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Physics and Mathematics in the Engineering Curriculum: Correlation with Applied Subjects*

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This paper presents a study in which the relationship between basic subjects (Mathematics and Physics) and applied engineering subjects (related to Machinery, Electrical Engineering, Topography and Buildings) in higher engineering education curricula is evaluated. The analysis has been conducted using the academic records of 206 students for five years. Furthermore, 34 surveys and personal interviews were conducted to analyze the connections between the contents taught in each subject and to identify student perceptions of the correlation with other subjects or disciplines. At the same time, the content of the different subjects have been analyzed to verify the relationship among the disciplines. A proper coordination among subjects will allow students to relate and interconnect topics of different subjects, even with the ones learnt in previous courses, while also helping to reduce dropout rates and student failures in successfully accomplishing the different courses.

Keywords: curriculum design; higher education; Bologna Declaration; engineering degrees

1. Introduction

Degree programs in Agricultural Engineering are the oldest ones in the higher education system in Spain. They began to be taught in the early nineteenth century, and they were essential degrees, focusing on agricultural practice and livestock. Thus, these degrees were initially based on the primary sector (agriculture, livestock and food), although their contents have later been expanded to cover new specialties (environment, gardening and landscaping, for example) according to the new economic and social demands. According to Fahey [1], educational programs focusing on multidisciplinary areas must train future professionals to manage problems that are not yet known to be problems. In this sense, in engineering studies it has been observed that employing learning methodologies far from real engineering problems reduces the motivation of students, leading to an early drop out of the study system [2]. Therefore, new specialties have emerged in recent years aiming to cover various issues, such as environment and ecology, among others.

Even today, two degrees in Agricultural Engineering are still being offered in Spain, from the old curricula system before the new degrees implemented in the framework of the European Higher Education Area (EHEA) were started: a five-year scientific bachelor's degree (Agricultural Engineering, taught at the Higher Technical School of Agricultural Engineering) corresponding to the 1996 study plan program offered at the Technical University of Madrid; and a three-year technical program (Technical Agricultural Engineering degree, University School of Technical Agricultural Engineering) from the 1999 study plan also offered at the Technical University of Madrid. Both programs will coexist (until they are completely phased out) with the new four-year bachelor's degrees introduced in 2010, following the Bologna process. Both programs were designed in response to the need to improve agricultural techniques through technology to achieve higher crop yields [3]. Accordingly, the profession of Agricultural Engineer is similar to the European profile, including degrees in biological system engineering, biosystems engineering or environmental engineering, and concerned with engineering focused on living beings or the environment [4–7].

An important aspect to be emphasized is that these degrees covered not only agricultural pro-

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cesses, such as plant breeding, plant production, animal production and agricultural mechanization, but also food processing and the design of infrastructures through subjects such as Food Technology, Agribusiness and the Construction of Rural Buildings. As a result, these engineering studies have many parts in common with other engineering degrees, such as Electrical, Civil Engineering or Architecture.

Therefore, despite having a significant biological and/or biochemical component, these engineers also solve problems ranging from structural building calculations, to design and calculation of facilities (e.g. electrical engineering or hydraulics), or design and calculation of machinery, topography and mapping, among others. To be successful in these applied subjects, a minimum number of hours of instruction are needed [8], but they also require an appropriate knowledge of basic subjects, such as Physics and Mathematics, as well as Biology, Botany, Agricultural Chemistry, Soil Science or Biochemistry. These form the basis of the engineering competences.

Mathematical modeling provides an essential tool for development in other subjects [9–11]. Physics is needed in formulations for describing real phenomena. Countless studies have shown that physics and mathematics are essential in an engineering degree [12, 13], and even the students' performance in Maths courses may indicate the trend toward overall performance in the program of studies [14].

Basic subjects are usually covered in the first years of the syllabus of an engineering degree program, leaving specific engineering subjects for later [8, 15]. A common problem is the development of degree programs where basic and applied subject contents are designed and programmed separately [16, 17]. As a result, students are unable to interrelate concepts, which negatively affects the teaching–learning process and also discourages students, decreasing their grades [18]. Other factors that can explain the poor grades obtained in basic subjects are the inadequate learning strategies adopted by students during lectures [19], the lack of spatial representation abilities needed to acquire the expected mathematical problem-solving ability [20], or deficiencies in the most important variables used for solving physics problems [21].

Some teaching teams have developed educational alternatives to traditional teaching in order to avoid this, further motivating students and integrating mathematics and physics contents in the engineering practice [22]. For example, innovative methodologies, such as problem-based learning (PBL), have been used in many universities to integrate basic and applied subjects to solve real problems [23–25]; PBL has been used to encourage cooperative work [17, 23, 26], where a project is used to integrate competences; and the so-called 'Just in Time Teaching' (JiTT) has been employed [27] to explain the contents of basic subjects while introducing the directly related concepts of applied subjects.

