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Comparative Analysis of ISO GPS Knowledge and Usage in the Italian Market

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Abstract

This research consists in a detailed analysis of the ISO Geometrical Product Specifications (GPS) system's knowledge and usage in Italy. Data was collected by means of a questionnaire, from a wide range of industrial sectors and academic institutions. The dataset encompasses 143 responses, forming the basis for an in-depth examination of ISO GPS system implementation in Italy. This analysis involves three levels of comparison: (1) an examination of knowledge level and typical usage between Beginners and Experienced individuals, (2) an investigation into ISO GPS adoption patterns in Industry and Academia, with and without specific ISO GPS training, and (3) an exploration of differences among professionals who are responsible for conveying geometric specifications and those in charge of interpreting and applying them. The findings reveal significant insights into ISO GPS implementation in both academic and industrial domains. They highlight the need for the improvement of ISO GPS education offer and the development of more effective utilization practices, with potential implications for future ISO GPS standards development strategies.

Keywords: ISO GPS; Geometrical Product Specifications; Training; Geometric Specifications Management.

1. Introduction

The full set of documents used to describe the significant technical characteristics of a products, e.g., the geometry, the functionality, the manufacturability, etc., compose the Technical Product Documentation, or TPD.

The technical language defined by the ISO GPS normative system aims to establish a common language able to translate any functional requirements into a set of admissible geometrical and/or dimensional deviations considered as tolerances. When the functional requirements, stated in the TPD as tolerances, are not conveyed coherently and clearly, different issues are anticipated. Firstly, the final product could experience a performance deficit. Secondly, a higher number of scraps coming from the manufacturing process could occur leading to a higher overall manufacturing cost.

Starting from the mid-'90s, when the ISO GPS language was introduced, it demonstrated itself as a useful tool for decreasing ambiguity when compared to the linear dimensioning scheme [1]. This was later formalize, at the standard level in ISO 14405-2 [2]. At the same time, the authors has experienced a lack in the ISO GPS system implementation. This evidence was collected through different industrial collaborations with several Italian firms, both multinational enterprises and small/medium enterprises (SMEs).

A similar evidence was obtained also in Germany, with particular focus on SMEs [3,4]. Simultaneously, it is agreed

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that only a complete application of the ISO GPS system leads to the advantages previously addressed [5].

This is the reason why it is crucial to map the current implementation of the ISO GPS system in Industry. Both knowledge and usage of the language are important to map critical areas in the standardization system to push the transition towards an implementation of the ISO GPS system closer to the industry needs.

A survey comparing the usage of the ASME Y14.5 vs the ISO GPS system was conducted in 2017. The result from this investigations showed that ASME standard is more used worldwide [6]. Even though a significant number of entries to the enquires come from international companies, being the survey based in the USA, the result may be be affected by a bias towards the ASME standard since international companies that were reached are likely to be direct suppliers of companies based on the USA. Lately, in China, the status of delivery of ISP GPS was surveyed showing that a significant gap between industry and education exists [7]. A survey testing the awareness, use, and need for tolerance analysis demonstrated how it is not used systematically in most of the instances; however, companies recognize that managing geometric deviations is important [8]. Another research in Germany, as first step evaluated the use of a maturity model as a tool for assessing the integration of the ISO GPS system within a company [3], as second, they developed a survey based tool to systematically guide the ISO GPS system implementation within companies [4].

In a previous work, a tool for the evaluation of knowledge and usage of the ISO GPS system in Industry and Accademia developed on the concept of maturity model was presented [9]. Based in this tool, the aim of the paper is to assess and discuss the current ISO GPS implementation in Italy.

2. Tools and methods

To assess the current implementation of the ISO GPS system the questionnaire previously described in [9] is used. It is based on the maturity model concept and is divided into 6 different sections: general concepts of geometric specification, geometrical tolerances, datum system, dimensional tolerances, modifiers and indication, and tolerance stack-up. Per each section, after a first self-evaluation between beginners and experienced users, the knowledge and use is assessed through self-assessment questions. A level of application-based question is used to estimate the competence under the form of "applied knowledge" and "applied usage".

