Open and Low Cost Techniques to Foster Engineering Education: The Smart Egg Classifier Example

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***Abstract*—Rapid growth of the electronics industry resulted in a plethora of innovative and cheap devices, while fluent documentation and user-friendly programming environments are available for them. Modern educational systems worldwide have exploited this situation by incorporating practices reflecting this progress, under the STEM umbrella. Remarkable progress has been made in secondary education, but tertiary education should also follow. In this regard, the approach being presented highlights the design and implementation steps of a system for automatic classification of eggs. The whole approach utilizes open and easy-to-find software and components, e.g., arduino-like boards, cheap electronic and electromechanical modules and recyclable materials. The prototype system has been developed by students of agricultural engineering, assisted by their professors, and tested during the STEM4Agri Erasmus project, with most of the focus on its university and vocational education exploitation perspectives. According to a first set of survey findings, this STEM activity paradigm has many and multi-perspective benefits for the participants and can be seen as a flagship case of activities that should be incorporated into the curricula of educational institutes to keep in pace with the recent technological achievements and the forthcoming job transformation necessities.**

Keywords—Engineering education, Digital transformation, Multidisciplinary education, Artificial intelligence

I. Introduction

Rapid growth of the electronics industry resulted in a plethora of innovative and cheap devices, while fluent documentation and efficient, user-friendly programming environments are available for them. Modern educational systems worldwide have exploited this situation by incorporating practices reflecting this progress, under the STEM umbrella. Remarkable progress has been made in primary and secondary education [1-3], but tertiary education should also follow, despite potential drawbacks, as the engineering institutes worldwide should update their lesson curricula in order to provide the means for demystifying the booming of digital technologies and to make the learning process more appealing via targets that match solutions for real-world problems [4-7].

Indeed, tackling with modern world challenges has mutual benefits for the students and the society. Students are better intrigued in their learning process and improve their job finding prospects while society is increasing its well-being potential favoured by well-trained professionals. Not surprisingly, the definition of «21st century skills» is synthesized as the conceptual foundation required to solve problems effectively, efficiently and with solutions that are reusable in different contexts [8-9].

Speaking about problems, one of the most intense ones on Earth is to cover the nutritional needs of a continuously growing population, against the depletion of natural resources, as United Nations organization alarms [10]. In response to this necessity, according to FAO [11], the agricultural productivity should be increased by 60 per cent. Unfortunately, the latter goal is not easy to be met by traditional means. Indeed, the lack of labour caused by socio-economical instabilities and pandemics intensifies the problem. On the other hand, the exploitation of modern technologies, like electronics, robotics, IoT and AI seems to provide a promising alternative for keeping hope alive [12-15]. Apparently, well-educated personnel increases the success perspectives of this mission and exploits the new job dynamics being offered [16].

Motivated by the encouraging analysis results on pre-existing educational activities involving engineering [17-19], this research work puts light on methods for facilitating the understanding of practices making the food supply chain more efficient and to better communicate the principles behind modern technological applications, like robotics, control and programming. More specifically, a characteristic mechatronic system case is presented, capable of classifying eggs of different colour. This example has been developed by students of agricultural engineering, assisted by their professors, and evaluated during the STEM4Agri Erasmus project, with most of the focus on university and vocational education exploitation perspectives. Cheap microcontrollers, sensors and actuators, along with recyclable materials and parts of retired electromechanical equipment are combined together toward the delivery of a working whole, while guidelines for an educationally meaningful exploitation of the overall activity are also given. The whole activity, combining intriguing characteristics and simplicity in its concept, and having a compact and presentation-friendly form, encourages the building of modern skills that facilitate the understanding of key-importance operations that can make food supply chain more efficient in terms of quality and quantity and improve the career prospect of the participants. The pilot mechatronic construction being made, and its educational exploitation, exhibit a good practice example for assisting people to respond to the digital transformation necessities of the new era.

In order to facilitate the description of this work, apart from this introductory section, the rest of this paper is organized as follows: Section II highlights the preparatory arrangements and the main exemplary system components. Section III provides interesting design and implementation details. Section IV is dedicated to evaluation results and discussion. Finally, Section V contains some important concluding remarks.

