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Digital tools in soil science related field studies: Training support and lifelong learning

Herramientas digitales para los estudios relacionados con la ciencia del suelo: Apoyo a la formación y al aprendizaje a lo largo de la vida
Ferramentas digitais para estudos relacionados com a ciência do solo: Apoio à formação e à aprendizagem ao longo da vida

AUTHORS

Bosch-Serra A.D.[@]
angela.bosch@macs.udl.cat

Estudillos G.

Yagüe M.R.

Virgili J.M.

[@] Corresponding Author

Department of Environment and Soil Sciences, University of Lleida. School of Agrifood and Forestry Science and Engineering. Avda. Alcalde Rovira Roure 191. E-25198 Lleida, Spain.

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ABSTRACT

The acquisition of professional skills can be helped by using digital tools (DT). The adaptation of the Spanish curricula to the European Higher Education zone has brought with it further demands to improve students' foreign language performance. Any tool requires to be evaluated by potential users. We aimed to assess the usefulness for learning of two multilingual DTs, dealing with water quality for irrigation and fertigation planning through a case-study approach. Our hypothesis was that the tools will be useful for students, and also for professionals as Decision Support Systems (DSS). During three academic years, the DTs were evaluated in the context of regular university subjects, and in lifelong learning courses for professionals. A questionnaire with a Likert scale was completed by the DT users. The technical-scientific content, the pedagogical content, and the friendliness for users were evaluated. Data analysis was done by analysis of variance and according to the classes of user: gender, age, previous studies and current activities. Saving time in routine calculations using DTs brought benefits in lighter workloads for students, which was balanced with an increase in discussions. It also led to a sustained interest, even when the use of a foreign language was introduced. Time saving and the teaching content were also appreciated by professionals. The general average score given to the materials was 4.15 out of 5. The multilingual DTs designed for solving real-life problems were appreciated by students to support learning in agronomic engineering subjects and in foreign languages. The DTs can be disseminated to professionals, as they appreciate the up-to-date technical-scientific content as well as the effectiveness of the calculations.

RESUMEN

Las herramientas digitales (HT) son útiles para la adquisición de competencias profesionales. Además, dan respuesta a la necesidad de mejorar las competencias lingüísticas de los estudiantes en España, ligadas a la adaptación de los planes de estudio al Espacio Europeo de Educación Superior. No obstante, cualquier herramienta debe ser evaluada previamente por los potenciales usuarios. En este trabajo nuestro objetivo fue evaluar la utilidad de dos HT en el aprendizaje relacionado con el manejo del agua (calidad de agua para riego) y de la nutrición de la planta (planificación de la fertirrigación) mediante el estudio de casos. La hipótesis de partida suponía que las HT desarrolladas beneficiarían a los estudiantes y también a los profesionales como un sistema de apoyo a la toma de decisiones. Para corroborarlo, las HT se evaluaron durante tres años en el marco de los estudios universitarios

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de grado y máster, y también en cursos de formación permanente para profesionales. La metodología se basó en la realización de encuestas y los usuarios de las HT rellenaron un formulario basado en la escala de Likert. Se evaluó el contenido científico-técnico, el enfoque pedagógico y la facilidad de uso. Los resultados se analizaron mediante un análisis de varianza y en base a los parámetros de género, edad, estudios previos y actividad profesional de los encuestados. Los resultados obtenidos indican que las HT permiten ahorrar tiempo en aspectos más rutinarios de cálculo, tiempo que se invierte en discusiones y puesta en común del problema analizado. También facilitan una actitud de mayor interés en el tema expuesto, incluso cuando éste se introduce en una lengua distinta a la lengua materna. Los profesionales del sector evalúan positivamente el ahorro de tiempo y la manera de exponer los contenidos técnicos en las HT. La puntuación general media obtenida por las HT fue de 4,15 sobre 5. Los estudiantes valoran las HT multilingües, tanto como apoyo al aprendizaje en los estudios de ingeniería agronómica como para la adquisición de competencias lingüísticas. El acceso a los materiales por parte de profesionales del sector es valorado positivamente por ellos, apreciando especialmente la actualización en los contenidos científico-técnicos y la eficiencia en los apartados que incluyen cálculos matemáticos.

RESUMO

As ferramentas digitais (HT) são úteis para a aquisição de competências profissionais. Para além disso, a adaptação dos curricula espanhóis ao espaço da Educação Superior Europeia exige uma melhoria do desempenho dos estudantes no âmbito das línguas estrangeiras. Contudo, qualquer ferramenta deve ser previamente avaliada pelos seus potenciais utilizadores. Neste trabalho, o nosso objectivo foi avaliar a utilidade de duas HT na aprendizagem relacionada com a gestão da água (qualidade de água para rega) e da nutrição das plantas (planeamento da fertirrigação) mediante o estudo de casos. A hipótese de partida presupunha que as HT desenvolvidas beneficiariam os estudantes, e também os profissionais com um sistema de apoio às decisões. Para o comprovar, fez-se a sua avaliação durante três anos académicos no contexto de disciplinas universitárias comuns, e também em cursos de formação permanente para profissionais. A metodologia baseou-se na realização de sondagens e os utilizadores das HT preencheram um formulário baseado na escala de Likert. Avaliou-se o conteúdo técnico-científico, o enfoque pedagógico e a facilidade de uso. Os resultados analisaram-se recorrendo a uma análise de variância e com base nas caraterísticas do utilizador: género, idade, estudos prévios e atividade profissional atual. Os resultados obtidos indicam que as HT permitem poupar tempo em aspetos mais rotineiros de cálculo, o que é equilibrado com mais tempo investido em discussões do problema analisado. Também facilitam uma atitude de maior interesse no tema exposto, inclusive quando este é feito numa língua diferente da língua mãe. Os profissionais do sector avaliam positivamente a poupança de tempo e a maneira de expor os conteúdos técnicos nas HT. A pontuação geral média obtida pelas HT foi de 4,15 em 5. Os estudantes valorizam as HT multilíngues, bem como o apoio à aprendizagem nos estudos de engenharia agronómica e na aquisição de competências linguísticas. O acesso aos materiais por parte de profissionais do setor, é valorizado positivamente por eles, apreciando especialmente a atualização dos conteúdos técnico-científicos e a eficácia nos cálculos matemáticos.

KEY WORDS
Case studies, decision support system, European Higher Education Zone, fertigation, professional skills, water quality for irrigation.

PALABRAS CLAVE
Estudio de casos, sistema de apoyo a la decisión, Espacio Europeo de Educación Superior, fertirriego, competencias profesionales, calidad de agua para riego.

PALAVRAS-CHAVE
Estudo de casos, sistema de apoio à decisão, Espaço Europeu de Educação Superior, fertirrega, competências profissionais, qualidade de água para rega.