Case study learning strategies have revealed the possibility of integrating knowledge in a professional based context, which is very useful for engineering studies [28]. Moreover, coaching strategies are now also being implemented in higher education environments for both the holistic growth of students [29] and the improvement of teachers' skills [30]. Computing is introduced into the area of physics, through virtual laboratories, trying to improve computer skills [31, 32]. Students from Chalmers University of Technology in Sweden used Matlab software to solve mathematical problems [8]. Olds and Miller [33] proposed what they called the Connections Program, in which first-year students at Colorado School of Mines rounded off their academic education (Physics, Mathematics, Chemistry, Earth sciences and Economics) with engineering practices (Engineering Practices Introductory Course Sequence called EPICS).

Other suggested options are laboratory practice or projects [16] or the organization of competitions requiring multidisciplinary knowledge [25, 34]. One example of this methodology is the international agricultural robotics contest [35], sponsored by the Technical University of Madrid, where organized groups of students trained in different disciplines have to design and build a robot with specified characteristics. Other experiences have also been designed to motivate and recruit future engineers, e.g. students were asked to explain certain historical events, such as the sinking of the Titanic or the Columbia space shuttle explosion, by using physics laws and equations [34].

Chow et al. [36] found that the mismatch between the teaching contents of basic and applied subjects is sometimes caused by the continuous changes in society and technology, requiring feedback between science, mathematics and engineering [22, 37]. If there is a lack of correlation, the teachers designing the subjects should reconsider the needs in order to redefine the curriculum and apply mathematics and physics as tools for solving engineering problems [38] and, if possible, include tools that support the integration of more than one subject [8].

The main aim of this study is to assess whether students well trained in basic subjects also achieve good results in applied subjects, and to explore the correlations existing between the basic subjects named Physics I, Physics II, Mathematics I and Mathematics II with some engineering applied subjects (Agroindustrial Engine and Machinery,

Table 1. Number of credits per subject included in the different 1999 degree study programs

	Agroindustries			Agricultural Mechanization and Rural Buildings			Gardening and Horticulture			Crop and Animal Production		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Basic subjects												
Physics	12.0			12.0			10.5			10.5		
Mathematics	10.5	4.5		15.0			15.0			15.0		
Basic engineering subject (technical drawing)	4.5			4.5			4.5			4.5		
Other basic life or environmental science subjects	37.5			39.0			37.5			36.0		
Applied subjects												
Subjects applied to engineering	6.0	31.5	18.0		49.5	18.0	7.5	16.5	12.0	7.5	22.5	6.0
Subjects applied to life or environmental sciences		30.0	9.0		16.5	16.5		48.0	18.0		39.0	25.5
Economics			9.0			9.0			9.0			9.0
No. credits of core and compulsory subjects		172.5			180.0			178.5			175.5	
Optional and free-electives		67.5			60.0			61.5			64.5	
No. total credits		240			240			240			240	

Agroindustrial Buildings, Electrical Engineering, Geomatics[1], Agricultural Engine and Machinery, Agroindustrial Buildings, Design and Calculation of Structures) in the Technical Agricultural Engineering degree taught at the Technical University of Madrid. The global aim is to improve the relationship between the two groups of subjects, trying to coordinate the discipline contents in order to develop a program of basic and applied subjects that is consistent with the social needs. The contents of these subjects have been included at the end of this paper in order to facilitate comprehension by the reader.

1.1 Characteristics of the evaluated degree (1999 Technical Agricultural Engineering degreeprogram)

The Technical Agricultural Engineering degree (a 1999 degree program to be phased out) that we are going to analyze is taught at the Technical University of Madrid (University School of Technical Agricultural Engineering). This study uses data from this degree program because a highly significant number of graduates have completed the degree. Furthermore, this study is potentially useful for improving the learning guides of the new degree being introduced.

With a total of 240 credits (one course credit is equivalent to ten hours of classroom teaching), the degree includes four specific fields of study or specialities in the degree program (Agricultural Mechanization and Rural Building (AMRB), Agroindustries (AI), Gardening and Horticulture (GH), and Crop and Animal Production concentration (CAP)), which share the same basic subjects of Mathematics and Physics, and differs in the applied subjects.

Each speciality is distinguished by its clear specialization in certain subjects. Table 1 shows the credits/subjects breakdown by speciality, year and type. This table has been elaborated from data degrees available at the website of the University School of Technical Agricultural Engineering (2014) [39]. Credits for mathematical topics are the same across all four specialties (15.0 credits); physics credits are slightly higher in the AMRB and AI specialties (12.0 credits, compared with 10.5 in GH and CAP). As a basic engineering subject, Technical Drawing has also been included. This subject is traditionally taught at all engineering degrees. It is included therefore, in all fields of study or specialities. At the same time, other basic life or environmental science subjects were included, such as Botany, Chemistry, Animal Production or Biology. Within the disciplines applied to engineering, subjects such as structural Design, Electric, Hydraulic and Irrigation or Projects were included. In the same way, within the group of subjects applied to life or environmental sciences, subjects such as Crop Production, Field Crops and Plant Protection were included.

The specialities lines with more credits for engineering subjects (Agroindustrial Engine and Machinery, Electrical Engineering, Geomatics and Agroindustrial Buildings) are AMRB and AI, with 72.0 credits and 60.0 credits, respectively, when compared with the other two specialities lines, with 40.5 credits in both cases.

[1] Geomatics, which is also known as geospatial technology or geomatics engineering, is the discipline for gathering, storing, processing, and delivering of geographic information, or spatially referenced information.