II. Methods and Materials

A. Educational Settings

The experimental egg classification system which is described herein was carried out by university students of agricultural engineering, assisted by their professors, 6 persons in total, as final degree project (FDP) activity, during the last year of their studies (i.e., over a 6-month period). The main functions of this mechanism were also explained to students of agricultural engineering as part of their university lessons on the topics of automatic control, electronic measurements, programming and computational intelligence. The activities inspired by the egg classifier project were following the project based learning (PBL) approach [20]. The university students had comparatively little experience in programming, electronics and system assembly. For this reason, the participation in these activities were encouraging the students' acquisition of hand-on experiences with physical systems, control, electronic assembly and programming and thus were better preparing them for their future careers. The whole approach had also collaborative learning (CL) [21] characteristics as the more expert students in a relevant subject assisted the rest of the classroom to understand the functions of the main system. The duration of the overall system implementation was eight months, approximately, and all the activities took place in 2023.

The ERASMUS STEM4Agri, EU funded project (grant agreement 2021-1-EL01-KA210-VET-000032913) cultivates the knowledge transfer from the universities to the vocational institutes, fostering the digital agriculture concept. During this project, trainers and trainees at the larger vocational institute of Greece, i.e., the DIEK Aigaleo, were encouraged to improve their knowledge about modern technologies like electronics, automation, programming, and physical process modelling, assisted by the university persons (both professors and students) participating to the project. Seizing this opportunity, the main logic behind the discussed egg classification system was also explained by the university persons to trainers and trainees from the DIEK Aigaleo, via a short, in-purpose, composed presentation and as part of their specialty lessons.

Similar educational paradigm approaches are extremely suitable for preparing students of tertiary education to become well trained professionals, in a drastically changing technological environment, with immediate benefits for the agricultural production sector and beyond. As already mentioned, the presented activity aims at encouraging the cultivation of valuable skills, like electromechanical and electronic system assembling, programming, and process control. Apart from the pure technological skills, students are called improve their capabilities on how to collaborate, to assess, describe and present cutting edge problems and their solutions.

It is worth noting that, throughout the egg classifier project development and explanation, valuable feedback was collected for improving the initial system, from both persons at the Agricultural University of Athens and at the DIEK Aigaleo, while analytical evaluation forms were filled and processed, on a completely anonymous and voluntary basis.

B. Exemplary Mechanism Overview and Components

Technically speaking, an electric geared motor is used to move a belt porting the eggs close to the sensing element. A classification algorithm, utilizing the Euclidean distance metric [22], decides on the type of the egg under testing, which it is then pushed to the left or to the right of the belt, according to its characteristics, assisted by an angle servomotor. The whole approach utilizes open and easy-to-find software and hardware components, e.g., arduino boards [23], some cheap electronic and electromechanical modules for sensing and acting, recyclable materials and parts of retired equipment. The necessary programming and process monitoring is achieved via the Arduino IDE software [24]. Fig. 1 provides an overview of the interoperating components, while Fig. 2 depicts the prototype construction, which is compact and portable.

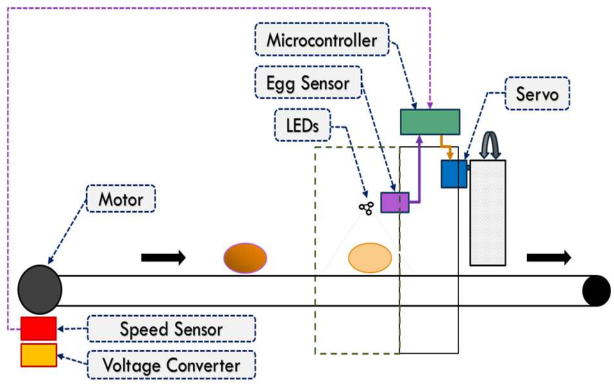


Fig. 1. Interoperability overview of the proposed egg classification system

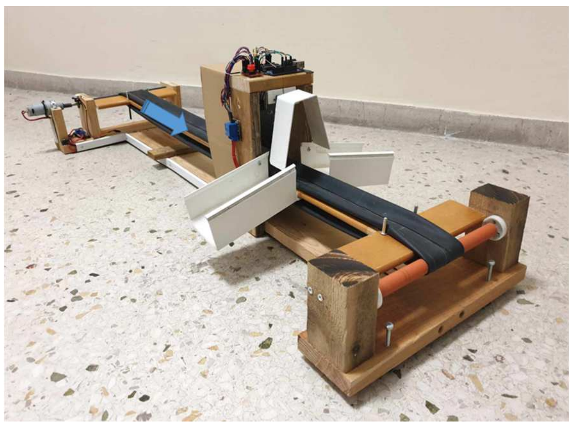


Fig. 2. The prototype smart egg classification system being implemented.