1. Introduction

In Spain, as in other European countries such as France and Italy, agronomic engineering is a branch of engineering studies. Nowadays, the convergence process for the Spanish educational curricula to the European Higher Education Area (EHEA) is a matter of continuing interest and requires action from the teaching profession (EACEA 2012). In this process, the need is widely accepted to equip engineers efficiently with professional skills, which are critical aspects of an engineer's job (Trevelyan 2010). However, it is essential to complete these technical and scientific skills with the additional one of being able to communicate in different languages, as is expected with other sociotechnical issues (Litchfield et al. 2016). This skill will be of special value to those involved with multi-national scientific projects across the EU and in the wider world.

New teaching and training tools are needed. The Accreditation Board for Engineering and Technology (ABET 2014) underlined the usefulness of simulation digital tools to help students to identify, formulate, and solve engineering problems. However, computer-based tools in engineering studies must also be evaluated in educational terms. The transfer of learning, or the use of knowledge that was accumulated while learning one task to another task, is considered a determinant of computer tool effectiveness (Ruohomaki 1995). Simulation tools are one of the mechanisms to improve students' performance, but allowing student's decision vs. fully automatic processes enhances the learning experience (Davidovitch et al. 2006). In many cases, it is not necessary that tools simulate all possible scenarios. Students just need a flexible system with different options to support them in the calculation process while helping them to assimilate information. This saves time and allows them to move on to consider new problems.

The fundamentals of crop production, which include soil and water management aspects, is one of the core subjects in all agronomy-related engineering degrees. It is viewed as an opportunity to introduce new skills of learning, to widen the understanding of agricultural scientific terminology within native languages and also, to improve the use of foreign languages, because of its compulsory character. The introduction of a foreign language requires time and effort from the student, so it requires reducing the workload of students in some other routine aspects of learning such as repetitive calculations. It was in this context that two learning tools were developed. One dealt with the evaluation of water quality for irrigation and the other with fertigation scheduling. Scientific knowledge was introduced through different case studies. The digital tools were also made available in four different languages: English, French, Spanish and Catalan, the two latter being the official languages in Catalonian universities (in north-eastern Spain). The tools therefore provide to students (nationals, from Erasmus programs, other provenances, etc.) or professionals in the agricultural sector the opportunity to acquire an international terminology in the water quality or fertigation related areas. To be fluent in one other European language (degree B2), apart from the official ones in Catalonia, is compulsory for students following their university courses in Catalonian universities (Ley 2/2014). At the start of the project, in order to introduce Catalan, which is a Latin language, into university studies, some extension chapters (pdf format) were written in this language. The interest of including Catalan is based on it being the mother tongue of the majority of farmers around the area of Lleida University's influence, and it must be understood and used by future professionals working in the agricultural systems of the locality.

On the other hand, Spanish universities are not directly linked to extension services as USA universities are. Thus, some resources developed as teaching materials are rarely accessible to professionals, in spite of their potential interest for the sector. In order to overcome this constraint, the computer tools were also developed as a Decision Support System (DSS). The DSS allows interacting directly with computers to create information and is useful in making decisions (Waghmode and Jamsandekar 2014). However, in our case, it was created in the framework of a problem-solving method of learning.

Educational researchers and practitioners differ somewhat in defining the advantages of solving problems (Van Merriënboer 2013) although they converge in some key aspects. Some authors consider that problem-solving can foster students' ability to think, and even more, to promote their creativity and motivation in learning science (Watts 2004); other authors (Hmelo-Silver 2004) state that problem-solving exercises offer the potential to help students to develop flexible knowledge and effective skills for applying to the solving of problems. In a professional context, it can be said that every day, everyone has to solve problems. When problem solving is contextualized as a skill, it is seen as something that is developed over time as a function of practice. Thus, these types of programmes are essential (Van Merriënboer 2013) because "all of life is a problem solving experience" and students must be well prepared for that (Watts 1994). Moreover, these programmes can sustain the professional with up-to-date knowledge of the topics concerned.

Water and fertilizers are critical factors with regard to the capacity and productivity of agricultural systems in semiarid environments. These are important aspects in agronomic engineering and in the learning process for students involved in these areas.

Irrigated agriculture is dependent on an adequate water supply of usable quality. This fact requires the evaluation of irrigation water, in which emphasis is placed on the chemical and physical characteristics of the water (Ayers and Westcot 1985).

Fertigation provides an excellent opportunity to maximize yields and minimize environmental pollution (Hagin et al. 2002) by reducing fertilizer applications. Fertigation places chemical fertilizers in the desired location, the root zone (Bar-Yosef 1999) mainly when drip irrigation is implemented (Bar-Yosef 1992), and allows its application whenever fertilizers are needed by the crop in the appropriate form and amount. The consequence is an increased return on the investment in fertilizer.

Apart from the development stages of the crop, the fertigation plan needs to consider other aspects such as irrigation water quality (Kafkali and Tarchitzky 2011), management of crop residues (Ramos and Pomares 2009) and soil type (Usón et al. 2010) with the aim to adjust the amount of nutrients applied. The choice of proper fertilizers for fertigation is a demanding task for farmers and extension professionals. Attention should be paid to the fertilizers' solubility, compatibility, suitability to dissemination through irrigation water, pH, concentrations in use, etc. (Phocaides 2007), and a support tool to facilitate these tasks is required for future advisors (our students).

In this context, we provide students with two digital tools which are available from the university intranet and linked to specific courses. We also made them available to agricultural professionals or general public in a CD format (http://www.publicacions.udl.cat/es/), thus starting a new transfer line for teaching materials.

Our hypothesis was that providing such tools, which allows reductions in the time spent on routine calculations, will help students and professionals to go deeper into theoretical knowledge and its application in further case-studies, but we also aimed to help them to go deeper into the acquisition and use of different foreign languages. The aim of this work was to investigate whether our arguments, supporting problem solving and its implementation through the support of spreadsheet programs, would attract young students and "life-long learning students", and could be translated into a more efficient method of learning. We were also interested in knowing whether gender, age, previous studies or current activities influenced the results obtained. Thus, the tools were assessed by the students and professionals via surveys. Surveys included aspects such as their opinion about the tool components (languages, structure, etc.), and their effectiveness in improving agricultural education teaching and their usefulness in supporting professional decisions. Survey instruments have been proved to be an effective tool to assess educational aspects in soil science related studies (Baveye and Vermeylen 1994).

2. Materials and methods

This section provides information on how the spreadsheet programs were developed and how they were assessed by students in agricultural engineering and by agriculture professionals: outstanding farmers, agriculture advisors or extension specialists.