In contrast, the two specific lines with a greater engineering subject workload (AMRB and AI) are less concerned with matters related to biological production and environment. Likewise, subjects such as Biology, Crop and Animal Production, Genetics and Breeding are more important in the GH and CAP concentrations, where the workload for these and other related subject totals 103.5 credits and 100.5 credits, respectively.

As a synthesis of all subjects studied and as part of the degree program, students of all specialities lines must complete a compulsory final project. This professional or research work may take the shape of a final technical project or degree thesis.

1.2 Evolution of the Technical Agricultural Engineering degree: design according to the Bologna process

The Bologna Declaration [40] set up a European Higher Education Area (EHEA) whose objectives are to facilitate the mobility of students and professionals among European countries, promoting competitiveness and internationalization, and improving professional skills [37, 41]. This called for a transformation of the higher education system, which has been carried out in recent years and which will result in the current program of studies (the 1999 degree program in the case of the Technical University of Madrid, Technical Agricultural Engineering degree being phased out and the new program of studies adapted to the Bologna process being designed).

In this context, the Technical University of Madrid has designed three four-year degrees (240 European Credit Transfer System, ECTS) that will replace the Technical Agricultural Engineering degree in the EHEA and provide graduates with direct access to the Master's program in the same area. The new degrees are:

- Degree in Engineering and Agricultural Science, specialized in planning, design and implementation of agricultural production and rural infrastructures.
- Degree in Food Engineering, specialized in planning, design and implementation of production processes in the food industry.
- Degree in Agricultural Engineering, specialized in planning, design and implementation of Crop and Animal Production.

Furthermore, a Master program in Agricultural Engineering has been designed. This two-year Master's degree (120 ECTS) also complies with the EHEA guidelines through the Spanish official higher education organization and planning.

2. Materials and methods

Lecturers from three different Technical University of Madrid departments ('Rural Engineering', 'Cartographic Engineering, Geodesy and Photogrammetry-Graphic Expression', and 'Science and Technology Applied to Agricultural Engineering'), and three prestigious educational innovation groups (EIG) ('Electrical Technologies and Automatic of Rural Engineering', 'Physics and Mathematics applied to Agricultural Engineering' and 'Innovative Teaching Techniques applied to Agricultural Engineering Training' Educational Innovation Groups) worked together in this study. The study was carried out on a total of 206 students from the two specialities of the 1999 Technical Agricultural Engineering degree program with most engineering contents: Agricultural Mechanization and Rural Buildings specialty (AMRB) and Agroindustries specializing line (AI). The students were 2005–2009 graduates, inclusively. The study aimed to relate student outcomes in the basic technical subjects (Physics I, Physics II, Mathematics I and Mathematics II) to some applied subjects (Agricultural Engine and Machinery, Agroindustrial Buildings, Electrical Engineering, Geomatics, Agroindustrial Engine and Machinery, Structures Design and Calculation) in the Technical Agricultural Engineering degree offered by the Technical University of Madrid. These applied subjects were selected based on their technical importance in the agricultural area, considering *a priori* that they rely on the contents of basic subjects mentioned above. Table 2 lists the characteristics of these subjects. The term 'Core' refers to those subjects that had to be included in every degree study program for 'Technical Agricultural Engineering' developed at any Spanish University. On the other hand, the term 'compulsory' refers to those mandatory subjects defined by the university developing the degree study program. So, a 'compulsory' subject is not necessarily required to be a mandatory subject in other curricula developed by other universities. This table has been elaborated from the syllabi of both specialities, available on the website of the University School of Technical Agricultural Engineering (2014).

A database was built that included both student data (age, sex, year of admission in the degree, year of degree completion, excluding the final project, year of the final project and grade) and data related to student performance in the analyzed subjects (pass grade, years to complete subject, number of attended exams, number of unattended exams). Of a total of 216 records, some atypical records were removed, leaving a total of 206 cases included in the study: 84 were graduates of the AMRB specialty,

Table 2. Characteristics of the subjects covered by the study in the 1999 agricultural technology degrees of AI and AMRB

	Agroindustries (AI)			Agricultural Mechanization and Rural Buildings (AMRB)		
	Year	**Credits**	**Type**	**Year**	**Credits**	**Type**
Mathematics I	1	6.0	Core	1	6.0	Core
Mathematics II	1	4.5	Core	1	4.5	Core
Physics I	1	6.0	Core	1	6.0	Core
Physics II	1	6.0	Core	1	6.0	Core
Geomatics	1	6.0	Core	2	9.0	Core
Agroindustrial engine and machinery	2	6.0	Core	–	–	–
Agricultural engine and machinery	–	–	–	2	7.5	Core
Electrical engineering	2	6.0	Core	2	4.5	Core
Agroindustrial buildings	3	6.0	Compulsory	–	–	–
Design and calculation of structures	–	–	–	2	7.5	Core

and 122 of the AI specialty. All the students whose data were considered for this study were 2005–2009 graduates. Subject academic performance rates were calculated from the database (average efficiency rate: inverse of the number of years taken to pass the subject). Correlations between the number of years to pass the basic and applied subjects and between the average grades for these two groups of subjects were also calculated. In addition, we obtained the p-value to test the hypothesis of whether the correlation between these variables is different from zero. P-values lower than 0.05 indicate correlations significantly different from zero, with a confidence level of 95.0%.