The tools being selected have large supporting communities and thus are very suitable for quite inexperienced programmers, like the students of agricultural engineering. A key component for the implementation of the egg classification process is the multifunction APDS-9960 [25] sensing module. The way that this sensor is utilized becomes more apparent in section III. The whole construction is not optimal, but allows for several improvements and modifications, thus (and intentionally) turning its imperfections to beneficial learning opportunities for all the participants.

III. Implementation Details

This section highlights interesting implementation details of the proposed experimental educational approach, as the exemplary system can be divided to three separate parts: the chassis hosting the transfer belt, the sensing and control module, and the classification actuator module. Furthermore the logic behind its operation has some interesting points requiring further analysis.

A. The Main Chassis Construction

The egg transfer mechanism mainly consists of recyclable materials and retired parts, namely, pieces of wood for the chassis, rollers from a broken printer, a tire tube as belt and a brushed geared DC motor from an electric screwdriver. The approximate length and width of the mechanism porting the transfer belt is 110cm and 25cm, respectively. The necessary power is supplied to the motor through a 12V 5A source, via a cheap relay and a DC-DC step down converter that regulates the voltage and thus the current that goes into the motor. The step down module was manually adjusted, via a screwdriver, so as the belt to achieve a speed close to $0.25 m \cdot s^{-1}$. Additionally, from the same power supply, a separate line gives constant 12V to the arduino microcontroller that acts as the 'brain' of the classification system and to the rest of the components being necessary. It is worth noting that on axis of the geared motor, a photo interrupter was fixed, so as to provide pulses to the arduino for estimating the current speed of the belt. The reason why this is important is explained in section B. Details of the belt drive system and its regulating and sensing components are given in Fig. 3.

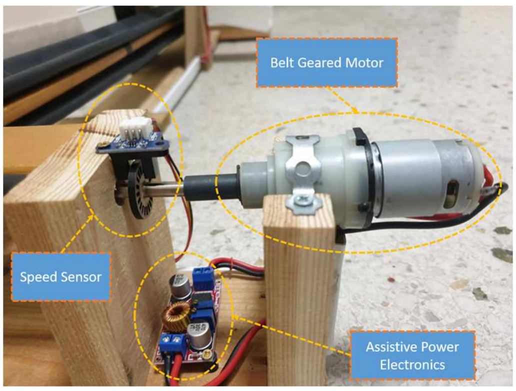


Fig. 3. Belt drive motor, its voltage regulating circuit and its speed sensor (photo interrupter)

B. Classification Sensing and Decision Unit

At distance equal to the 2/3 of the total belt length, away from the motor, a Π-shaped wooden hyper construction is hosting the necessary equipment implementing the egg classification sensing and decision logic. The core Arduino microcontroller is connected with a budget-friendly APDS-9960 sensor (for proximity, light, RGB, and gesture perception), potentiometers, and a handmade power distribution circuit board with a toggling push button. It also hosts the single channel relay module controlling the power to the belt motor and an SG90 servo motor utilized for pushing the eggs out of the belt. A removable controlled light chamber was constructed by cardboard and was attached to the wooden Π-shaped frame. This chamber is equipped with six LEDs, providing light optimally adjusted via a second step-down DC-DC converter and serving the critical purpose of enhancing the accuracy of the classification process by eliminating the effect of external light variation.

The start/stop push button activates the relay that gives power to the belt motor. Subsequently, the conveyor belt commences its movement, transporting the eggs toward the classification module. As the object (i.e., the egg) progresses along the conveyor belt, the microcontroller is calculating the speed of the belt (typically every 0.5s), with the assistance of the photo interrupter sensor which is fixed on the belt motor. This calculation is crucial for setting the exact delay between the moment the classification decision is taken and the moment that this decision is converted to action, otherwise the classification mechanism is susceptible to product misjudgment or mishandling. The latter delay is necessary as the APDS-9960 sensor and the SG90 servo actuator are not exactly at the same location.