2.1. Description of the digital tools

The water quality for irrigation (Bosch-Serra 2010) and the fertigation tool (Bosch-Serra 2013) were firstly included in a wider innovative learning project for students. First of all, the user can choose the working language. The language options are: English, Spanish, French and Catalan, with the possibility to change the language at any time when running it. The tools include different sections of very intuitive content (**Figures 1 and 2**): 1) an introduction composed of a short presentation; 2) an information section which contains the scheme of the water quality or fertigation programming; 3) the assessment of water quality or the fertigation computer program for a weekly schedule; 4) a basic case study, to facilitate the initial use; 5) the references and 6) the credits or the basic information for librarians (for the CD version).

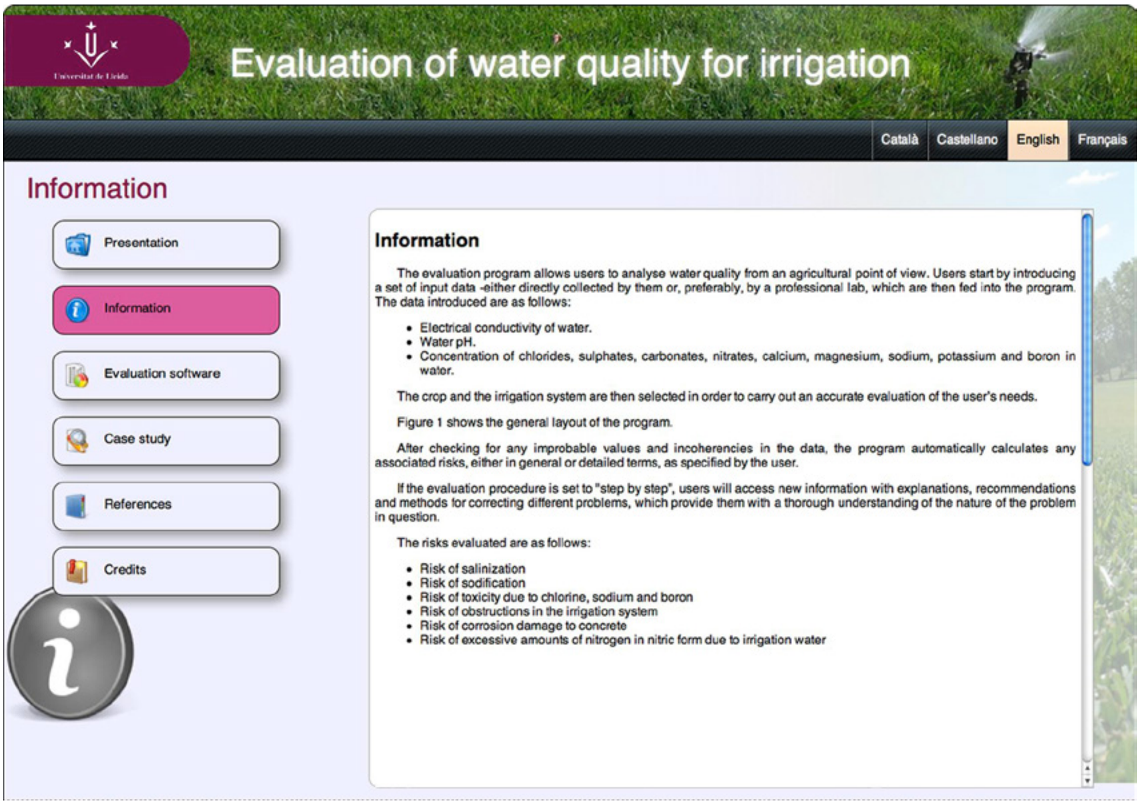

Figure 1. Main screen (htlm format) with the description of the different parts included in the *Evaluation of water quality for irrigation tool.*

The programs have a similar scheme for evaluation of water quality for irrigation (**Figure 3A**) and for fertigation programming (**Figure 3B**). Both use the international metric system.

In the project, the spreadsheet programs run on Excel® from Microsoft Office, version 2003 or later ones (it is compulsory that the user should enable macros' functioning). They are supported by "help windows" which include the "key" theoretical aspects on which calculations are based or information about legislation to be taken into account in the solving of problems (DAAM 2009, 2010). Waghmode and Jamsandekar (2014) remarked on the analytical support of Excel® in DSS design. For Catalan

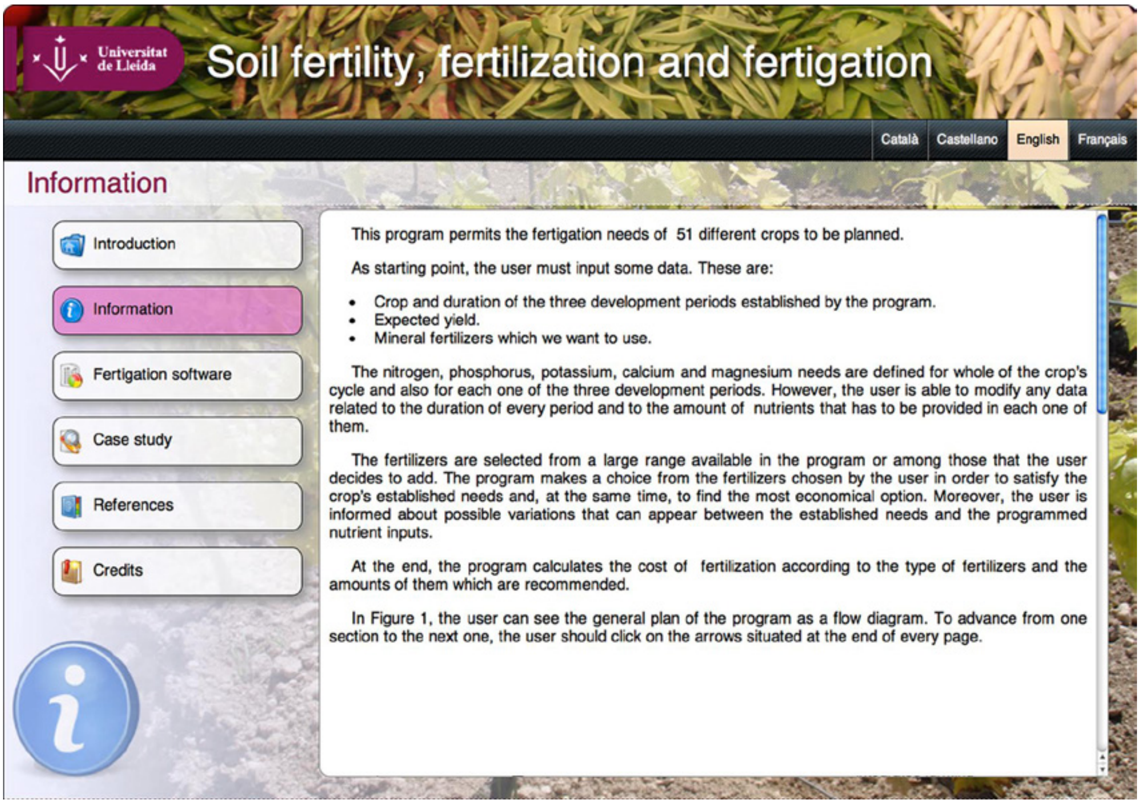

Figure 2. Main screen (htlm format) with the description of the different parts included in the *Soil fertility, fertilization, and fertigation tool.*