The questionnaire was circulated in Italy before training sessions and consulting and through direct invitation by the authors and external partners.

The data that were collected are post processed to obtain the knowledge, usage, applied knowledge, and applied usage percentage. Each entry is also given a rating based on a weighted average between applied knowledge and applied usage according to the following equation.

$$R = \frac{0.5 \cdot \text{Knowledge}_{\text{applied}} + 1 \cdot \text{Usage}_{\text{applied}}}{1.5} \quad (1)$$

The entries are divided into different categorical groups: beginners vs experienced, industry vs academia, trained vs untrained, and readers vs writers of specifications. The comparative analysis is performed using one-way ANOVA, considering the null hypothesis that no differences exist. Differences will be considered significant (and the null hypothesis will be rejected) if the p-value is lower than 0.05.

3. Descriptive analysis

A total of 188 responses to the questionnaire were collected in Italy. A summary of the participants is presented in Tab. 1.1. In brief, 123 responses were collected from the industry, while 65 were from academia. Less than one-third of the participants had participated in specific ISO GPS training in the past (32.98%), with a higher percentage among the industry respondents (38.21% versus 23,08% in academia). Only 24.47% of the participants indicated that they actually write specifications. Once again, the percentage was slightly higher for the industry compared to academia (28.46% versus 16.92%).

Table 1. Summary of the participants to the survey.

	Total		Industry		Academia	
Partecipants:	188	100%	123	65.43%	65	34.57%
With training:	62	32.98%	47	38.21%	15	23.08%
Write geometric specification	46	24.47%	35	28.46%	11	11.67%
Read-only geometric specification	142	75.53%	88	71,54%	54	88.33%

Looking exclusively at the entries from industry, the distribution of entries among different industrial sectors is shown in Fig. 1. The majority of entries were collected from the automotive sector, totaling 49 entries. The second most represented sector is professional services with 19 entries, followed by Household consumer durables with 18 entries and Metal and mining with 16 entries.

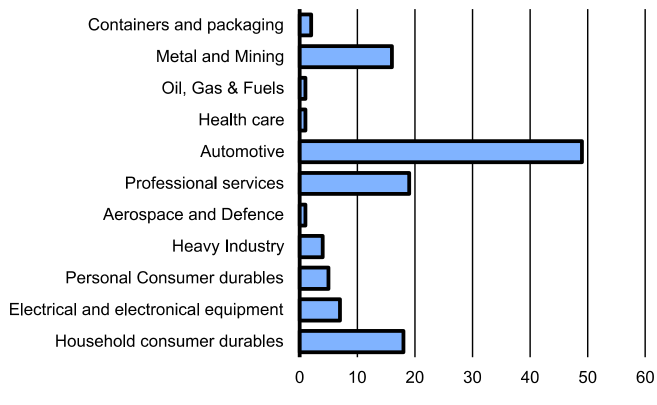

Fig. 1. Industrial sectors covered by the survey.

However it is not the aim of this work to investigate differences among different industrial sectors.

In Fig. 2 the knowledge and usage curves are presented, considering the responses for the sections: Geometric Tolerances, Datum Systems, Dimensional Tolerances, and Modifiers and Indications. The overall curves are derived by averaging the curves obtained for each individual section.

The knowledge curve is noticeably suboptimal, with an overall knowledge rating (curve integral) of 6.7/10, while the usage rating remains at 5.1/10. Comparing the usage curve with the applied knowledge curve, a significant overlap is observed. Specifically, the applied knowledge rating matches the usage rating at 4.9/10. Interestingly, the applied knowledge, reflecting unbiased knowledge, aligns closely with actual usage: only what is practically used is also genuinely understood. Lastly, the applied usage rating stands at 3.7/10.