When the eggs are exactly below the APDS-9960 sensor the Euclidean distance based algorithm classification algorithm decides on the type of the egg and the proper command is given to the SG90 servo that handles it properly. Further details on this process are given is sections C and D. Fig. 4 illustrates the main microcontroller unit and egg characteristic lighting and sensing arrangements for the classification system being presented (with the cardboard cover removed).

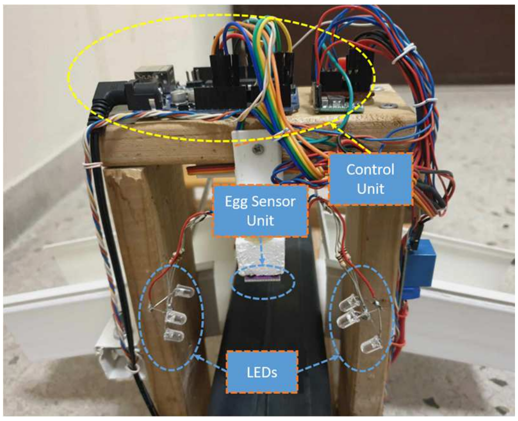


Fig. 4. Main control unit and egg characteristic sensing arrangements for the classification system being presented

C. Classification Action Unit

For transforming the classification decisions into action, the SG90 servo motor, fixed at the top of the Π-shaped construction, is equipped with a plastic U-shaped separation module, for implementing a three-way object separation capability. This module dynamically changes the route of the egg being on the belt, in accordance with this classification decision. For demonstration purposes, the eggs are categorized into three groups: white, brown, and light brown.

The mechanism, with its flexible plastic parts, which are remnants taken from an old electric installation, secures the path of the eggs in the prearranged direction. White eggs are moved to the left, while brown eggs to the right. On the contrary, it allows eggs of intermediate colour to continue their trip on the belt up to the belt end, passing through the module, as it does not move. Fig. 5 illustrates details of the classification action mechanism, comprised by the SG90 angle servo and the accompanying plastic parts.

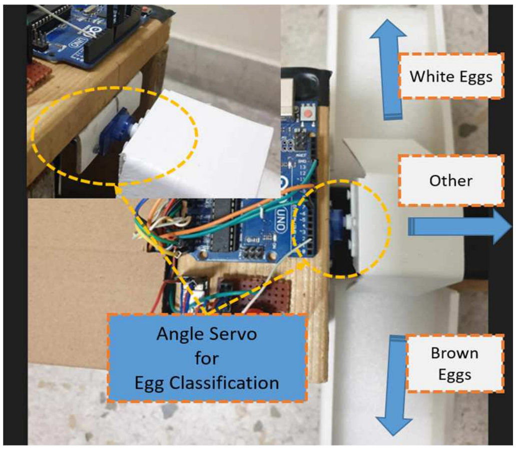
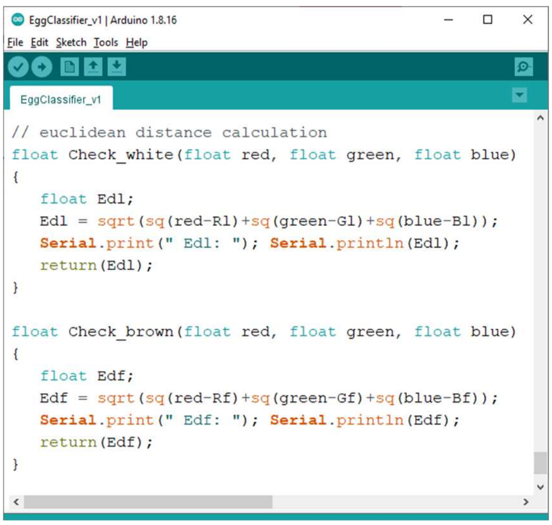


Fig. 5. Details of the classification action mechanism comprised by an SG90 angle servo and accompanying plastic parts