readers, because there is a lack of scientific publications in this language, a book about water quality for irrigation or about different fertilization aspects is included in each of the tools. They are developed as text chapters in the Catalan language which can be seen and printed with the Adobe Acrobat Reader© program. The first spreadsheet program carries out the assessment of water quality for irrigation. The input data are very simple to acquire: which crop must be irrigated? what irrigation system will be used? and what are the chemical water characteristics (electrical conductivity, pH, concentration of chlorides, sulphates, nitrates, calcium, magnesium, sodium and boron)? The evaluated risks are: salinization, sodification, toxicity, corrosion damage and excess of available nitrogen.

The second spreadsheet program allows the user to carry out the fertigation programming of 51 different field crops: fruit trees and vegetables. As starting point, the user must input data. They are: 1) the choice of the crop and the duration of the three established development periods (in days) from an initial starting date; 2) expected yield as a basis of nutrient requirement calculations and 3) mineral fertilizers which the user wants to use from a list of 27 different fertilizers, which includes their nutrient contents and cost. The user has the possibility to include other fertilizers, different from the ones on the list, or to change any cost to adapt the program to real values.

The program, according to the yield to be achieved, calculates nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) needs for the complete crop cycle. Data can be modified as to the total nutrient amounts required but also in their distribution during the crop cycle, separately for each nutrient. As the user acquires more experience, it can be included in the DT.

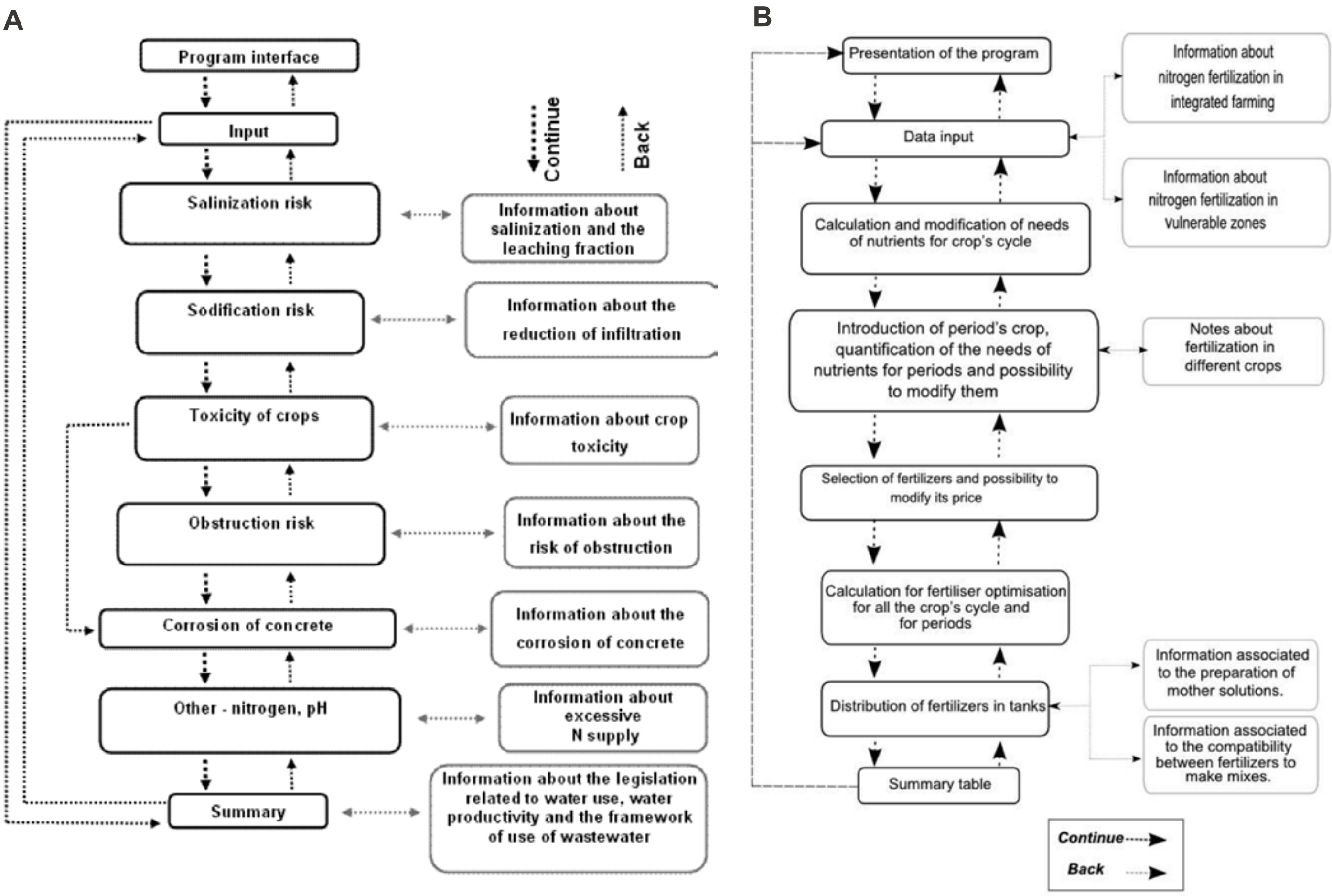

Figure 3. General schemes of the spreadsheet programs. A) Evaluation of water quality for irrigation and B) Fertigation programming.

If different fertilizers are available, the program firstly makes a choice in order to satisfy the established crop nutrient needs and, at the same time, it looks for the lowest cost option. Moreover, the user is informed about possible variations that can appear between the established needs and the programmed nutrient inputs.

The weekly schedule of fertilizer distribution considers their compatibility, thus, either one or two tanks are considered, in order to avoid precipitation. Their volume capacity can be adjusted by the user. Furthermore, in fertigation the economic costs of the different options are included.

The use of the programs is made more friendly and reinforced by the use of coloured boxes. The colours used are the institutional ones from Lleida University and they are introduced associated with their different meanings (black: data filled in by user; yellow: results and advice; pink: the context; salmon: output of program calculations).

For each spreadsheet, the integration of all outputs is presented in a summary table which facilitates comparisons between different scenarios. All screens can be saved in a pdf (Adobe Acrobat Reader©) format.