This same study could be conducted in the future with other subjects covered by the curricula specializing in biological production and the environment.

2.1 Relationship between the contents of basic and applied subjects

The design of a study program for a degree is always difficult, but it is an especially complex task if a wide range of knowledge areas need to be covered, such as technical drawing, plant production, construction or microbiology. The subjects should include a number of contents needed to develop specific skills. However, they are often designed without a clear perspective of their possible influence on other subjects that are taught later in the program of studies, or the competences needed in a professional career. Therefore, in order to identify whether the contents of the basic subjects covered in this study are useful in some applied subjects, lecturers identified the physics and mathematics contents involved in the subjects taught. In this way, parts of the applied subjects that needed previously introduced and taught concepts in the basic subjects were analyzed.

2.2 Student perception

Very frequently, and already from very early on in their degree, students often question the importance of basic subjects for the development of their future career. A number of basic subjects are taught during the first year, which usually coincides with the highest academic failure and dropout rate, and, in some cases, no mention is made of their future applications.

During the 2011–12 academic year, 34 final-year Technical Agricultural Engineering degree students (11 AMRB students and 23 AI students) were surveyed and interviewed about their perceptions of the applicability of Physics I, Physics II, Mathematics I and Mathematics II to the applied subjects covered in the study: Agricultural Engine and Machinery, Electrical Engineering, Geomatics, Design and Calculation of Structures in the case of the AMRB specialty, and Agroindustrial Engine and Machinery, Agroindustrial Buildings, Electrical Engineering and Geomatics for the AI specialty. It is important to note that the subjects 'Design and Calculation of Structures' and 'Agroindustrial Buildings' have a similar content for both specialities lines, despite having a different name. Thus, the term 'Construction' will be used hereafter to refer to these subjects, adding in parenthesis the abbreviation for the specialty considered in each case. For the same reason, the term 'Engine and Machinery' will be used to replace 'Agroindustrial Engine and Machinery' and 'Agricultural Engine and Machinery'.

Respondents entered grades, number of exams taken and years completed to pass each subject in the surveys. They also stated their opinion on the linking strength between basic and applied subjects (1: totally unrelated, 5: totally related). In addition, different opinions on this relationship were gathered in these interviews with students.

3. Results and discussion

3.1 Correlation between basic and applied subjects

The mean efficiency rates for each subject and specialty are shown in Table 3. The efficiency rate

Table 3. Mean efficiency rates obtained for the subjects considered in the study

Subjects	Specialties	
	AMRB	AI
Physics I	0.31	0.28
Physics II	0.41	0.44
Mathematics I	0.27	0.22
Mathematics II	0.28	0.26
Engine and Machinery	0.25	0.30
Electrical engineering	0.49	0.50
Construction	0.42	0.34
Geomatics	0.26	0.48
Mean efficiency rate	0.34	0.35
Standard deviation of efficiency rate	0.09	0.11
Coefficient of variance (%)	26.9	30.3

for an individual student is obtained as the inverse of the total number of examinations taken to pass the subject. Thus, the efficiency rate obtained for any subject is the mean value of the efficiency rates of all the students considered in the analysis. Table 3 shows that the lowest efficiency rate in AMRB is for an applied subject (Agricultural Engine and Machinery (0.25)), whereas the lowest rate for an AI specialty corresponds to a basic subject (Mathematics I (0.22)).

We analyzed the correlations between the number of years taken to pass the basic and applied subjects and between the average grades gained in these two subject groups. In the case of the AMRB specializing line, there were weak relationships between the variables. For example, the highest ratio between Mathematics I and the other basic variables was between Mathematics I and Mathematics II with a correlation coefficient of 0.29.

Coefficients were also low regarding applied subjects, suggesting that there is not a significant relation between subjects. The highest determination coefficient (0.34) was obtained between the basic subject Physics I and the applied subject Geomatics, with a p-value of 0.0014. Weak relationships were found between Mathematics II and Electrical Engineering (correlation coefficient of 0.33 and p-value of 0.0017) and Physics II and Electrical Engineering (correlation coefficient of 0.29 and p-value of 0.0078).

For the AI specializing line more, albeit weak, relationships were found between these variables than for the AMRB specialty. In this AI major, the highest coefficient of determination was between Physics II and Geomatics, where the value of the determination coefficient was 0.40; between Physics I and Geomatics, where the value was 0.39. The correlations between the basic subjects and Electrical Engineering were significant: 0.35 with Physics I, 0.34 with Mathematics II and 0.34 with Physics II.

Another variable studied was the average grade for the basic and applied subjects. For both specializing lines, the average grades for the basic subjects were slightly lower than for the applied subjects.

Taking into account the number of years enrolled to pass the subject, it took an AMRB student on average 6.4 years to pass the worst subject (where worst subject means the subject that took the student the longest time to pass) and 4.7 years to pass the second worst subject. An average AI student took 6.1 years to pass the worst subject and 4.7 years to pass the second worst subject. These two subjects were often Mathematics I and Mathematics II, followed by the combination Mathematics I and Engine and Machinery (AI specialty). These correlations suggest that Mathematics I and Engine and Machinery (AI), and Physics I and Construction (AI) were related regarding time to successfully pass the subjects. However, data showed no clear relationships between basic and applied subjects. The correlation coefficients between the number of years for the worst subjects was 0.27 (between Mathematics I and Mathematics II).