D. *Classification Intelligence*

The main classification algorithm for a given egg object, with the help of the APDS-9960 sensor, intercepts four integer values, namely read-green-blue (RGB) and ambient light, and creates three corresponding to the RGB normalized float values, by dividing the read, greed and blue quantities with the ambient light value. Employing the Euclidean distance formula, the vicinity of the current egg from the brown and from the white egg patterns is checked. Distance values shorter than an empirically defined threshold from a specific egg category (i.e., the brown or the white one) are translated into classification of the current egg into this category. A code instance providing details on the Euclidean distance metric calculation is depicted in Fig. 6.



```
// euclidean distance calculation
float Check_white(float red, float green, float blue)
{
   float Edl;
   Edl = sqrt(sq(red-Rl)+sq(green-Gl)+sq(blue-Bl));
   Serial.print(" Edl: "); Serial.println(Edl);
   return(Edl);
}

float Check_brown(float red, float green, float blue)
{
   float Edf;
   Edf = sqrt(sq(red-Rf)+sq(green-Gf)+sq(blue-Bf));
   Serial.print(" Edf: "); Serial.println(Edf);
   return(Edf);
}
```

Fig. 6. Indicative microcontroller code implementing the Euclidean distance calculation metric based on the egg color characteristics

The optimal RGB values for the brown and the white egg patterns have prior been computed and permanently stored into the microcontroller memory, via a process that can be perceived as an early stage of machine learning, as manual training is imperative for the algorithm to comprehend the physical world, i.e., to properly identify and classify the eggs according to their colour. Eggs that are not close to the brown enough nor to the white enough are falling into the 'other' category. A potentiometer was used to alter the distance threshold (i.e., the radius in the 3-dimentional RGB space) from the egg prototypes and thus the sensitivity/inclusiveness of the classification algorithm. The proper delay for the angle servo activation was also computed, as the speed of the belt may vary according to its gear motor lubrication or the egg number it is carrying. In Fig. 7 the complete flow diagram of the egg classifying machine operation is given.

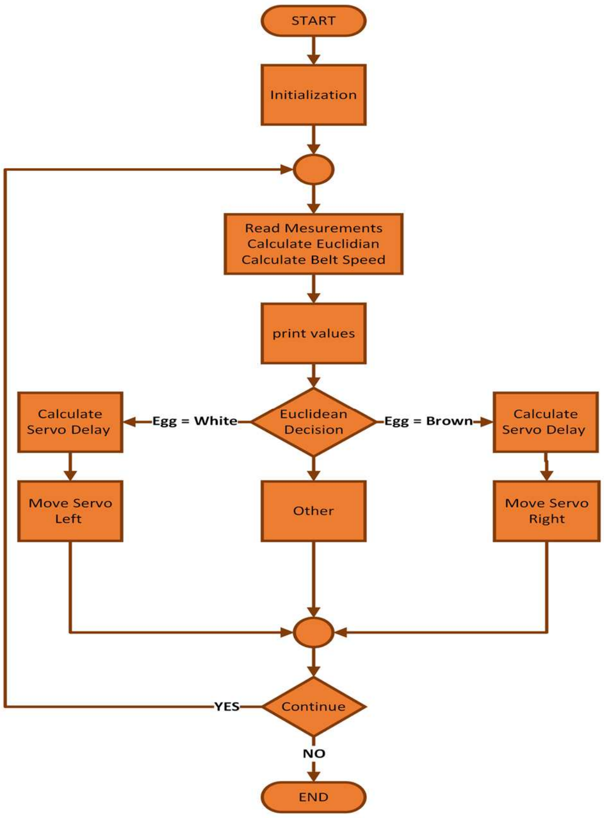


Fig. 7. The main logic diagram for the smart egg classification system being presented

IV. Evaluation Results and Discussion

The proposed educational paradigm has been assessed from different perspectives, to extract useful conclusions.

A. *Brief Technical Assessment*

During the development of the system being discussed, participants first had to boil and then to test a lot of eggs, eating the cracked ones due to classification failures. The maximum rate at which consecutive eggs could be handled was close to 2 objects per second. The accuracy of the whole process was progressively improved, from below 50% to slightly above 90%, via the introduction of add-ons like the controlled light chamber, the normalization of the RGB values, the belt speed calculation and the redesign of the angle servo attachments. These incremental improvements were acquainting in parallel the participants with the idiosyncracies of a real-system and were providing valuable learning opportunities for them.