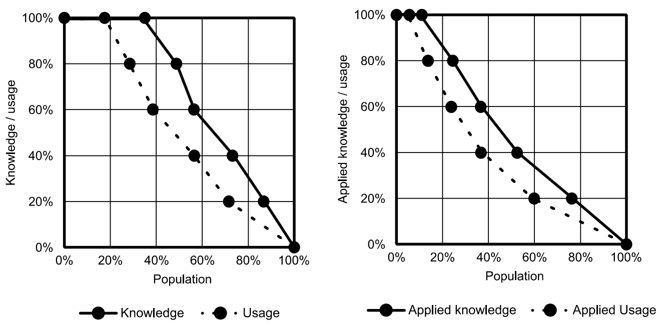

Fig. 2. Overall knowledge and usage distribution found averaging KPIs from 1 to 4.

The application-based curve shifts to the left, resulting in lower ratings. This suggests that the ISO GPS system is frequently misapplied by users. A noteworthy observation is that a substantial number of application-based questions received incorrect answers, even when the “don't know” option was available. These incorrect responses indicate instances of misuse or misinterpretation of the system in real-world applications.

4. Comparative analysis

Three different levels of comparative analysis are provided. The first level looks at differences among different categorical categories. The second level looks at differences among the different sections that were defined to split the ISO GPS system. The third and last level looks at difference among different categories in each section.

4.1. Comparison among categories

Table 2 presents the results for the one-way ANOVA considering the average knowledge and usage. On one hand, the differences in both knowledge and usage between the Industry and academia are not significant, with p-values of 0.205 and 0.062 respectively. Therefore no statistically significant differences can be recorded. On the other hand, the differences in both knowledge and usage are significant for people with training versus those without training (p-value < 0.001). With training, both average knowledge and usage increase by about 20%.

Furthermore, when comparing individuals who write geometric specifications to those who read them, the differences in knowledge and usage are not significant (p-value 0.195 and 0.531 respectively).

Table 2. Quantitative differences in overall Knowledge and usage between categories.

	Average Knowledge			Average usage		
	μ	σ	p-value	μ	σ	p-value
Industry	62 %	25 %	0.205	45 %	25 %	0.062
Academia	57 %	26 %		38 %	28 %	
With training	75 %	21 %	0.000	56 %	25 %	0.000
No training	53 %	24 %		36 %	24 %	
Write specification	64 %	21 %	0.195	45 %	23 %	0.531
Read specification	59 %	26 %		42 %	27 %	

In Table 3, the results for the one-way ANOVA considering the average applied knowledge, and applied usage are presented. Concerning the comparison between industry and academia, all differences are not significant (p-values > 0.05). The impact of training is also confirmed to be significant (p-values < 0.001).

Regarding applied knowledge and usage, the evaluations already made for knowledge and usage for the categories write vs reads geometric specification (Table 2) are confirmed: the difference in knowledge and usage are not significant (p-value > 0.05).

Table 3. Quantitative differences in overall applied Knowledge and usage and overall grade between categories.

	Average applied Knowledge			Average applied usage		
	μ	σ	p-value	μ	σ	p-value
Industry	45 %	22 %	0.159	33 %	21 %	0.123
Academia	40 %	23 %		27 %	23 %	
With training	56 %	22 %	0.000	42 %	22 %	0.000
No training	37 %	20 %		25 %	19 %	
Write specification	47 %	23 %	0.205	33 %	22 %	0.523
Read specification	42 %	22 %		30 %	22 %	

4.2. Comparison among sections

In Fig. 3, the confidence intervals for the grades from sections: general concepts of geometric specification, geometrical tolerances, datum system, dimensional tolerances, modifiers and indication, are presented. A notable observation is that the confidence intervals for “dimensional tolerances” and “Modifiers and Indications” are nearly perfectly aligned.

Similarly, the confidence intervals for “General concepts,” and “geometric tolerances” are also closely aligned.