Data showed higher determination coefficients between the total number of years to pass the basic subjects (Mathematics I, Mathematics II, Physics I and Physics II) and the total number of years to complete the degree (0.46 for AMRB, and 0.46 for AI); and between the total number of years to pass the analyzed applied subjects and the total number of years to complete the degree (0.38 for AMRB, 0.40 for AI). The four basic subjects studied here account for much (about 45%) of the time taken in years to complete the whole degree. The percentage of the time taken by a student to pass the evaluated degree programs increases by up to 60% if the four applied subjects considered in this study are also included. However, the correlation was again very low between the total number of years to pass the basic subjects, and the total number of years to pass the applied subjects (0.11 for AMRB, 0.14 for AI).

Summarizing, the results of this part of the study did not reveal any potential relationships between the learning outcomes of the students in basic and applied subjects, nor did it show high values of the correlation coefficient between the parameters of the two subject groups (basic and applied).

3.2 Relationships between contents of basic and applied subjects

Lecturers involved in the study identified the contents of each basic subject that were applied to Electrical Engineering, Engine and Machinery, Construction and Geomatics subjects, respectively (Tables 4–7). Units of the basic subjects employed in applied subjects are highlighted in bold type throughout Tables 4–7, while units of the applied subject using the corresponding unit of the basic subject are mentioned in parenthesis. For example, '*Unit 2. Vector analysis*' taught in the basic subject 'Physics I' is used for the units 2 (Single-phase alternating current), 3 (Three-phase alternating current) and 4 (Lines and distributions) of the applied subject 'Electrical Engineering' (Table 4). The units of these subjects have been included at the end of the paper to facilitate comprehension by the reader.

As a whole, applied subjects included in the study cover most of the subjects taught in Physics I but not

Table 4. Relationship between the basic subjects considered in the study and the applied subject 'Electrical Engineering'.

Basic subjects	Units related with Electrical Engineering subject
Physics I	**Unit 2. Vector analysis** (Unit 2. Single-phase alternating current. Unit 3. Three-phase alternating current. Unit 4. Lines and distributions)
	Unit 7. Work and Energy (Unit 1. Fundamentals and electrical safety. Unit 2. Single-phase alternating current. Unit 3. Three-phase alternating current. Unit 4. Lines and distributions. Unit 5. Measurement and protective equipment. Unit 6. Lighting technology)
	Unit 12. Electric current (Unit 1. Fundamentals and electrical safety)
	Unit 13. Circuits (Unit 1. Fundamentals and electrical safety)
	Unit 14. Electromagnetism (Unit 1. Fundamentals and electrical safety)
	Unit 16. Electromagnetic induction (Unit 1. Fundamentals and electrical safety)
	Unit 17. Alternating current (Unit 1. Fundamentals and electrical safety. Unit 2. Single-phase alternating current. Unit 3. Three-phase alternating current)
	Unit 18. Generators and engines. Three-phase current (Unit 1. Fundamentals and electrical safety. Unit 3. Three-phase alternating current)
	Unit 19. Semiconductors (Unit 6. Lighting technology)
Physics II	**Unit 5. Vibrations and waves** (Unit 1. Fundamentals and electrical safety. Unit 5. Measurement and protective equipment)
	Unit 6. Waves (Unit 1. Fundamentals and electrical safety. Unit 5. Measurement and protective equipment)
Mathematics I	**Unit 1. Vector spaces** (Unit 2. Single-phase alternating current. Unit 3. Three-phase alternating current. Unit 4. Lines and distributions)
Mathematics II	**Unit 1. Vector functions** (Unit 2. Single-phase alternating current. Unit 3. Three-phase alternating current. Unit 4. Lines and distributions)
	Unit 6. Interpolation (Unit 6. Lighting technology)

Table 5. Relationship between the basic subjects considered in the study and the applied subject 'Engine and Machinery'

Basic subjects	Units related with Engine and Machinery (AI)	Units related with Engine and Machinery (AMRB)
Physics I	**Unit 1. Physical laws, measurements and errors** (Unit 1. Internal combustion engines. Unit 2. Electric engines)	
	Unit 2. Vector analysis (Unit 3. Tractor. Unit 5. Machinery for land tillage)	
	Unit 3. Static (Unit 3. Tractor)	
	Unit 7. Work and energy (Unit 1. Internal combustion engines)	
	Unit 18. Generators and engines. Three-phase current (Unit 1. Internal combustion engines. Unit 2. Electric engines).	
Physics II	**Unit 4. Hydrodynamics** (Unit. 4 Facilities and hydraulic—pneumatic equipment)	**Unit 8. First law of thermodynamics** (Unit 1. Internal combustion engines)
	Unit 8. First law of thermodynamics (Unit 1. Internal combustion engines)	**Unit 9. Second law of thermodynamics** (Unit 1. Internal combustion engines)
	Unit 9. Second law of thermodynamics (Unit 1. Internal combustion engines)	**Unit 10. Thermodynamics of a perfect gas** (Unit 1. Internal combustion engines)
	Unit 10. Thermodynamics of perfect gases (Unit 1. Internal combustion engines)	**Unit 11: Thermodynamics of a mixture of gases** (Unit 1. Internal combustion engines)
	Unit 11: Thermodynamics of mixtures of gases (Unit 1. Internal combustion engines)	**Unit 12: Phase change Thermodynamics** (Unit 1. Internal combustion engines)
	Unit 12: Phase change Thermodynamics (Unit 1. Internal combustion engines)	**Unit 15: Applied thermodynamics** (Unit 1. Internal combustion engines)
	Unit 15: Applied thermodynamics (Unit 1. Internal combustion engines)	
Mathematics I	**Unit 1. Vector spaces** (Unit 3. Tractor. Unit 5. Machinery for land tillage)	
Mathematics II	**Unit 1. Vector functions** (Unit 3. Tractor. Unit 5. Machinery for land tillage)	

