Article

Food Control and a Citizen Science Approach for Improving Teaching of Genetics in Universities[S]

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Abstract

A Citizen Science approach was implemented in the laboratory practices of Genetics at the University of Oviedo, related with the engaging topic of Food Control. Real samples of food products consumed by students at home (*students as samplers*) were employed as teaching material in three different courses of Genetics during the academic year 2014–2015: Experimental Methods in Food Production (MBTA) (Master level), and Applied Molecular Biology (BMA) and Conservation Genetics and Breeding (COMGE) (Bachelor/Degree level). Molecular genetics based on PCR amplification of DNA markers was employed for species identification of 22 seafood products in COMGE and MBTA, and for detection of genetically modified (GM) maize from nine products in BMA. In total six seafood products incorrectly labeled (27%), and two undeclared GM maize (22%) were found. A post-Laboratory survey was applied for assessing the efficacy of the approach for improving motivation in the Laboratory Practices of Genetics. Results confirmed that students that worked on their own samples from local markets were significantly more motivated and better evaluated their Genetic laboratory practices than control students ($\chi^2 = 12.11$ $p = 0.033$). Our results suggest that citizen science approaches could not be only useful for improving teaching of Genetics in universities but also to incorporate students and citizens as active agents in food control. © 2016 by The International Union of Biochemistry and Molecular Biology, 44(5):450–462, 2016.

Introduction

Many changes have occurred in Spanish higher education in the last years. In the University of Oviedo (Asturias, north Spain) these changes have been mainly related with the University adaptation in 2010 to the European Higher Education Area (EHEA) (The so-called Bologna process) in all the offered degrees. The reduction in duration of the University Degrees (from five to four academic years), the active involvement of students in their learning process, and the introduction of new teaching methods, can be considered as the main basis for these fundamental changes in the current Higher Education [1]. It is now established that teachers must stop having a unique leading role in the learning process [2]. This role must be shared between students and teachers [2, 3]. Also it is needed to develop new teaching approaches in classrooms and laboratory practices since they are not the main, or unique, source of knowledge anymore [3]. In the EHEA the teaching-learning process implies that students are responsible for their own learning. However, students must be really motivated for leading this process. Students lack of motivation is one of the most serious problems in the university [4, 5]. Students motivation and their implications in the learning process are indispensable elements at the present time to successfully achieve a progressive adaptation to the EHEA.

Motivation is defined as an internal state that activates, guides, and maintains behavior. Thus the term "motivation" in education applies to any process that activates and/or maintains learning behavior [6]. It has been defined as

either "extrinsic" or "intrinsic" where intrinsic motivation refers to doing something because it is inherently interesting or enjoyable, and extrinsic motivation refers to doing something because it has a separable outcome [7]. Intrinsic motivation is generally considered to be more effective in promoting learning and achievement [7]. Classroom strategies can be used to optimize student motivation [8]. Lepper and Hodell [9] proposed that intrinsic motivation could be enhanced by providing challenge, curiosity, fantasy and control in classrooms. The motivation constructs are also linked to the construct of "interest." Interest has been defined as a psychological state characterized by focused attention, increased cognitive and affective functioning, and persistent effort [10]. Situational interest concentrates on classroom events and their immediate impact on students. It could increase student's engagement and use of deep learning strategies overriding the effects of personal interest [11]. Novelty, meaningfulness, and involvement are important sources of situational interest in science classes [12]. The development of valid instruments (surveys) for measuring motivation and/interest is one of the main research areas in educational sciences [8, 13]. The Motivated Strategies for Learning Questionnaire (MSLQ), designed to measure college student's motivational orientations, has been a fundamental educational keystone and is still used today by many educational researchers [14–16]. Motivational strategies in expositive classes can clearly encourage student participation and motivation, but laboratories are one of the preferred academic activities for biology students [17, 18]. This way, laboratories should also be used as a teaching element of methodological change and educational innovation. This is especially important for subjects of relatively high difficulty, such as Genetics [18]. Motivation and interest can be achieved if students learn, but at the same time, help with school projects to solve social problems with relevance for their own communities [8, 19]. This active role of students can be coupled with a Citizen Science Approach. In a Citizen Science dynamics students would adopt the dual role of citizens and researchers [20].

Citizen science is a concept that defines public participation in the production of scientific knowledge [21, 22]. This participation encourages the active contribution of citizens to research through intellectual effort, general knowledge, and citizen's tools or resources. Participants provide experimental data for research, pose new questions, and create, along with researchers, a new scientific culture [23]. Currently, many research and educational institutions are running citizen science programs as a tool for engaging both teachers and students in discussions about biomedical science (i.e., University of Bristol and Welcome Trust, UK), genetic diversity and its conservation [24], and in unravelling the human population history [25]. Our students are citizens, and simultaneously the best connection between the university and communities/citizens (parents, friends, neighbors etc.). Indeed, community's knowledge about Universities is usually limited to student's marks and classes while the public perception about the relevance of research work at the universities is usually poor [26, 27]. As mentioned before, the changes promoted by the Bologna process also require methodological changes to offer a better education [28]. We have attempted here an innovative approach to design laboratory practices. Mobilization of students as the samplers for their laboratory practices in Genetics, using commercial products from local markets should play a double role: to generate new, and interesting data for local communities, and at the same time to gain more interest/motivation of students for the courses. The research area of Food Control could be appropriate for enrolling our students in both activities.