2.2. Survey design

The population (n = 151) covered by the survey during three academic years was representative of potential users (Table 1). It included undergraduate agricultural students: MSc

Table 1. Demographic and profile characteristics of the respondents (n = 151)

	Mean (± SD)[a]	
Age	25.0 (± 8.5)	
	Responders (total number)	***Responders (%)***
Gender		
Male	97	64.2
Female	54	37.8
Previous studies		
University	51	33.8
Secondary School	93	61.7
Vocational education	7	4.5
Actual activity		
MSc student	17	11.3
BSc student	100	66.2
Advisor-extensionist	15	9.9
Farmer	9	6.0
Others	10	6.6
Population in work environment		
< 1,000	31	20.5
1,000-10,000	59	39.1
10,000-100,000	30	19.9
> 100,000	31	20.5

[a]SD = standard deviation.

or BSc degrees (during the academic years 2013/14, 2014/15 and 2015/16) and agricultural professionals (extension workers, outstanding farmers, etc.) following updated courses during the same period. The size of classes differed, as BSc classes are compulsory and they are attended by an average of 30 students, while other optional courses are followed by 10-15 people. All of them attended problem-solving classes related to the topics of water quality or/and fertigation. They ran the spreadsheet programs in different languages, i.e. different from their mother tongue. They also used the developed tools to tackle different authentic life problems. Participants were asked to voluntarily fill in the questionnaire.

The survey covered questions about the learning benefits experienced by using the developed digital materials (**Tables 2 and 3**), the usefulness of tool components (**Table 4**), and some information about the users' background. The questionnaire was divided into three parts. The first part was devoted to class establishment (**Table 1**). It included some anonymous demographic information and personal data such as gender, age, previous studies and current activities. The second part was devoted to obtaining information about the users' perceptions of the tools. The survey was broken down into 30 questions associated with some statements. Two questions were added about the Catalan chapters but because of their strictly local interest, these are not presented in this paper. The three main evaluated aspects were: 1) technical-scientific content (5 statements); 2) benefits of the developed digital tools in the learning process: pedagogical content (9 statements) and 3) the friendliness of the developed materials when using them in real problem solving: usefulness (16 statements). A general users' tools perception was included in one question asking about general qualification from 1 (very deficient) to 5 (excellent). The respondent could answer the three main aspects by choosing between the following Likert scale: 1 = strongly disagree, 2 = disagree, 3 = uncertain, 4 = agree, 5 = strongly agree. The third part included open questions about the most interesting aspects of the developed tools, their potential improvement and a space for free observations.

Table 2. Frequency of answers included in each box of the Likert scale[a]. The mean value achieved for the statements related to the technical-scientific content of the developed materials is included (n = 151)

Breakdown of the different statements contained in the questionnaire and its associated number	1	2	3	4	5	Mean value
	---------------------------------Frequency (%)-----------------------------					
29. The knowledge provided by the digital tool may be transferable and useful to the agricultural field, i.e., in the real context.	0	1	17	52	29	4.1
30. The program, apart from being effective in calculations, allow the user to be more efficient, which means time and money savings.	0	1	12	53	34	4.2
31. The chance provided in terms of going deeper inside the fertilization or water quality concepts, through the book chapters, is useful.	0	3	20	50	28	4.0
34. The digital tool adapts to the goal of its use, i.e., it helps in optimizing the solution to the raised fertigation or water quality problem.	1	1	16	53	29	4.1
35. The digital tool can be recommended to another partner; e.g., if someone asks you about how to set up a fertigation schedule or evaluation water quality, you will recommend these CD.	0	0	10	52	38	4.3
Total Item						***4.1***

[a]Likert scale: 1 = strongly disagree; 2 = disagree, 3 = uncertain; 4 = agree; 5 = strongly agree. n: total number of responders.

Table 3. Frequency of answers included in each box of Likert scale[a] and mean value achieved for the statements related to the benefits of the developed materials in the learning process: pedagogical content knowledge (n = 151)

Breakdown of the different statements contained in the questionnaire and its associated number	1	2	3	4	5	Mean value
	---------------------------------Frequency (%)-----------------------------					
20. The digital tool is flexible enough to be adapted to the previous knowledge that the user has in relation to the fertigation programming or to the evaluation of water quality.	0	3	23	50	24	4.0
21. The contents of the digital tool help in the acquisition of new technical concepts.	0	3	15	55	27	4.1
22. The contents of the digital tool facilitate the acquisition of problem-solving skills related to the fertigation programming or to the evaluation of water quality.	0	3	20	50	28	4.0
23. The digital tool promotes a reflection on the need to integrate the answers to the diverse problems in the fertigation programming or in the evaluation of water quality.	0	3	26	39	32	4.0
24. The digital tool helps to interrelate different knowledges that are useful for fertigation programming or for the evaluation of water quality.	0	3	22	58	17	3.9

25. The digital tool facilities the independent learning up to the level the user considers necessary and according to his professional activity.	0	9	25	49	17	3.7
26. The digital tool uses an understandable and formative technical vocabulary.	3	2	15	47	33	4.1
27. The digital tool facilities the acquisition of vocabulary related to the topic in other languages.	0	5	17	48	31	4.0
28. The digital tool is useful as an introduction to the ITC (Information and technologies communication) field.	1	7	29	46	17	3.7
Total Item						***3.9***

[a]Likert scale: 1 = strongly disagree; 2 = disagree, 3 = uncertain; 4 = agree; 5 = strongly agree. n: total number of responders.

Table 4. Frequency of answers included in each box of Likert scale[a], and mean value achieved for the statements related to the friendliness of the developed materials when using them (n = 151)

Number and breakdown of the different statements contained in the questionnaire	1	2	3	4	5	Mean value
	--------------------------------Frequency (%)----------------------------					
6. The digital tool is easy to handle as its use does not require specific informatics' background, just the general ability from a person who has a PC computer.	0	6	13	42	39	4.3
7. The digital tool can be used for years (timeless) by the fact that it works on all versions of Excel and it does not require the payment of a specific licence.	2	3	9	43	43	4.2
8. The digital tool is functional because it does not require any special computer support; e.g. it does not need a connection to an external server through Internet.	0	3	11	33	53	4.4
9. The digital tool follows a logical order, i.e. it presents a coherent structure.	0	1	10	47	42	4.3
10. The computing environment is simple, it only needs a few data which are essential but which can be easily obtained by the user.	0	1	15	44	40	4.2
11. The results (program outputs) are introduced simply, being easy to interpret.	0	2	13	52	33	4.2
12. It is easy to scroll from one screen to another (navigation system).	0	0	8	44	48	4.2
13. Each screen displays enough information about which program step is going on.	0	1	9	60	30	4.2
14. Each screen helps to understand what is being calculated.	0	2	15	53	31	4.1
15. In each screen, the information density is the appropriate.	0	3	19	52	26	4.0
16. Within each screen, the additional information is easily accessible.	0	3	12	48	36	4.2