Table 6. Relationship between the basic subjects considered in the study and the applied subject 'Construction'

Basic subjects	Units related with Construction subject
Physics I	**Unit 2. Vector analysis** (Unit 11. Wind action. Unit 12. Actions applied on the structure)
	Unit 3. Static (Unit 1. Structural layout of a building. Unit 6. Structural safety concepts. Unit 8. Permanent loads. Unit 9. Service loads. Unit 10. Snow loads. Unit 14. Introduction to the calculation of steel structures. Unit 16. Resistance of cross sections. Unit 21. Resistance verification of rigid shallow foundations. Unit 22. Resistance verification of flexible shallow foundations)
	Unit 5. Kinematics of the point and solid (Unit 13. Serviceability limit states. Unit 20. Stability verification of shallow foundations. Unit 21. Resistance verification of rigid shallow foundations. Unit 22. Resistance verification of flexible shallow foundations)
	Unit 7. Work and Energy (Unit 14. Introduction to the calculation of steel structures. Unit 15. Classification of cross sections. Unit 16. Resistance of cross sections)
Physics II	**Unit 1. Elasticity** (Unit 1. Structural layout of a building. Unit 13. Serviceability limit states. Unit 14. Introduction to the calculation of steel structures. Unit 15. Classification of cross sections. Unit 16. Resistance of cross sections. Unit 17. Buckling resistance of members. Unit 18. Lateral torsion buckling of members)
Mathematics I	**Unit 2. Linear applications** (Unit 7. Rules for the combination of actions and structural verifications)
	Unit 3. Euclidean vector spaces (Unit 11. Wind action)
	Unit 6. Definite finite integral (Unit 11. Wind action. Unit 12. Actions applied on the structure)
	Unit 10: Differential calculus of two- and three-variable real functions (Unit 17. Buckling resistance of members. Unit 18. Lateral torsion buckling of members)
Mathematics II	**Unit 1. Vector functions** (Unit 11. Wind action)
	Unit 5. Second order differential equations (Unit 14. Introduction to the calculation of steel structures. Unit 17. Buckling resistance of members. Unit 18. Lateral torsion buckling of members)
	Unit 6. Interpolation (Unit 11. Wind action. Unit 12. Actions applied on the structure)
	Unit 7. Approximate solving equations (Unit 14. Introduction to the calculation of steel structures)
	Unit 8. Numerical integration (Unit 14. Introduction to the calculation of steel structures. Unit 16. Resistance of cross sections. Unit 17. Buckling resistance of members. Unit 18. Lateral torsion buckling of members)

Table 7. Relationship between the basic subjects considered in the study and the applied subject 'Geomatics'

Basic subjects	Units related with Geomatics
Physics I	**Unit 1. Physical laws, measurements and errors** (Unit 1. Introduction. Fundamental principles)
Physics II	**Unit 5. Vibrations and waves** (Unit 2. Topographical instruments. Unit 7. Remote sensing)
	Unit 6. Waves (Unit 2. Topographical instruments. Unit 7. Remote sensing)
	Unit 14. Meteorology (Unit 3. Topographic methodology)
Mathematics I	**Unit 10: Differential calculus of two- and three-variable real functions** (Unit 1. Introduction. Fundamental principles. Unit 4. Mapping and automating processes)
Mathematics II	**Unit 8. Numerical integration** (Unit 1. Introduction. Fundamental principles)

in Physics II. Physics II focuses on six thermodynamic topics covered in Engine and Machinery, which bear hardly any relationship with the other subjects. Regarding Geomatics, the need to introduce concepts of optics in either Physics I or Physics II was identified, since Geomatics applies concepts related to lenses and focal length.

For Mathematics I and Mathematics II, the study identified a gap in trigonometry-related aspects in all applied subjects. These basic subjects explore contents related to vectors and differential and integral equations, which are present, to some extent, in all applied subjects. However, the use of differential or integral equations in the applied subjects is in most cases confined to mathematical proofs for deducing formulas that are easier to apply (e.g. using Laplace to transform differential equations into algebraic equations) or by approximation in subjects applied to real phenomena.

An example is the use of mathematics for the electrical transitory phenomena of the electrical circuits' topic, such as capacitor charging and discharging. An example of the application of mathematics in construction is the buckling equation used in the calculation of the critical load for the column buckling status.