Food control and traceability are really important for communities. Traceability implies the identification of the source of a food, and to keep track of it through all its lifespan [29]. This means that the transmission of information to consumers on the nature and properties, origin, and other data about food constituents along the entire production chain must be ensured. This information must keep original data and all the successive transformations of food accompanying the product through all the chain levels in food production. The traceability should be extended until the final product arrives in stores or supermarkets, where the consumers must receive accurately all the information (via product labeling) in accordance with the regulations regarding the composition, origin and characteristics of the food they buy [29, 30]. In the absence of fraud, if fish products are labeled properly consumers can be informed about the species contained in a commercial package and can eat seafood safely. However, mislabeling of commercial fish can reach high levels in some products like surimi [31], being a potential source of accidental exposure to allergenic species. More than 20% mislabeling has also been detected in marketed lots of hake [32–34] and other fish [35].

Another area of community's interests is the use of Genetically Modified Organisms (GMOs) [36]. GMOs are organisms that have been genetically engineered incorporating into their genome new genes from other organisms, or their own genes modified. A GMO has a new combination of genetic material, which confers new properties (pest resistance, herbicide resistance, production of nutritional substances and/or drugs or changes in organoleptic properties) [36–38]. Currently, scientific advances regarding GMOs and their many applications in nutrition, medicine and agriculture have opened many hopes and avenues of study; as well as fears, which right now are related to the environmental risks, ethics conflicts, allergies, sensory impairments, and farmer's dependence on multinational GMOs producers [38–40].

The main goal in this project is the implementation of a Citizen Science approach in the laboratory practices of

FIG 1   *Labels of food products analyzed by students in Laboratory Practices in the courses **MBTA**: (a) Hake breaded sticks, labeled only as Hake 35%; BMA: (b and c) Sweet Corn (two different trademarks) and COMGE: (d) Loins-hake fillets, Merluccius spp., (e) Whole fresh cod, Gadus morhua; at the University of Oviedo, Spain. Commercial trademarks have been covered. Publication permits from students were obtained for this report.* MBTA: Master in Food Biotechnology. Experimental Methods in Food Production. BMA: Grade in Biology. Applied Molecular Biology. COMGE: Grade in Biology. Conservation Genetics and Breeding. *[Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]*

Genetics in the University of Oviedo, linking them with the very challenging topic of Food Control as a tool for improving motivation in our students. The approach is based on the use of real samples of commercial food products consumed by students at home (students as samplers) in laboratory practices. The objective is to provide an educational experience that brings the greatest learning gains to our students, by offering them the first research challenge whose results could help to preserve consumer's rights and the welfare of their communities. The specific aims will be the development of the current laboratory practices of Genetics through the implementation of this citizen science approach. We will attempt also, as another specific aim, to measure the impact of these modified laboratories on student's motivations and on their evaluations of the quality of teaching activities. A set of a Likert-based items will be employed. They are currently on evaluation in pilot experiences of the Citizen Science National Project MINECO CGL2013-42415-R.

Material and Methods

Genetics is taught at University of Oviedo in five Degrees (Chemistry, Nursing, Medicine, Biotechnology and Biology) through fourteen different courses and in three different Master Programs (Master in Food Biotechnology, Master in Applied Biotechnology for Conservation and Sustainable Management of Plant Resources, and the Erasmus Mundus Master in Marine Biodiversity and Conservation). The novel approach was implemented in three different courses of Genetics during the academic year 2014-2015: Experimental Methods in Food Production (MBTA) in the Master in Food Biotechnology; Applied Molecular Biology (BMA) in the Degree in Biology; Conservation Genetics and Breeding (COMGE) in the Degree in Biology. Previous meetings with students in each of the courses were held. In all the cases students agreed to participate in the project and gave permission to use their results in future publications/reports. Below it is explained how the laboratory activities in each of the courses were organized and also a brief explanation

about the molecular markers and the laboratory protocols chosen for each of the laboratory practices in these three courses. Finally, we explain how the survey was designed and how it was conducted in these laboratory practices.

Course Experimental Methods in Food Production (MBTA)

During the course of the experience, six different teaching areas (Microbiology, Genetics, Analytical Chemistry, Bioprocess, Nutrition and Complex Structures) offer laboratory practices to students throughout all the academic year. Genetics includes 7 hours of laboratory practices by group distributed on three different days. Two groups of 10 students were cited for laboratory practices in November (25th to 27th), 2014, in the course Experimental Methods in Food Production. They were organized in six working groups and four commercial seafood products [Smoked salmon, Hake breaded sticks, Cod crumbs and Loins-Hake fillets (Table I)] were chosen for genetic evaluations taking into account the consumption habits reported by the students and the availability of referenced scientific samples: Atlantic salmon (*Salmo salar*), Brown trout (*Salmo trutta*), Atlantic cod (*Gadus morhua*) and Atlantic hake (*Merluccius merluccius*). The food products were acquired by students in local markets and small samples conserved in ethanol (100%) while labels were conserved and brought to the laboratories (Fig. 1).

The Marker

The 5S rDNA gene encodes a small component of the large subunit of the ribosomal RNA. In vertebrates, it is organized into clusters or tandem repeats several hundred base pairs which consist in coding regions and non-coding spacer regions (NTS). The size of the coding sequences is always 120 bp while the NTS length varies [41]. The differences in the length of the fragments can be used to differentiate between species [34, 35, 42]. The expected size fragments of PCR bands from the reference samples are: *S. salar* 255 bp, *S. trutta* 276 bp, *M. merluccius* 371 bp and finally *G. morhua* 540 bp [43–45]. This method is particularly useful for the identification of larvae, eggs, and processed foods including canned and frozen products [35, 46].