17. The answer time (solution) for each issue is fast enough.	0	3	15	36	46	4.2
18. The parameters modification, when looking for alternative solutions to the initial one, it is easy to perform.	0	3	21	50	27	4.0
19. The system alarm about potential errors in the problem approach or in the introduction of data is visible enough.	0	9	19	45	27	3.9
32. The introductory citations and pictures, in each of the book chapters, help to look at the problem transversely and they motivate further interest for the subject.	0	3	24	47	26	4.0
33. The CD format, which includes the separation of the program and the textbook chapters, it is easy to handle.	0	3	23	50	24	4.0
Total Item						***4.2***

[a]Likert scale: 1 = strongly disagree; 2 = disagree, 3 = uncertain; 4 = agree; 5 = strongly agree. n: total number of responders.

2.3. Statistical analysis

The main three assessment aspects (technical-scientific content; pedagogical content and the usefulness of digital tools) were evaluated by analysis of variance (General Linear Model procedure or GLM), according to the users' classes: gender (male, female), age, previous studies and current activities (Table 5). Age classes were established in four intervals: < 25 years old, ≥ 25-35 years old, ≥ 35-45 years old and ≥ 45 years old which were more or less associated with the period of their careers (students, young professionals, "pushing" professionals who represent the renewal of professional lines, senior professionals). Previous studies were divided into three classes: University studies (with a BSc, MSc or PhD degree), Secondary school studies (it includes current BSc students) and higher training studies (Vocational education that can also include BSc students). Current activity was divided into MSc or BSc students and into extension workers, outstanding farmers and other professionals.

When the analysis of variance was significant, pair comparisons were established between classes using the least significant difference (LSD) test. The statistical analysis was performed using the statistical package SAS v9.4 (SAS Institute Inc. 2002-2012).

3. Results and discussion

The mean age of responders was 25 years old (**Table 1**). The majority were male (around 64%, **Table 1**) which is not unusual in Spanish engineering studies (MECD 2015) nor in agronomic engineering studies more focused on field problems than on economics or laboratory problems. A great part of them (> 75%) had previous university studies or they were following masters or BSc degrees. The main activity of responders was BSc studies. The rest of the responders were well balanced between the remaining options (**Table 1**). The population size of the city linked to their agricultural engineering activity (practical work for students) was mainly between 1,000 and 10,000 inhabitants (40%), which is the common size of villages, in the area of Lleida university influence, with an important agricultural activity. The other options had a similar percentage, around 20% (**Table 1**).

3.1. Assessment of the digital tools

The assessments, from all responders (n = 151), were divided into three main issues: technical-scientific content, benefits of the developed materials in the learning process or pedagogical content knowledge, and their friendliness for the users.

Technical-scientific content

The mean score for the users' perception of the technical and scientific significance of developed materials had a value of 4.1. In all statements, the frequency of 4 and 5 scores (4 = agree and 5 = strongly agree) surpassed 78%. Responders were confident in the use of such materials in the real-life context. They viewed the additional documentation as an aid to go further with the case study. As a consequence, they felt positive about recommending their use (**Table 2**), also because of time and money savings.

Benefits of the developed digital tools in the learning process: pedagogical content

The benefits of developed materials in the learning process had an average score of 3.9 (**Table 3**). The highest scores (4.1) were related to the acquisition of new technical concepts and technical vocabulary. Response data showed that the users were strongly engaged in the problem-solving skills related to the fertigation programming or to the evaluation of water quality. There was a strong agreement among them that the developed materials reinforced learned theory with practice. Students embraced this approach and they developed a sense of confidence in their ability to programme fertigation on a field basis. The fact that the task was from real life, gained their interest more strongly than would a traditional lecture solving questions on the blackboard. The score for the acquisition of technical vocabulary in other languages, which is important in the world global context, averaged 4.0 (**Table 3**).

The friendliness of the developed digital tools

The usefulness of the digital aspects had the average score of 4.2. The highest scores (**Table 4**) were associated to the functionality of the digital tools (4.4), the logical order or the coherent structure of the DT (4.3) and the "friendliness" aspect when handling them (4.3). Users were overwhelmingly positive about the ability to download the spreadsheet program because in this way they can work anywhere, especially in the countryside, without being limited by internet connexions which are not always present or which may have a limited availability in Spanish rural areas.

3.2. Evaluation of digital tools according to the users' classes

Questionnaires' answers were analysed according to the different users' classes or groups (**Table 5**) which included: gender (**Figure 4**), age (**Figure 5**) previous studies (**Figure 6**) and current activity (**Figure 7**). Statements were split in the three main evaluation aspects described in the survey design plus a general perception.

Gender had a significant effect ($p < 0.05$) on the scores for friendliness and usefulness of the developed DT (**Figure 4**). The female score averaged 4.3 while male score averaged 4.1. Various reasons can explain these results. One reason could be that as the male gender is more fascinated with technology (McIlwee and Robinson 1992) they already know of other more elaborated resources. Another reason could be that females appreciate tools that can save time in their activities. The age range (**Figure 5**) influenced the assessment score. The youngest (< 25 yr old), always gave lower scores than people from the next "year interval" of young professionals (25-35 yr old) probably because as they are still university students, and they have not yet faced real professional problems. We also found that the students evaluated the friendliness-usefulness of the tools similarly to the eldest group of people (> 45 yr old), although difficulties can have different reasons. In the pedagogical content they also gave the lowest score, which can be partially attributed to the complexity of learning new engineering technologies, while elder interviewees have a wider knowledge of the subject. This aspect was noticed by Durward and Vikas (2004) who stated some constraints in the problem-solving learning method and established the need to well-advise students to understand why/how they work.