Moreover, triangulation is known to be a key topic in a topographic survey. This makes it essential for students to know trigonometry contents to successfully address a professional activity of this kind. Examples of physics are thermodynamics applied to diesel combustion engines (diesel engines) in use in agriculture and gardening. That is, the thermal phenomena that occur in the fluid

Table 8. Student perception of the relationship between basic subjects and applied subjects for the two specializing lines considered (AMRB and AI)

	Electrical engineering		Engine and machinery		Construction		Geomatics	
Basic subject	**AMRB**	**AI**	**AMRB**	**AI**	**AMRB**	**AI**	**AMRB**	**AI**
Mathematics I	2.2	2.4	1.7	2.3	1.9	2.7	1.6	2.3
Mathematics II	1.5	2.1	1.7	2.0	2.3	2.5	1.5	2.0
Physics I	3.1	3.5	2.5	3.7	2.8	3.4	1.2	1.9
Physics II	3.4	2.6	2.4	3.4	1.5	3.9	1.2	1.9

mixture within the piston causing it to move, in tractors and other agricultural machinery (e.g. harvesters, tractors, mowers), producing work by transforming chemical energy into heat, and heat into mechanical energy, which causes the movement of the camshaft. Theoretically, the compression and expansion processes take place adiabatically, that is, without heat exchange with the outside.

It would be recommended to use these and other examples to relate the contents taught as part of the basic subjects to their direct applications in the later applied subjects and provide examples of their use in the agricultural and food industry, which are the future careers of these students. This would improve student understanding of the subject and motivate further study, increasing the success rate.

3.3 Student perceptions of the relations between subjects

The survey results were analyzed, calculating the average relationships between each of the basic subjects for each of the applied subjects covered by the study (1: Totally unrelated, 5: Totally related). These results are shown in Table 8. The averages, in the case of the AI specialty, are higher than 3.0 for Physics I related to Electrical Engineering (3.5), Engine and Machinery (3.7) and Construction (3.4), and for Physics II related to Engine and Machinery (3.4) and Construction (3.0).

For the AMRB speciality line, subjects with an average greater than 3.0 are Physics I and Physics II related to Electrical Engineering (3.1 and 3.4, respectively). In the latter case, only 18.2% of respondents felt that these subjects were related to each other.

Notably, in the case of the relationship between Physics I or Physics II and Geomatics, 52.2% of AI specialty student respondents felt that there was no relationship between the subject syllabuses. Compared with the same combination of subjects for the AMRB specialty, 81.8% of respondents believed that they were unrelated.

By contrast, 34.8% of AI specialty respondents consider that Physics I is totally related to the subjects of Construction and Engine and Machinery.

Thus, there are cases in which students perceive no relationship between a basic and an applied subject, although there should be such a correlation, for example, between Physics and Electrical Engineering or between Physics and Geomatics. As shown by the statistical analysis reported in the previous section, there is no relationship between the grades earned by students in basic and applied subjects, suggesting that the tested skills are completely different and possibly unrelated. However, the contents of the basic subjects themselves are designed to be useful in applied subjects. Therefore, our study suggests that there is a dysfunction between the expected and the observed learning outcomes of the different types of subjects. Basic subjects are designed to be useful in applied subjects, but, in practice, the tested skills show no relationship between them, and most students do not perceive a connection between both types of subjects. This gap should be corrected in the design of the subjects included in the new programs of studies developed according to the EHEA. The authors suggest that the following measures could be implemented in order to palliate the deficiencies detected:

- During the first year of the degree, seminars or workshops taught by industry professionals as well as faculty teaching applied subjects should address different applications of the basic subjects in Agricultural Engineering.
- Conferences should be held with the participation of companies and graduates currently working in the agricultural sector to raise awareness of the career opportunities of the new degree.
- Departments should exchange equipment and facilities related to the basic subjects to explain phenomena that can be illustrated directly through numerical modeling or by using scale models.

4. Conclusions

The results obtained in the study performed show that there is no direct relationship between the grades obtained in the basic and applied subjects analyzed in the AI and AMRB specializing lines, nor between the number of examinations taken to pass both types of subjects. A slight correlation was found between the total number of years to pass the basic subjects and the total number of years required to complete the degree.

The analysis of the contents of basic subjects used in the applied subjects showed that most of the topics covered in Physics I are used in the applied subjects, while only a few topics of Physics II are used in the applied subjects considered in this study. The study also identified a gap in the trigonometry-related aspects, which are important in all applied subjects, but have not been properly addressed in the topics covered by Mathematics I and II basic subjects.

Another conclusion that can be drawn is that the students did not usually perceive a strong relationship between the basic and applied subjects analyzed in the study. The basic subjects of Physics I and II are perceived by students to be related to most of the applied subjects for both specialties, excepting for Geomatics. It is also important to note that every Mathematics basic subject is perceived by the students to be very related to the applied subjects in both specializing branches because the average of the perceived relation is lower than 3 (in a 1 to 5 Likert type scale, ranging from totally unrelated to totally related, respectively). The degree of relation between basic and applied subjects tends to be weak, since the maximum values are obtained for the pairs Physics II—Construction (3.9 for AI specialty) and Physics I—Engine and Machinery (3.7 for AI specialty).