The Laboratory Protocol

DNA was extracted for PCR (Polymerase chain reaction) amplification of the 5SrDNA gene following the Chelex-based protocol described in [35]. PCR amplification of the 5SrDNA was performed using the primers described by Pendas et al. [44]. Amplifications were carried out using the GeneAmp PCR system 2400 by Perkin Elmer Cetus using the Roche system's PCR Master (Cat # 11636103001) and approximately 50 ng of DNA sample. PCR was performed with an initial denaturing step (5 min at 95℃) followed by 40 cycles consisting of: denaturing 20 s at 95℃; 20 s annealing at 50℃; extension at 72℃ for 20 s; and a final extension at 72℃ for 7 min. The fragment sizes of the PCR products were determined in agarose gel (2%) by comparison with PCR Sizer 100 bp DNA Ladder (Norgen Biotek Corp. Cat. # 11400) and staining with SimplySafe™ (EURx Cat. # E4600-01).

Course Conservation Genetics and Breeding (COMGE)

Laboratory practices in this course include 21 hours by group distributed in three sessions of 2–3 days. Two groups of 10 and 8 students were cited for laboratory practices in March (2-4), 2015, in the course Conservation Genetics and Breeding. They were advised to bring fresh fish products (samples in Ethanol 100%) purchased in local markets by their families for consumption at home, together with pictures of fish product labels. A total of 18 commercial products from 11 putative different fish species were received at the laboratory (Fig. 1, Table I). Samples DNA were extracted following the Chelex-based protocol described in Ref. 35.

The Marker

In 2003, Paul Hebert proposed the "DNA Barcode" as a method for species identification [47]. This barcode uses a very short genetic sequence from a standard part of the mitochondrial genome in the same way a supermarket scanner distinguishes the products by black/white bars from the Universal Product Code (UPC). The genetic region used as standard Barcode for most animal groups is a 658 base pair fragment in the mitochondrial Cytochrome C Oxidase subunit 1 gene ("COI") [47].

The Laboratory Protocol

The COI gene was amplified from the samples by PCR using the universal COI primers for fish (COI-Fish-F and COI-Fish-R) published by Ward et al. [48]. Amplifications were carried out using the GeneAmp PCR system 2400 by Perkin Elmer Cetus using the Roche system's PCR Master (Cat # 11636103001) and approximately 50 ng of DNA sample. PCR was performed by an initial denaturing step (5 min at 95℃) followed by 40 cycles consisting of: denaturing 30 s at 95℃; 30 s annealing at 50℃; extension at 72℃ for 40 s; and a final extension at 72℃ for 7 min. The PCR products were electrophoresed in a 2% agarose gel, containing SimplySafe™ (EURx Cat. # E4600-01) and using Promega 100 bp DNA Ladder Molecular Weight Marker (Cat # G2101) for bands sizes inspections. Bands were purified using the simple protocol of Illustra Exostar 1-Step (GE Healthcare life Sciences, Cat. # US77701) and were sent to MACROGEN, Amsterdam, Netherlands for sequencing, using standard Sanger sequencing method [49]. The last sessions (two days) are dedicated to the work with sequences in web databases for species identifications. The databases used were Genbank database (http://www.ncbi.nlm.nih.gov/genbank/) and the database of the Project "Barcode of life" (http://www.barcodeoflife.org/).

TABLE I Summary of purposes, methods and results of laboratory practices in the courses MBTA, BMA and COMGE at the University of Oviedo, Spain

Course	MBTA		COMGE		BMA	
Number of students	20		18		21	
Purpose	Species Identifications		Species Identifications		GMO detection	
Genetic Method	PCR 5SrDNA gen		PCR COI gene + Sequencing		PCR Biogenic Kit (35S gen)	
Activity organization	Six groups		Individual		Individual	
Total number of comercial Products assayed	Four (three species)		18 (11 species)		Nine (21 samples)	
Positive results	Four (three species)		13 (eight species)		Eight (19) samples	
Detected Problems	Incorrect labeling		Six Incorrect labeling/one Species Substitution		Putative Maize GMO not declared	
	Genetic Species Identification	*Name of Commercial Products assayed*	*Genetic Species Identification*	*Name of Commercial Products assayed*	*Name of Commercial Products assayed*	*GMO detection*
	Not M.merluccius (1).	**Hake breaded sticks (Hake 35%) (1)**	S.salar (4)	Cultured Salmon (S.salar) (4)	Popcorn (3)	(−)
	M.merluccius (1)	Loins-Hake fillets (M.merluccius) (1)	P.hypophthalmus (1)	Panga Fish, Vietnam (P.hypophthalmus) (1)	**Sweetcorn (5)**	**(+) (2)**
Details	(S.salar) (1)	Smoked salmon S.salar (1)	**T. albacares (2)**	**Pacific Tunna (2)**	Cornmeal (2)	(−)
	(G.morhua) (1)	Cod crumbs G.morhua (1)	**X. gladius (1)**	**Indian Ocean Swordfish (1)**	Asturian Maize seeds (1)	(−)
			G. morhua (1)/ P.hypophthalmus (1)	**Whole Fresh Cod (G.morhua) (2)**	Giant Maize (1)	(−)
			M.poutassou (2)	**Atlantic blue whiting/ Cantabrian blue whiting (2)**	Chocolate Nestle (2)	(failed)
			M.merluccius (1)/ M.capensis (1)	**Hake (M.spp./M. merluccius) (2)**	Australian Soja seeds (1)	(−)
			(Failed)	Mauritanian Sole (1)	Soybean sprouts (5)	(−)
			(Failed)	Mediterranean herring (1)	Soybean seeds (1)	(−)
			(Failed)	Big-scale sand smelt (1)		

In parentheses the number of samples under analysis and in red the detected problems with labeling, putative frauds, or undeclared putative GMOs (see text for details). Commercial products names could include different trademarks. MBTA: Master in Food Biotechnology. Experimental Methods in Food Production. BMA: Grade in Biology. Applied Molecular Biology. COMGE: Grade in Biology. Conservation Genetics and Breeding. (+) Positive. (−) Negative.

