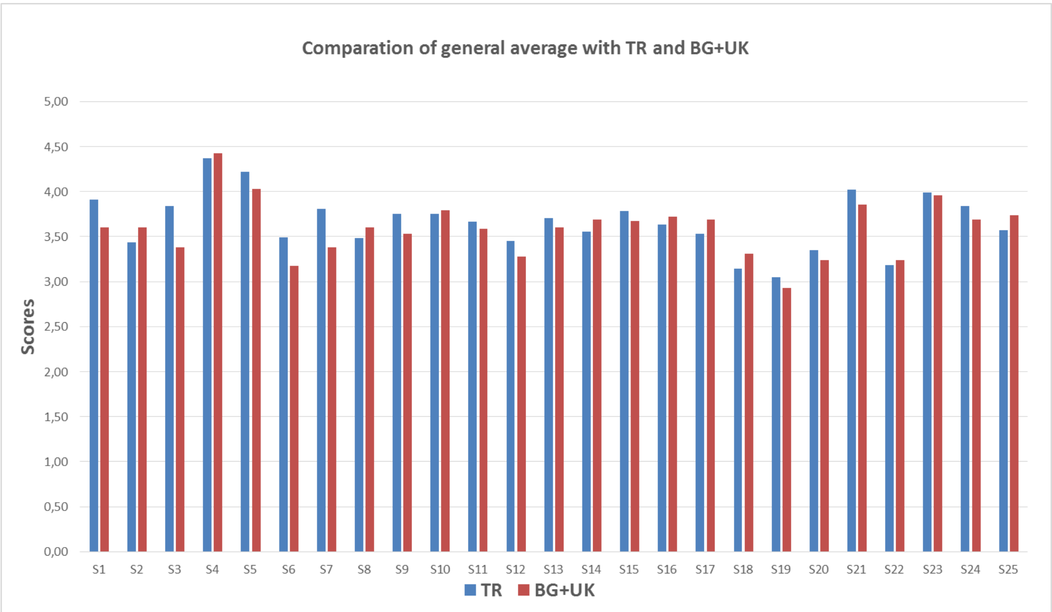

Figure 4. Comparison of Turkey and scores by other countries

The last 5 open-ended questions given in Table 4 that were questioned about technical drawing education were examined in detail by distribution and grouping of given answers. Answers to the questions “How *many hours a week training you had during your education?*". "*Have you had* *further training during your employment, if you do duration and subject?"* showed that 56% of respondents answered 4 hours and 35% of respondents answered 2-3 hours in response to the first question. For the latter question 80% of the participants stated that they did not receive further training, opposed to 1% stated that they received training on standards, tolerances and CAD. A further question asked *"Have you used VR or AR for game or training, if yes; do you think mobile phone, mobile devices will play an important role in education people?"*55% answered no, and 31% answered yes. The majority of correspondents who answered yes believe that AR/VR will be useful for training and education of TD. In response to the question "*When you need further information on technical drawing, what do you do first? e.g. search on google, check book, teacher or lecturer*", 48% answered with Google, 30% teachers, 16% books and other internet resources (YouTube etc.). The preferred method of finding information is to use common search engines, where the information gathered may or may not be reliable. Lastly, the question "*What is the last book or standard (training you had) you read about technical drawings?*" showed that 37% did not read, 21% used textbooks and 19% used standards.

No	Question		%
26	How many hours a week training you had during your education	4 hours	0,56
		2 -3 hours	0,35
27	Have you had further training during your employment, if you do duration and subject?	Nothing	0,80
		Tolerances/CAD	0,09
28	Have you used VR or AR for game or training, if yes; do you think mobile phone, mobile devices will play an important role in education people	No	0,55
		Yes	0,31
29	When you need further information on technical drawing, what do you do first? e.g. search on google, check book, teacher or lecturer	Google	0,48
		Books	0,16
		Teacher	0,30
		Internet	0,01
30	What is the last book or standard (training you had) you read about technical drawings?	Nothing read	0,37
		Course book	0,21
		Standards	0,19
		Autocad	0,09

Table 4. Answers to open-ended questions

As a result of these analyses, the topics grouped according to priority order. The subjects and grouped modules are listed in order of priority according to the need analysis results as shown below:

1. Geometric measurement and dimensional tolerances
2. Surface Treatment Markings/Surface Roughness
3. Dimensional Tolerances, Edge Tolerances, Shaft and Hole Tolerances
4. Sectioning and Projections and Perspective
5. Dimensioning and Tolerances
6. Working and assembly drawings

3. Conclusion

This study resulted in different analyses which constitutes an important database in terms of the number of participants, the participant diversity and also the origin country with many sub-analyses not given in the above findings. The variation of differentiation on schools and professions has generated important data for use in the content and material development phases. Research showed that there is an important deficit in all stakeholder groups and countries that cannot be covered by known methods, which could be assisted in the field of Technical Drawing Education. The outcome of this research is currently being used for development of VR/AR content of the technical drawing training programme that is compatible with the priority topics in the above analysis. It is envisaged that the use of VR / AR technologies, which will gain skills for visual memory during this advanced study, will make a significant contribution to the learning performance of the people.

Acknowledgements

This study is supported by "Virtual and Augmented Reality (V&AR) in Design for Manufacture" Project under EU Erasmus+ strategic partnership Project Funds.

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