The confidence interval for “Datum Systems” is distinctly different from those for “General concepts” and “Geometric tolerances,” and it is quite close to the intervals for “Dimensional Tolerances,” and “Modifiers and Indications”. It remains uncertain whether the grade for “Datum Systems” is significantly different from those for “Dimensional Tolerances,” and “Modifiers and Indications”.

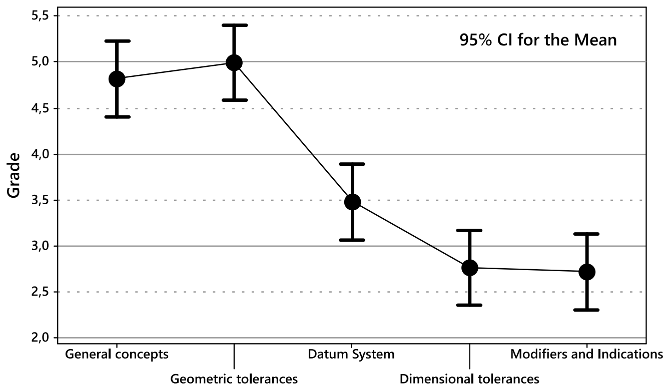

Fig. 3. Grade comparison among KPIs.

One-way ANOVA was employed to confirm the differences between sections, and the results are presented in Table 4. It is evident that significant differences exist (p-value <0.001).

Table 4. Quantitative differences in grade between categories.

	μ	σ	p-value	Grouping*
General concepts	4.820	3.290		A
Geometric tolerances	4.995	2.839		A
Datum System	3.479	2.760	0.000	B
Dimensional Tolerances	2.758	2.585		B
Modifiers and Indications	2.716	2.891		B

* Using the Tukey Method and 95% Confidence

In order to determine whether specific KPIs lack significant differences, a grouping analysis was conducted using the Tukey Method with a 95% Confidence level. This analysis revealed the formation of two groups: the first group consists of “General concepts,” and “Geometric tolerances,” while the second group encompasses “Datum Systems,” “Dimensional Tolerances,” and “Modifiers and Indications.” Within these two groups, no significant differences are observed. Hence, the grades for “General concepts,” and “Geometric tolerances” are significantly higher than those for the other sections.

4.3. Comparison among categories per each section

The results are shown in Table 5. As established in the previous sub-section, no significant differences were detected between the industry and academia. The analysis conducted for each section separately reaffirmed that these two categories exhibit no statistical differences except for the “Geometrical Tolerances” section. The previous analysis also established the presence of significant differences between individuals with training and those without training. This finding confirms the statistical difference for all sections. In a previous analysis, run with 143 entries [10], the difference for the section “Datum System” was found to be significant. This difference reveals that the result for this section is unstable. Observing the curves in Fig. 4, representing the knowledge and usage distribution relative to the Datum system section comparing those with training vs those without it, it is apparent that the knowledge and usage curves are quite divergent, while the applied knowledge and applied usage curves display more overlap. This outcome could potentially be attributed to the lack of proper training in understanding Datum Systems.

This suggests that among individuals with training, a higher percentage of incorrect responses were recorded. This phenomenon could signify that participants with training may have initially assessed themselves as experts but subsequently encountered difficulty in responding accurately to advanced questions. Alternatively, individuals without training might have chosen the “don't know” option, therefore selecting less incorrect answers. This subject is indeed intricate, and reaching a consensus is challenging even within ISO/TC 213. This committee is currently working on amending ISO 5459:2011, the standard addressing datum systems, due to its perceived shortcomings. However, the process is progressing gradually due to the complexities involved. At the time of writing, ISO/TC 213, WG 2 (Datums and datum systems) is

Table 5. Ratings comparison among different categories and KPIs.