Course Applied Molecular Biology (BMA)

In this course two teaching areas (Biochemistry and Genetics) offer laboratory practices to students. Genetics includes 7 hours of laboratory practices by groups distributed in two sessions of 2–3 days. Two groups of 10 and 11 students were cited for laboratory practices in April (6th–8th), 2015, in the course Applied Molecular Biology. A total of 21 samples from 9 different Maize or Soybean products from the local markets with chances of containing undeclared GMOs (i.e., Greenpeace's red and green lists of undeclared transgenic foods in Spain), were received at the laboratory to attempt GMOs detection (Fig. 1, Table I).

The Marker

The BIOGENICs Standard Kit (BIOTOOLS B&M Laboratories, S.A. Cat # 91.212), that allows the detection of GMOs in fresh and processed food for human or animal food, was used. The Kit technology consists of the detection and amplification of specific regions of GMOs that do not exist in native plants (the 35S promoter from the Cauliflower virus and the Agrobacterium NOS terminator) and present in approximately 90% of GMOs placed on the market to date [50, 51]. The Kit also includes control amplifications (Plants: *Rbc*L gen, Maize: Invertase gen and Soybean: Lectin gen) in order to discriminate between negatives due to inhibition of the reactions or real negative results.

#### The Laboratories Protocol

The DNA from samples was extracted using the GeneMATRIX Plant and Fungi DNA purification Kit (EURx Cat. # E3595). This kit is designed for rapid purification of DNA from a wide type of plant, fungi and lichens tissues. With the BIOGENIC Standard Kit, PCRs were done following the manufacturers recommendations, and results were observed after horizontal electrophoresis in agarose gels (2%) stained with SimplySafe™ (EURx Cat. # E4600-01) and using Low DNA Mass Ladder from Thermo Fisher Scientific Brands (Cat. # 10068-013).

Survey Design, Application and Analysis

To validate a motivational measuring instrument for application in citizen science projects is outside of the specific focus of this work. However, a set of Likert-based items currently under evaluation in pilot experiences of the citizen science Spanish national project MINECO CGL2013-42415-R were organized as a survey for our students. The survey structure and questions were discussed between teachers of Genetics and of Science Education from the University of Oviedo. Some of the items come from a set of already detected informative items employed in previous surveys used in experiences with students and ordinary citizens enrolled in citizen science activities from the University of Oviedo within a Science and Technology Foundation Project (Project FCT-13-6105) (Dopico E. In preparation, pers. comm). The survey was composed of seventeen items. Following a logical rationale, it was divided in three parts asking students their opinions about (I) the approach, (II) about the origin of the samples and their usefulness for food control and (III) about the laboratory results and their implications (Annex 1). The students scored from 1 (least) to 5 (most appreciated) different aspects of the practices following a Likert approach. The survey was conducted on a voluntary basis to students in courses MBTA, BMA and COMGE ($n = 59$).

The MSLQ motivation section and its scales for intrinsic goal orientation and task value [16] were taken as the basis for developing a modified motivation scale within our own survey. The scales in the MSLQ mentioned above use items about preference for challenging course material (item 1), preference about course material that arouses curiosity even when difficult (item 16), interest in the content area of the course (Item 17), course material usefulness for learning (item 23) and finally, attractiveness (item 23). These two motivation scales correlate well among them ($r = 0.68$), [14]) and show good correlation indexes with final course grades ($r = 0.25$ and $r = 0.22$) [15]. Our motivation construct included as working hypothesis that a student enrolled in this experience should show curiosity (item 1), should make comments to their families about the practices (item 2), should show preference for the approach (items 3–4), and finally should give a better evaluation (item 6) to the practices than students of control groups using a "classical" approach for laboratory practices. All these aspects could be a proxy of the items "preferences" and "curiosity" about course materials as in the motivation scale in MSQL. A multiple response set (called "motivation") including all those items was constructed for statistical analyses (IBM SPSS statistics 21). As a control, a shorter version of the survey was applied also to two other courses in the Degree in Biology: Genetics (GENETICS) and Evolutionary Biology (BEVOL) ($n = 38$). Both courses include laboratory practices but they were not included in this experience. Laboratories practices in GENETICS used 5SrDNA gene PCRs for species identification but using reference samples of Atlantic salmon (*S. salar*) and brown trout (*S. trout*) from the Department of Functional Biology. At the moment of survey applications, laboratories Practices in BEVOL used sequences retrieved from databases (GenBank) for phylogenetic reconstructions and species identification. The items selected for the short survey version were those included in our motivation scale about the approach (items 1, 2, 3, 4 and 6). The rest of the items [II-about the origin of the samples and their usefulness for food control (items 7 to 12) and III-about the laboratories results and their implications (items 13 to 17) (Annex 1)] could only be evaluated by students enrolled in this approach. All these items fall within cognitive scales that are currently the center of attention for upcoming studies and are included in the current development of cognitive measuring instruments for evaluating citizen science experiences.
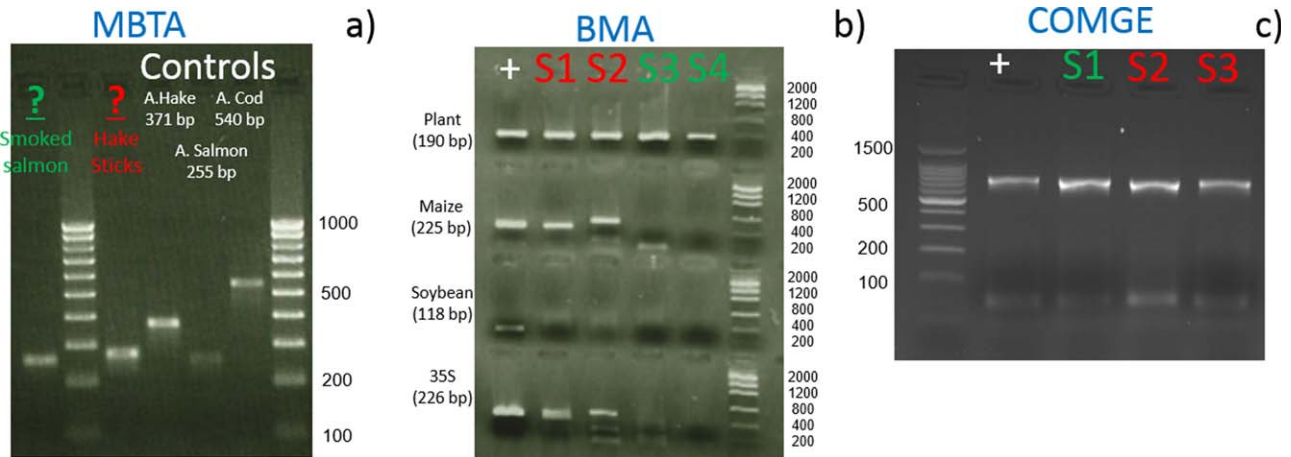
Captures from student results in laboratory practices in the courses **MBTA**, **BMA** *and* **COMGE** *at the University of Oviedo, Spain. (+: Positive control). (a) The 5srDNA gene was amplified in control samples from the species Atlantic hake (*M. merluccius*), Atlantic cod (*G. morhua*) and Atlantic salmon (*S. salar*). Students tested commercial smoked salmon and hake breaded stick samples for species identifications. The hake breaded stick sample seems to be a commercial fraud. (b) The BIOGENIC kits were used. Universal primers for amplifying* RbcL *(Plants), Invertase (Maize), Lectin (Soybean) and the Cauliflower Mosaic Virus Promoter 35S genes (typical in GMO constructions) were used as positive controls. Samples S1 and S2 showed 35S amplifications from putative transgenic maize, but lacked any labeling specifications about it. (c) The cytochrome oxidase I (COI) gene (700bp) was amplified in fish market samples. Bands were purified using a commercial kit and sequenced using Sanger's methodology. Results showed one incorrect labeling (Sample S2 labeled only as* hake spp. *but genetically identified as* M. capensis. *This species showed serious problems of overexploitation and is often the cause of consumers misunderstandings) and one commercial fraud labeled as Cod but identified as Panga fish (*Pangasianodon hypophth*almus) (Sample S3). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]*