Taking into account the 20€ for the Arduino Uno microcontroller board, the 4€ for the APDS-9960 sensor, the 4€ for the angle servo, the 2€ for the LEDs, the 10€ for the DC-DC converting modules, and another 10€ for the rest of the components that could not be covered by recycling/upcycling policy, the cost of the discussed system is estimated around 50€. This amount justifies completely the ‘low-cost’ character of the whole approach, especially given the educational exploitation perspectives of the proposed system.

B. *Educational Point of View*

Students of Agricultural Engineering at the Agricultural University of Athens (AUA) evaluated the proposed system. These persons participated in the implementation of the discussed pilot activity or in actions inspired by its functions, while all had at least entry-level experience in computer systems. Trainees at the DIEK Aigaleo also evaluated the same system, after an in-vivo presentation and a demonstration of its functions. The corresponding survey mainly included statements in Likert-type scale [31], which were addressed using the Google Forms [32] environment. Despite the small number of participants (30 persons from DIEK Aigaleo and 29 persons from AUA) and their diverse background, the survey being performed delivered interesting results.

The most indicative among these results are presented in this section, as bar charts. The results referring to university students are in blue color while the results reflecting the vocational institute trainee opinion are in green color. For each statement, the rate options were from 1 (for “Strongly Disagree”) to 5 (for “Strongly Agree”). In accordance with this scale, in the relevant figures (i.e., from Figure 8 to Figure 12), the horizontal axis contains bar (opinion group) characterization, by a number from 1 to 5, while the vertical axis the percentage of participants that fall into a specific opinion category.

More specifically, the top part of Fig. 8 illustrates that 84% of the AUA participants and 80% of the DIEK participants believe that the methodological approach to divide the explanation of the discussed activity into separate parts (i.e., electromechanical, electronic, programming) makes it more understandable. Furthermore, as inferred via inspection of the bottom part of Fig. 8, 94% of the AUA participants and 90% of the DIEK participants find that this activity is beneficial for communicating the agri-food sector automation concept.

Beyond this, according to the top part of Fig. 9 (61% of the AUA participants and 59% of the DIEK participants), the equipment being used exhibited similarities with a real-word production unit. The cost of parts comprising the discussed system is considered very affordable by the participants, as depicted in the bottom part of Fig. 9 (96% of the AUA participants and 91% of the DIEK participants).

According to the opinions reflected at the top and at the bottom part of Fig. 10, respectively, participants find the proposed activity beneficial for their career development in modern agriculture area (92% of the AUA participants and 88% of the DIEK participants) and new technologies in general (84% of the AUA participants and 77% of the DIEK participants).

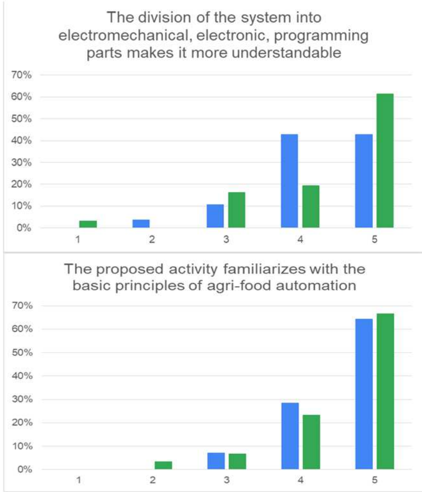


Fig. 8. Participants’ point of view on the methodological approach to divide the explanation of the discussed activity into separate parts and its suitability for the agri-food automation concept (blue bars for AUA, green for DIEK Aigaleo)

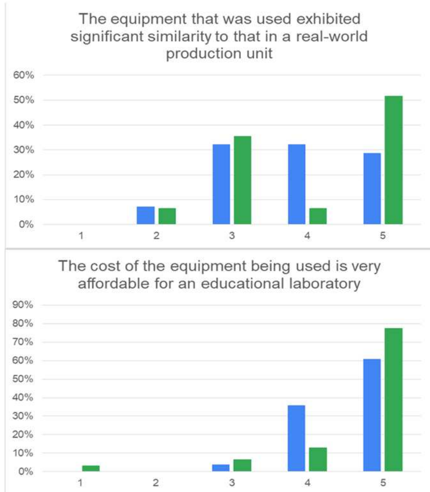


Fig. 9. Participants’ point of view on the similarity of the equipment being used with a real-word production unit and its cost as part of an educational laboratory (blue bars for AUA, green for DIEK Aigaleo)