	General concepts			Geometric Tolerances			Datum Systems			Dimensional Toleraces			Modifiers and Indications		
	μ	σ	p-value	μ	σ	p-value	μ	σ	p-value	μ	σ	p-value	μ	σ	p-value
Beginner	3,67	2,96	0,000	4,85	3,00	0,332	3,14	2,61	0,003	2,10	2,08	0,000	2,11	2,55	0,000
Experienced	7,84	1,92		5,27	2,51		4,53	2,96		4,20	3,00		5,77	2,61	
Industry	4,96	3,37	0,427	5,39	2,64	0,009	3,63	2,67	0,298	2,74	2,65	0,872	2,89	2,83	0,265
Academia	4,56	3,14		4,25	3,07		3,19	2,93		2,80	2,49		2,39	3,00	
With training	7,08	2,55	0,000	6,00	2,58	0,001	4,19	3,08	0,013	4,05	2,90	0,000	4,43	3,08	0,000
Without training	3,71	3,04		4,50	2,84		3,13	2,53		2,13	2,16		1,87	2,39	
Write specification	5,54	3,39	0,086	5,14	2,49	0,693	4,05	2,91	0,110	2,96	2,77	0,551	2,77	3,34	0,889
Read specification	4,59	3,23		4,95	2,95		3,30	2,70		2,69	2,53		2,70	2,74	

focused on amending the existing standard to address certain critical aspects before embarking on the task of creating a new edition.

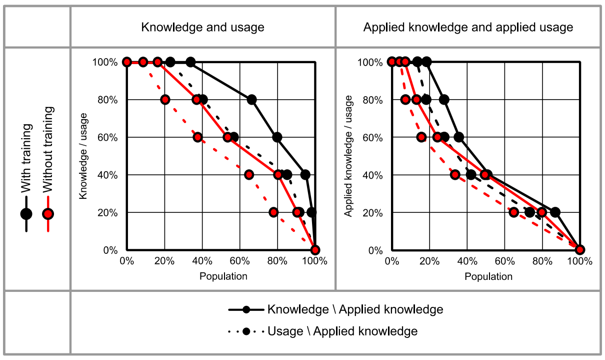

Fig. 4. Comparison between (Applied-) Knowledge and usage curves for people with training and those without training relevant to the Datum System section.

The overall differences between those who write and those who read geometric specifications was determined to be not significant (Table 3, and Table 4). This result is confirmed by analyzing each section separately.

By scrutinizing each section separately, it becomes possible to examine the differences between beginner and experienced users. Conducting this analysis overall was not feasible, as each respondent to the questionnaire could independently choose between beginner and experienced status for each section. It is noticeable that significant differences are present for all sections except "Geometrical tolerances" (p-value 0.332).

5. Conclusions

This paper presents the results obtained in the Italian market regarding the knowledge and use of the ISO GPS system using the questionnaire previously developed by the authors.

The questionnaire proven to be a user-friendly and straightforward tool for evaluating the current dissemination and understanding of the ISO GPS language. Its brevity, requiring only 10 to 15 minutes for completion, makes it suitable for a variety of scenarios, including training, consulting, and invitation-based dissemination.

Indeed, these were the methods employed to gather entries for the Italian market. The Design Tools and Methods in Industrial Engineering Laboratory at the University of Padova and its collaborators distributed the questionnaire before training and consulting sessions.

The analysis presented in this paper involved 143 participants, but the questionnaire remains open and continues to accept new responses.

The survey is already available for international use (currently available in English, German, and Italian), and its European release is ongoing [11].

Findings from the Italian survey revealed that the overall implementation of the system is far from optimal and requires further investment. The differences between industry and academia were not statistically significant. Moreover, it is evident that the subject is not adequately covered at the academic level.

The study also unveiled that the responsibility for drafting geometric specifications primarily lies with the R&D/Design department, sidelining manufacturing and quality control. Therefore, investments in dedicated ISO GPS training are necessary to streamline the overall management of geometric specifications.

Overall, the results are inadequate, given that the knowledge rating stood at 6.4/10 and the usage rating at 4.7/10. These figures are even lower when considering application-based results: the applied knowledge rating is 4.7/10, and the applied usage rating is 3.4/10.

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