Before implementing a correlational analysis of the items or an analysis based on the criterion of internal consistency [52, 53] the item 3, considered as an inverted one, was transformed using $Pi = (Pm + 1) - Po$, where Pi was the transformed punctuation, Pm was the maximum value (five in this case) and Po was the real punctuation of the item. For each of the items the correlation between the item and the complete test, once removed from the latter, was assessed. This correlation is the Corrected Index of homogeneity (IHC) following Peters & Van Vorhis [54]. To interpret the approach, this index is usually taken as the reference value 0.20. So that all the items that are IHC with values less than 0.20 should be eliminated. To evaluate the psychometric properties of any test, reliability and content and construct validity are important [55]. The reliability refers to the degree of accuracy that offer the measurements obtained by a test. A method widely used for estimating the reliability of a test consists in calculating Cronbach's alpha coefficient [55]. A fairly widespread approach to interpret the alpha coefficient is that it has to be equal to or greater than 0.70 for saying that the test has a sufficient reliability [55]. The validity of the test mainly depends on asking questions that measure what we are supposed to be measuring and can be established testing scores in two groups of subjects that hold extreme and opposed attitudes, and using hypotheses validations [53, 55]. However, the validity of a test can be only established with a large amount of evidence and many respondents, which was out of the focus in this work. Despite this, short motivation scales have been extensively used showing good predictive values and thus validity [15, 16]. Moreover, specific and direct questions about curiosity and preferences ensure that questions will measure what is supposed to be measured [16]. All the statistical analyses, including comparison between the groups in terms of means and distributions, were afforded in this work using non-parametric tests (Mann-Whitney tests and $\chi2$ tests) in the IBM SPSS statistics 21.