The absence of statistical relationships between the grades obtained in basic and applied subjects, along with the results of the survey conducted on students to check the perceived relations between both sets of subjects may suggest that basic and applied subjects are, in practice, not properly aligned, despite the learning outcomes being highly related. This indicates a lack of coordination when designing the contents and methodologies used in basic and applied subjects.

In the framework of the new degrees implemented according to the principles of EHEA these conclusions should be considered to redesign the syllabus of basic subjects in order to ensure they really do serve as groundwork for more applied subjects.

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Appendix

Physics I

UNIT 1: Physic laws, measurements and errors
UNIT 2: Vector analysis
UNIT 3: Static
UNIT 4: Graphic static
UNIT 5: Kinematics of the point and solid
UNIT 6: Newtonian dynamics
UNIT 7: Work and energy
UNIT 8: Fundamental theorems of dynamics
UNIT 9: Dynamics of the fixed-spindle solid
UNIT 10: Passives strengths
UNIT 11: Electrostatic
UNIT 12: Electric current
UNIT 13: Circuits
UNIT 14: Electromagnetism
UNIT 15: Magnetic properties of matter
UNIT 16: Electromagnetic induction
UNIT 17: Alternating current (AC)
UNIT 18: Generators and engines. Three-phase current
UNIT 19: Semiconductors

Physics II

UNIT 1: Elasticity
UNIT 2: Fluid balance
UNIT 3: Molecular properties of liquids
UNIT 4: Hydrodynamics
UNIT 5: Vibrations and waves
UNIT 6: Waves
UNIT 7: Thermodynamics
UNIT 8: First law of thermodynamics
UNIT 9: Second law of thermodynamics
UNIT 10: Thermodynamics of perfect gases
UNIT 11: Thermodynamics of mixtures of gases

UNIT 12: Phase change Thermodynamics
UNIT 13: Humidity
UNIT 14: Meteorology
UNIT 15: Applied thermodynamics

Mathematics I

UNIT 1: Vector spaces
UNIT 2: Linear applications
UNIT 3: Euclidean vector spaces
UNIT 4: Diagonalization of endomorphism
UNIT 5: Hyperbolic functions
UNIT 6 Definite finite integral
UNIT 7: Improper integrals. Gamma function
UNIT 8: Successions and numerical series
UNIT 9: Taylor formula. Power series
UNIT 10: Differential calculus of two- and three-variable real functions

Mathematics II

UNIT 1: Vector functions
UNIT 2: Double and triple integrals
UNIT 3: Curvilinear and surface integrals. Integral theorems
UNIT 4: First order differential equations
UNIT 5: Second order differential equations
UNIT 6: Interpolation
UNIT 7: Approximate solving equations
UNIT 8: Numerical integration
UNIT 9: Numerical integration of differential first order equations

Construction

UNIT 1: Structural layout of a building
UNIT 2: Cross sections used in steel structures
UNIT 3: Roof and walls in metallic agroindustrial buildings
UNIT 4: Principles for the design of foundations. Geotechnical report
UNIT 5: Structure of the Technical Building Code
UNIT 6: Structural safety concepts
UNIT 7: Rules for the combination of actions and structural verifications
UNIT 8: Permanent loads
UNIT 9: Service loads
UNIT 10: Snow loads
UNIT 11: Wind action
UNIT 12: Actions applied on the structure
UNIT 13: Serviceability limit states
UNIT 14: Introduction to the calculation of steel structures
UNIT 15: Classification of cross sections
UNIT 16: Resistance of cross sections
UNIT 17: Buckling resistance of members
UNIT 18: Lateral torsion buckling of members
UNIT 19: Design and calculation of structural roof elements
UNIT 20: Stability verification of shallow foundations
UNIT 21: Resistance verification of rigid shallow foundations
UNIT 22: Resistance verification of flexible shallow foundations

Electrical Engineering

UNIT1: Fundamentals and electrical safety
UNIT 2: Single-phase alternating current (AC)
UNIT 3: Three-phase alternating current (AC)
UNIT 4: Lines and distributions
UNIT 5: Measurement and protective equipment
UNIT 6: Lighting technology
UNIT 7: Electricity tariffs

Agroindustrial Engines and Machinery

UNIT 1: Internal combustion engines
UNIT 2: Electric engines
UNIT 3: Tractor
UNIT 4: Facilities and hydraulic - pneumatic equipment
UNIT 5: Machinery for land tillage
UNIT 6: Machines for crop harvesting

Agricultural Engines and Machinery

UNIT 1: Internal combustion engines
UNIT 2: Electric engines
UNIT 3: Tractor
UNIT 4: Soil physical properties
UNIT 5: Machinery for land tillage
UNIT 6: Machinery for sowing, planting and transplanting
UNIT 7: Machinery for composting and crop protection
UNIT 8: Machinery for crop harvesting

Geomatics

UNIT 1: Introduction. Fundamental principles
UNIT 2: Topographical instruments
UNIT 3: Topographic methodology
UNIT 4: Mapping and automating processes
UNIT 5: Surveying
UNIT 6: Photogrammetry
UNIT 7: Remote sensing

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