Table 5. Analysis of variance (GLM procedure) of the technical-scientific content, pedagogical aspects and friendliness of the developed digital tools according to user's classes: gender, age, previous studies and current activity

Source	DF	Sum of squares	Mean square	F-value	Pr > F
The technical-scientific content					
Gender	1	0.090	0.090	0.38	0.54
Age	3	2.209	0.736	3.27	0.02
Previous studies	2	2.656	1.326	6.02	0.003
Current activity	4	4.469	1.117	5.29	0.0005
Pedagogical content					
Gender	1	0.024	0.024	0.09	0.76
Age	3	5.463	1.821	7.94	< 0.0001
Previous studies	2	3.354	1.677	6.93	0.001
Current activity	4	4.960	1.240	5.29	0.0005
The friendliness of use					
Gender	1	1.064	1.064	5.51	0.02
Age	3	3.346	1.153	6.19	0.0005
Previous studies	2	4.671	2.336	13.74	< 0.0001
Current activity	4	4.336	1.084	6.21	0.0001
General					
Gender	1	0.092	0.092	0.29	0.59
Age	3	1.365	0.455	1.46	0.23
Previous studies	2	0.984	0.492	1.58	0.21
Current activity	4	2.570	0.642	2.11	0.08

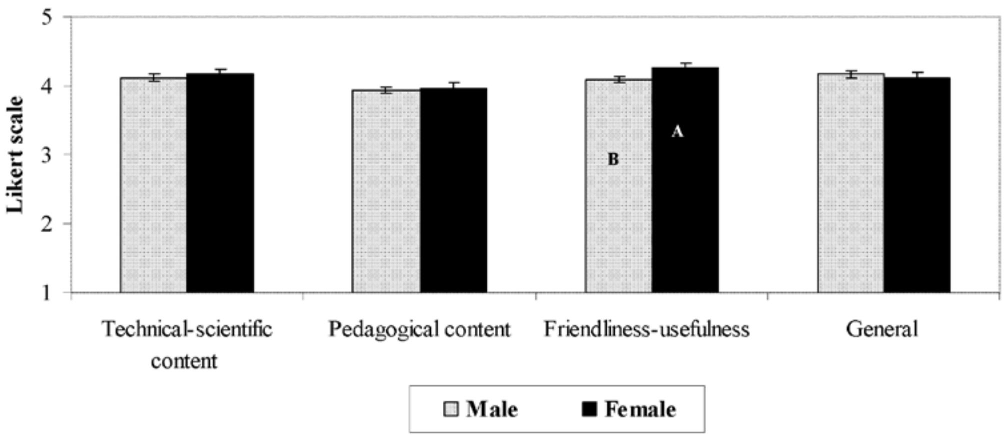

Figure 4. Mean value in Likert scale, according to gender classes, of the different evaluated aspects: technical-scientific content, pedagogical content, friendliness-usefulness and a general assessment of the digital tools in real-life solving-problems. Likert scale: 1 = strongly disagree; 2 = disagree, 3 = uncertain; 4 = agree; 5 = strongly agree. Bars indicate standard error of the mean. Male number: 97, Female number: 54. Within columns, each pair of means followed by different letter are significantly different according to the least significant difference test (α = 0.05).

Similar evaluations were obtained when answers were arranged by previous studies (**Figure 6**), with the lowest scores for a group with a secondary school education (the youngest) who are following the BSc level. The opposite was recorded from the answers of people with a university degree. For students in regular courses, the technical contents seem to be rated equal to some added lectures that they receive along with their degrees, although they are trained in the use of digital tools.

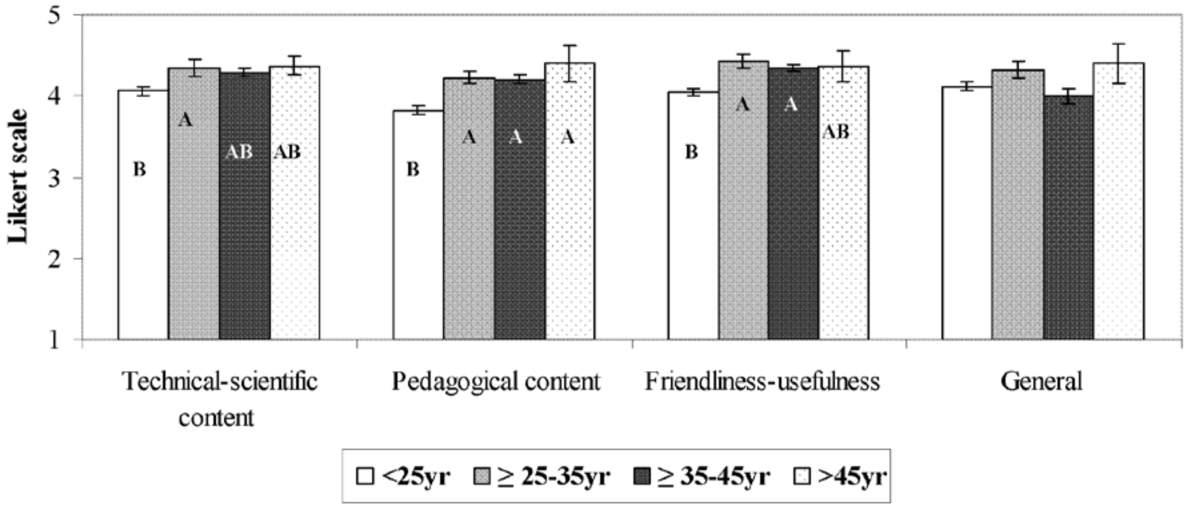

Figure 5. Mean value in Likert scale, according to the age of responders, of the different evaluated aspects: technical-scientific content, pedagogical content, friendliness-usefulness and a general assessment of the digital tools in real-life solving-problems. Likert scale: 1 = strongly disagree; 2 = disagree, 3 = uncertain; 4 = agree; 5 = strongly agree. The bars indicate standard error of the mean. Number of responders: 108, 22, 16 and 5 from < 25, ≥ 25-35, ≥ 35-45, > 45 years old, respectively. Within columns, each pair of means followed by different letter are significantly different according to the least significant difference test (α = 0.05).