Results

Laboratory Results

A total of 59 students participated in the laboratories practices of the three courses included in this experience: COMGE, BMA and MBTA (Table I). Students willingness to participate in these practices providing samples of food products that are usually consumed at home was really good and generated interest since significant electronic traffic through the university's virtual campus was noted between students and teachers. More than 15 electronic requests and also several questions in expositive classes were received by the teachers. Student asked for specifications and details about the type of samples they can bring to the laboratories for genetic analyses, about the best
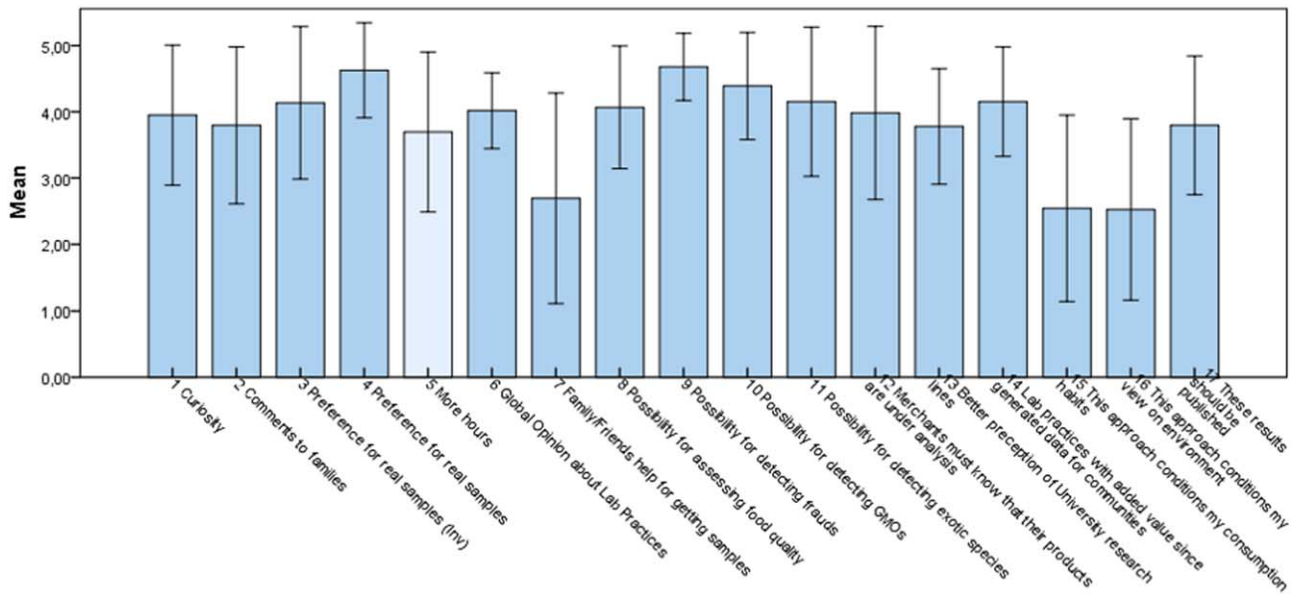
procedures for tissue preservations or about the quality of the label pictures. Two main "genetic purposes" were afforded: species identifications using PCRs and sequencing of the COI gene and PCRs of the 5SrDNA genes, and GMOs detection using the PCRs from the BIOGENICs standard kit (35S and NOS genes). Thirty one commercial products were under analyses, 22 of them for species identifications and 9 for GMOs detection experiences (Fig. 1, Table I).

A first significant result arose from the analyses of fresh (COMGE) and processed (MBTA) fish products and in maize and soybean products (BMA): labels were not correct in a 53% of fresh and processed fish products (without species scientific names). Moreover, none of maize and soybean products specified the inclusions or not of GMOs in its components (Fig. 1). Positive results (successful PCRs) were obtained by students in laboratories practices in 72% (COMGE), 100% (MBTA) and 88% (BMA) of the products under analyses (Table I). From the positive results obtained in the laboratories we detected four cases of incorrect labeling (lack of species definitions in Tuna, Cod, Blue Whiting and Hake products) and one case of species substitutions or fraud (Panga fish instead of Cod) in COMGE (fresh fish products), one doubtful labeling (Hake 35%) in processed fish products (MBTA) and two cases where the 35S gene amplifications obtained in two different products of sweetcorn (BMA) demonstrated the presence of undeclared GMOs in their composition (Table I, Fig. 2).

Obtaining PCR bands and sequences using the Ward's COI primers (COMGE) was not possible in a few of fresh fish samples (i.e., three out of the 10 fish species attempted) but in general it was an efficient protocol (Table I). In the course MBTA, PCR results were highly consistent (i.e., 100% of success) (Table I). In this last case the contradictory results obtained for the hake breaded sticks labeled as "hake 35%" just had as answer "not Atlantic Hake (expected band in 371 bp)" since the band was over the 255 bp band obtained from Salmon samples and below the 300bp band of the DNA mass ladders (Fig. 2). The BIOGENICs standard kit used in BMA worked very well for the PCR tests of plants (*Rbc*L gen), maize (Invertase gen), 35S and NOS genes but it was less efficient for the soybean positive test (i.e. Fig. 2 see samples S3 and S4 that failed in Lectin gen (soybean) amplifications. As mentioned above, two products of sweetcorn were positive for the 35S gene (none of products were positive for the NOS gene) which suggested GMOs were present (Fig. 2). From all the food commercial products tested in these laboratories practices of Genetics, seven out of 31 (23%) showed problems of incorrect labeling, species substitutions, or fraud, and possible undeclared GMOs compositions (Table I, Fig. 2).

The Survey Results

A collection of seventeen items was conducted as a survey, and on a voluntary basis, to students in the courses MBTA, BMA and COMGE and it was answered by 58 students (98%). The results revealed all the items were above of the IHC of 0.20 (ranging from 0.21 to 0.48) except for item 5 (more hours for laboratories practices) (IHC = −0.12). Calculations of the Cronbach's alpha coefficient gave a value of 0.79.