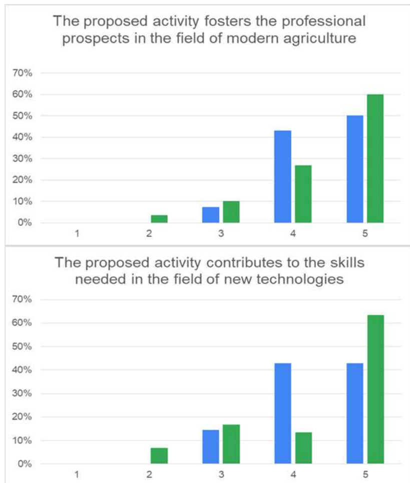


Fig. 10. Participants’ point of view on the benefits of the proposed activity for their career development in modern agriculture and new technologies in general (blue bars for AUA, green for DIEK Aigaleo)

Fig. 11 visualizes participants' opinions about the role of the proposed activity in problem-solving, in the cultivation of creativity and in communication and teamworking capacity building. As with the previous cases under evaluation, the majority of the AUA students and the DIEK trainees find its contribution beneficial for the cultivation of all these skills.

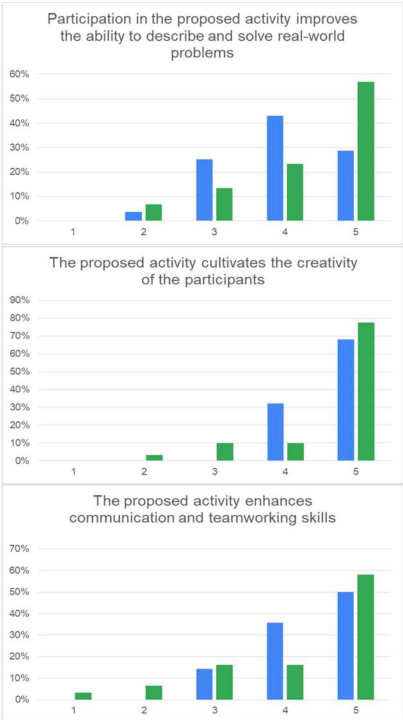


Fig. 11. Participants' opinion on the role of the activity in problem-solving, in the cultivation of creativity and in communication and teamworking capacity building (blue bars for AUA, green for DIEK Aigaleo)

Fig. 12 (top part) reflects willingness of the participants to follow similar activities in the future (72% of the AUA participants and 71% of the DIEK participants) and their positive attitude (bottom part) toward incorporating such activities into the institutional educational curricula (68% of the AUA participants and 74% of the DIEK participants).

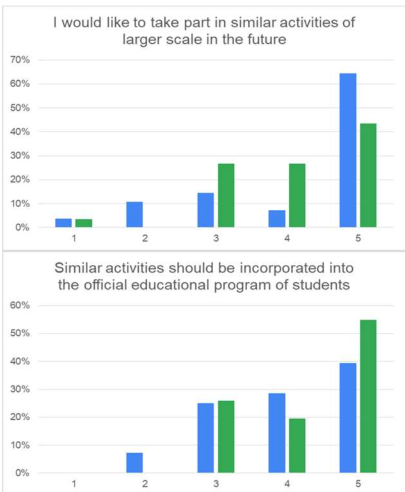


Fig. 12. Participants' opinion on their willingness to follow similar activities in the future and on incorporation into the institutional educational curricula (blue bars for AUA, green for DIEK Aigaleo)

C. *Further Discussion*

The whole approach utilizes low-cost electronic equipment, open software and easy-to-find materials, that assist students to create and evaluate a prototype egg classification mechatronic system. Such systems will play a dominant role in modernizing the food supply chain practices and providing trained personnel for, in line with the "from farm to fork" philosophy. Indeed, the proposed system, after the necessary adaptations, can be engaged in real-world food supply chain scenarios.