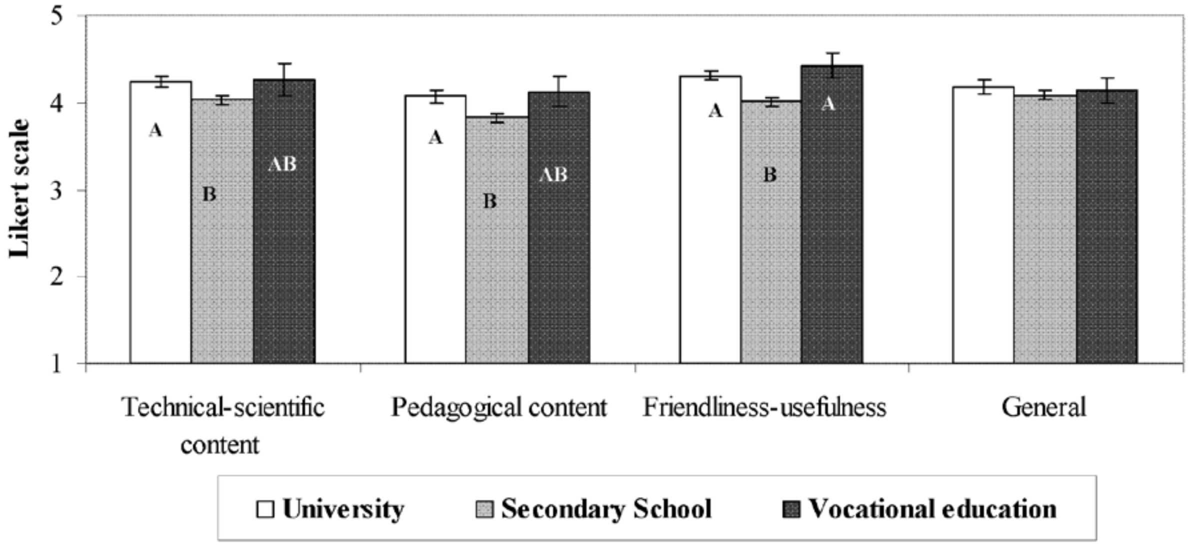

Figure 6. Mean value in Likert scale, according to previous studies of responders, of the different evaluated aspects: technical-scientific content, pedagogical content, friendliness-usefulness and a general assessment of the digital tools in real-life solving-problems. Likert scale: 1 = strongly disagree; 2 = disagree, 3 = uncertain; 4 = agree; 5 = strongly agree. The bars indicate standard error of the mean. Distribution of responders is presented in Table 1. Within columns, each pair of means followed by different letter are significantly different according to the least significant difference test (α = 0.05).

The higher scores given by farmers reinforce the practical usefulness of the tools and the comprehensible way in which they are presented. The professionals who are dealing with extension or with real-life problems also gave scores higher than did the BSc students (Figure 7), probably because they are updating their knowledge, but not all the contents are completely new to them. Despite the non-significant differences between classes in the general appreciation, scores were located in the upper range (Figure 7), demonstrating the usefulness of the materials and their pedagogical content.

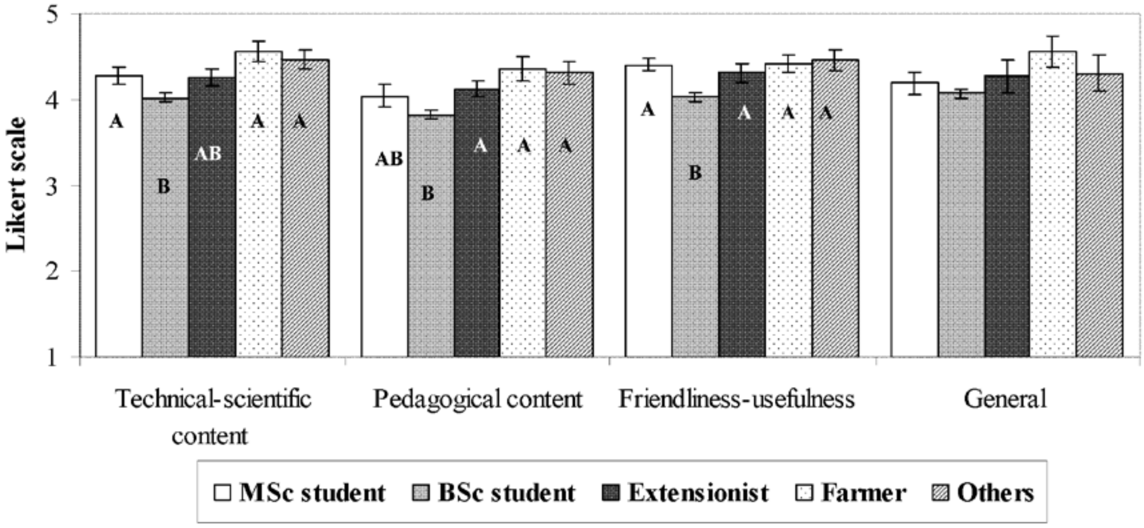

Figure 7. Mean value in Likert scale, according to the actual activity of responders, of the different evaluated aspects: technical-scientific content, pedagogical content, friendliness-usefulness and a general assessment of the digital tools in real-life solving-problems. Likert scale: 1 = strongly disagree; 2 = disagree; 3 = uncertain; 4=agree; 5=strongly agree. The bars indicate standard error of the mean. Distribution of responders is presented in Table 1. Within columns, each pair of means followed by different letter are significantly different according to the least significant difference test (α = 0.05).

The general users' perception of digital tools is that they are more challenging than traditional formats. The digitally-presented materials help the formal lectures in the guidance of the learning process (on the constructivist principle) providing a more enriched learning environment (Nordhoff 1999; Alston and English 2007), and prepared the users for problem solving in professional life. This point is reinforced by the fact that people with a university degree or outstanding farmers gave higher scores to the DT than BSc students, probably because they appreciate DSS as support to obtain quick and clear results (Table 6). An important factor for these responders is that they are not only facing the complexity of water and fertigation management in a real agricultural context. The assumption of the additional economic risk of decisions is included in their work.

Table 6. Free comments of the users grouped in two questions

Questions	Comments [a]
Which aspects do you consider as the most relevant?	- Easy to use. Results are obtained quickly and clearly (38) - Learning through solving real-life problems (35) - Optimization (agronomic and economic) in the use of resources (water and fertilization) (20)
Which aspects need some improvement or would you add?	- Inclusion of more nutrients in the fertigation programming (9) - Inclusion of the option to mix waters of different quality for irrigation (10)

[a]Numbers in brackets refer to the number of users who filled the boxes for free comments.

4. Conclusions

The digital tools materials developed were successfully used as flexible learning tools for students following regular courses and also for agricultural professionals in life-long learning courses. They were appreciated by users, as the score given to the various evaluated assessments was between 3.9 and 4.2 out of 5 (the positive and maximum appreciation), and for individual questions between 3.7 up to 4.3.

The feedback obtained in the survey confirmed that the tools were friendly to use, as the structure of materials was very intuitive and easy to handle, although this last point was more appreciated by female than by male gender interviewees. The spreadsheet programs applied in the context of real evaluation of water for irrigation and fertigation programming were found to be of benefit.

As hypothesized, it facilitated their use as decision support systems in the agricultural sector (mainly in the 25-45 yr old age group) where it was more appreciated than in the university campus itself. This finding also justifies encouraging Spanish universities to disseminate such materials to professionals.

The practice in reaching decision-making points, supported by "theoretical contents through help windows", reduced lecturer input outside of class time to support student learning. The reduction of time invested in routine calculations allowed users to efficiently work in further and different case management scenarios within the time constraints for different lectures within a subject. Students were so actively engaged in solving real-life problems that the difficulties of working in foreign languages were overcome without much difficulty. As it was always possible to simultaneously run a version in their mother tongue, doubts related to foreign agricultural terminology were instantly solved. This feature helped in the improvement of their language skills and was also appreciated for professionals. We found that users are highly demanding and that they would like an extension of the possibilities offered by the developed digital materials in the new versions of the developed digital tools.

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