Ten out of the 16 informative items revealed means close, or above, four (out of five) in the student's surveys
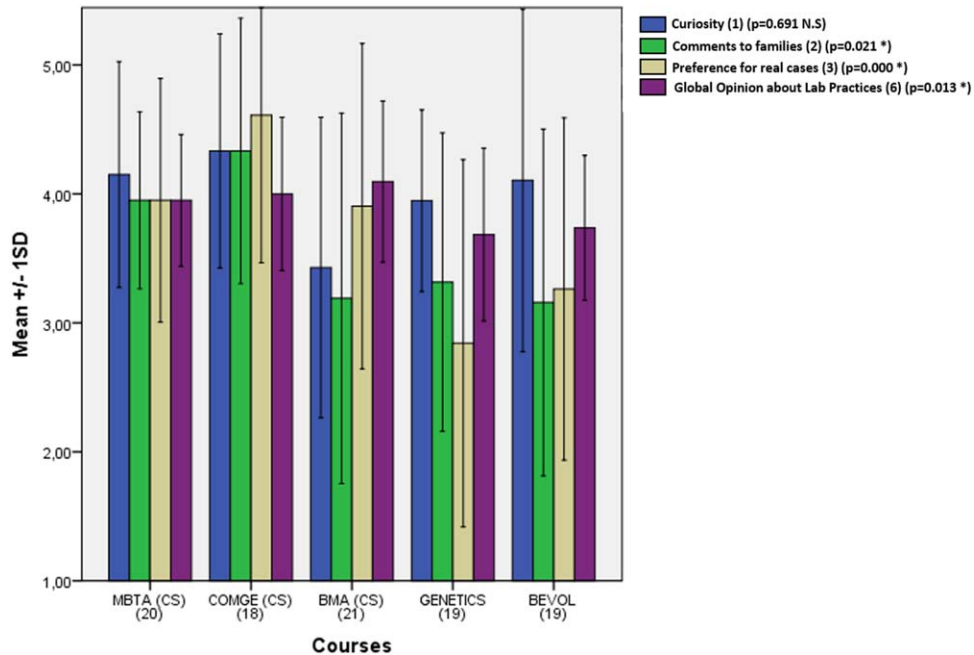
punctuations from the courses MBTA, BMA and COMGE (Fig. 3). The students were curious about laboratories practices (item 1, $\mu = 3.94$), commented this approach to families/friends (item 2, $\mu = 3.80$), clearly preferred to work with real samples in their laboratories experiences (item 3, $\mu = 4.13$; item 4, $\mu = 4.63$) and gave a good global rate to their genetics practices (item 6, $\mu = 4.02$) (Fig. 3). A short version of this survey was applied in the two control groups doing "classical laboratories practices" and using samples prepared by their professors (GENETICS) or virtual data (BEVOL) ($N = 38$). Those students, although curious about a possible different approach (item 1, $\mu = 4.03$, $p = 0.691$ NS), revealed that in general, their classical laboratories practices were less commented at home (item 2, $\mu = 3.24$, $p = 0.021$*), they were not completely sure about their preferences for learning using pre-established teaching materials or real samples in their laboratories experiences (item 3, $\mu = 3.05$ $p = 0.000$*; item 4, $\mu = 4.53$ NS), and gave minor global evaluation for the laboratories practices (item 6, $\mu = 3.71$, $p = 0.013$*) (Fig. 4). It was in COMGE and in the MBTA ones where students were more curious and interested/motivated by this approach, however in all the three courses included in this approach the global evaluations of the laboratories practices were rated over the four points (Fig. 4). In a global analysis using "Motivation" as a Multiple Response Set (including the motivation scale items), we could confirm that students taking part in laboratories

practices using real samples from local markets were more motivated and better evaluated their Genetics laboratories practices since punctuation distributions were clearly differentiated between the two approaches ($\chi^2 = 12.11$ $p = 0.033$*) and more than 67% of the students scored 4–5 points to those items included in our motivation scale (Fig. 5).

From a cognitive point of view, this kind of laboratories experiences seems to help students to know that genetics can help to determine food quality (item 8, $\mu = 4.07$), to detect frauds (item 9, $\mu = 4.68$), to detect GMOs (item 10, $\mu = 4.39$), to detect exotic species (item 11, $\mu = 4.15$), and support that this type of routine analyses in universities should be a worry for merchants/distributors (item 12, $\mu = 3.98$) while they also believed that generating data of interest for communities is useful and an added value (item 14, $\mu = 4.15$) (Fig. 3). On the other side, families did not participate/recommend the samples used in the laboratories (item 7, $\mu = 2.69$). Moreover this approach did not influence the label reading habits of students (item 15, $\mu = 2.54$) or how students evaluate their environment (item 16, $\mu = 2.53$) (Fig. 3). Finally, five students from this approach filled the last item of the survey asking them for any other possible comments to the practices. The comments were about the need for more funding to practices and teaching in science grades and masters of the University of Oviedo including the possibility to make individual (and not group) activities in the course MBTA.
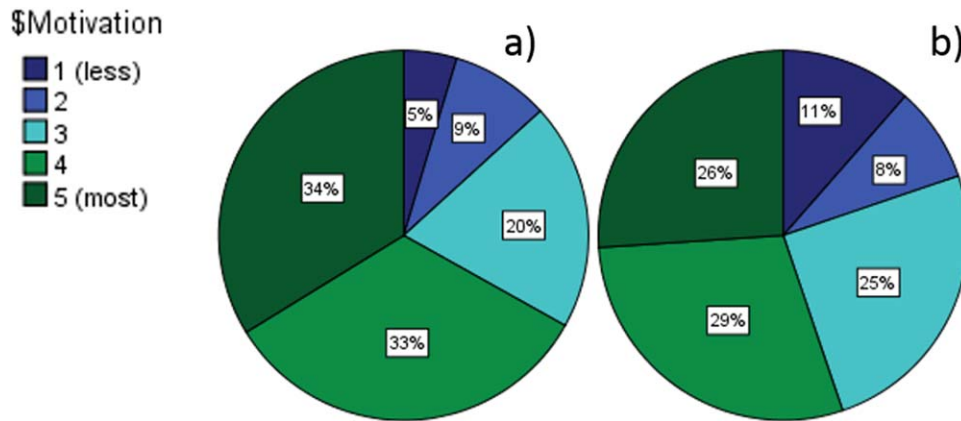
Discussion

Teaching Genetics in the University of Oviedo has changed in the last few years. Grades and Master programs have evolved to adapt to the EHEA with a significant reduction of the total number of credits and, as a general rule, a change to "Optative courses" instead of the classical mandatory ones from previous academic programs. The desired active role of students starts by choosing what courses they consider useful and attractive for completing their formative degree [4]. On the other hand, Genetics is an emergent science with technical novelties arising every day. A strategy to keep student's motivations high is needed. It has been argued that in order to enhance student motivation teachers should challenge students by setting tasks at a moderate level of difficulty, use novel or discrepant experiences to arouse curiosity, use fantasy, and increase the meaningfulness of content and tasks by relating them to the students' lives [8]. Putting together learning processes with highly topical problems could be a good teaching-learning strategy as has been observed in this work.

The genetic techniques used in this project are not a novelty. The PCR is a very well established technique. However, the public concern about food compositions and sustainability, and the use of GMOs, are indeed topical issues. According to a wide study at Spanish national level, the 61% of the respondents in a query always, or almost always, look at the labeling of food products, while 28% look at it sometimes [56]. This leaves a very small percentage of the population that shows no interest in this subject. The same study revealed that 84% of the people prefer a complete list of ingredients in all the food products they consume. Even when people do not understand the meaning of many of these ingredients, they considered that it gives them a sense of security [56]. Moreover, the European trend since 1996 in all countries has been towards the rejection of food with GMOs. Spain and Portugal, are the two European countries that have always remained with the higher groups of acceptance within the European average. However, acceptance percentage is only 31% in Spain and still more than half of the population stands contrary to the promotion of this type of food industry [57]. On the other hand, species identifications in food product labels have a significant relevance not only for consumer's safety, or rights, but also for good management strategies of natural resources as could be the case of the establishment of sustainable fishing quotas (i.e., [35] and references therein). Findings of this cooperative research in laboratories practices were of relevance. From all the food commercial products tested 23% (7 products) showed problems of incorrect labeling, fraud, or possible undeclared GMOs compositions. This percentage is of the same magnitude from other previous works addressing mislabeling in food products (i.e. [34]). In the field of food control, the role of universities as "food security guardians" or "routine screeners" of commercial products as part of the learning process of their students seems really interesting and useful. This can be clearly assimilated within the citizen science spirits and the approach can be extended beyond students to citizens through participative experiences (i.e. universities summer courses). Food control is today in the hands of food regulatory national agencies, but students and citizens can be incorporated as active agents by our universities and institutions to improve food safety.

For species identifications (afforded in COMGE and MBTA) the most complete approach was sequencing of PCR

bands of the COI gene. The COI identification system available in web databases such as BOLD and GenBank is very well established and accurate when species identifications are done using as cutoff values above a 98% of sequence similarities [58]. In the MBTA course we used the simplest but less accurate approach of using the 5SrDNA system that always needs reference samples. The results obtained for the hake breaded sticks product labeled as Hake 35% just revealed bands similar in sizes to those from the trout reference samples (*Salmo trutta*, 276 bp). However, this is not conclusive in terms of species identification and finally we addressed this issue and it was not trout. We afforded, a posteriori, the sequencing of a COI amplification from this sample for obtaining the species ID and the COI band was found to be 100% similar to the species *Macruronus magellanicus* (Grenadier fish/long-tailed hake) (Table I). The 5SrDNA approach has its limits and even when in previous discussions with students, professors could know putative fish species that will be tested in Laboratories and obtain scientifically referenced samples, the interpretation for incongruences in results among referenced samples and food products will be limited to reject, and not to identify, the species included in the food product. In our opinion, changes for upcoming courses could include use of individual samples in this practice (this year only four samples of food products by group were tested since this was the first experience). Other changes might be assessed in future but taking into account the limitations in time for the laboratories practices in this course (only 7 hours) and the current scenario of cutting down funds in the Spanish Higher Education. Moreover, food industry prefer cheap, reliable and fast tests and the use of Detection Kits has been the fashion in the last decade [59].

In the BMA course, where GMOs detection was afforded, some improvements could also be done. More specific primers for other plant species can be developed (currently positive PCR test are included just for maize and soybean) and in this way to make wider the option for students to test in the laboratories DNA extracted from more types of food products from local markets. The commercial kit from BIOGENICs results are useful but limited (i.e. the NOS gene did not amplified in samples). The truth is that there are many other markers for GMOs that can be used for testing its presence in food products (i.e. 5-enolpyruvylshikimate-3-phosphate synthase, cry genes, etc.) [60–62]. It will be easy to prepare stocks of primers for amplifying several commonly used transgenes in plant food products for the upcoming courses.

Much more interest, concentration and motivation inside laboratories than in previous years was detected in this project by the teachers. However, this should be objectively measured. The use of surveys for measuring college student's motivational orientations and their use of different learning strategies is a hot spot research area for education and psychology researchers [8, 10, 15, 16]. However, teachers of Genetics in the Grades of Biology and in the different Masters at Spanish universities are not, by a general rule, pedagogues or graduates from faculties of educational sciences. The access to teaching positions in Genetics depends much more on scientific and technical qualities demonstrated via CVs and published papers within the knowledge area (i.e., Genetics). Cooperative research projects allowing the interaction among social and science teachers could facilitate the implementation of innovative strategies for teaching genetics [i.e., 10].

One of the results from this experience is the need for validated instruments to effectively measure the cognitive and motivational improvements in learning for students and citizens when teaching using citizen science approaches. As far as we know, this is absent from the citizen science experiences being run today. It has been included in the lines of actions of the citizen science national project MINECO CGL2013-42415-R. A set of Likert-based items is currently on evaluation in piloting experiences. Even when not completely conclusive, the survey conducted in our modified laboratories experience already gave relevant information about cognitive and motivational states of students. A short and preliminary motivation scale conducted in this research show clear improvements in curiosity, attention, good spreading of the university activities to communities and better evaluations of the work of teachers and universities by students. Preliminary cognitive results were also encouraging. Using tasks related to the student's lives (problem-based learning) it is useful for science education [8, 19]. It seems that coupling learning and topical problems in a community is an approach that can (and should) be experimented in universities for teaching Genetics. Obviously this implies more work and planning from professors (which could face some reluctance) and the implementation of changes about how we teach Genetics at higher education. Our results suggest that it is worth it.

Acknowledgements

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