It must be noted that the educational character of the proposed activity suggested the adoption of lowered standards than the ones utilized in commercial counterparts, i.e., in terms of classification accuracy and object processing rate, while other features of eggs, like their size, were not examined. Nevertheless, the basic construction being presented has the potential to support various improvements toward this direction, delivering more mature versions in the future and at very reasonable additional cost.

Despite the diverse background of the participants, i.e., university students and vocational institute trainees, the evaluation results of the pilot system being presented converge highlighting its importance for the cultivation of multidisciplinary skills. These results are in accordance with the findings of other research works [19,28-30], in an area where the empirical studies are not many yet [29]. The evaluation by a greater number of participants, ideally after the incorporation of the specific laboratory activity into the official curriculum of the educational institutes getting involved, could provide valuable additional findings.

V. Conclusions

In this paper, the abundance of several innovative and low-cost electronics and of the accompanying software has been exploited to orchestrate an educationally meaningful STEM activity, at tertiary education level, describing a modern egg classification system. Similar constructions are facilitating the understanding of the innovative technologies being used in the modern food supply chain, and beyond. Indeed, according to a first set of survey findings, the example being selected, being both intriguing and simple, aims at highlighting the importance of such paradigm for making food supply chain process more efficient, in quality and quantity, and, in parallel, improves students' perception of modern technological topics. Furthermore, students acquire description, presentation and assessment skills for cutting edge systems. All this capacity building process is fostering their future professional career perspectives. Finally the example being presented can be seen as a flagship case of activities that should be incorporated into the curricula of technological institutes, in response to the recent technological achievements and the forthcoming job transformation necessities.

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REFERENCES

[1] S. Anwar, N. Bascou, M. Menekse, and A. Kardgar, "A Systematic Review of Studies on Educational Robotics". J. Pre-Coll. Eng. Educ. Res. 2019, 9, 2. https://doi.org/10.7771/2157-9288.1223.

[2] D. Scaradozzi, L. Cesaretti, L. Screpanti and E. Mangina, Identification of the Students Learning Process During Education Robotics Activities. Front. Robot. AI 2020, 7, 21. ISSN 2296-9144. https://doi.org/10.3389/frobt.2020.00021.

[3] S. Papadakis and M. Kalogiannakis, eds., (2021). Handbook of Research on Using Educational Robotics to Facilitate Student Learning. Advances in Educational Technologies and Instructional Design. IGI Global. doi:https://doi.org/10.4018/978-1-7998-6717-3.

[4] J. T. C. Tan, L. Iocchi, A. Eguchi and H. Okada. 2019. Bridging Robotics Education between High School and University: RoboCup@Home Education, 2019 IEEE AFRICON, Accra, Ghana, 2019, pp. 1-4. https://doi.org/10.1109/AFRICON46755.2019.9133791

[5] L. M. C. Benavides, J. A. Tamayo Arias, M. D. Arango Serna, J. W. Branch Bedoya and D. Burgos, (2020). Digital Transformation in Higher Education Institutions: A Systematic Literature Review. Sensors, 20(11), p.3291. doi:https://doi.org/10.3390/s20113291.

[6] Y. Sahin and U. Celikkan, Information Technology Asymmetry and Gaps Between Higher Education Institutions and Industry. J. Inf. Technol. Educ. Res. 2020, 19, 339–365. https://doi.org/10.28945/4553.

[7] P. Migliorini, A. Wezel, E. Veromann, C. Strassner, D. Średnicka-Tober, J. Kahl, S. Bügel, T. Briz, R. Kazimierczak, H. Brives, A. Ploeger, U. Gilles, V. Lüder, O. Schleicher-Deis, N. Rastorgueva, F. Tuccillo, L. Talgre, T. Kaart, D. Ismael and E. Rembiałkowska, Students' Knowledge and Expectations about Sustainable Food Systems in Higher Education. Int. J. Sustain. High. Educ. 2020, 21, 1087–1110. https://doi.org/10.1108/IJSHE-12-2019-0356.

[8] E. Silva, Measuring skills for 21st-century learning. Phi Delta Kappa, 90(9), 2009, 630634.

[9] V. J. Shute, C. Sun, and J. Asbell-Clarke, Demystifying computational thinking. Educ. Res. Rev. 2017, 22, 142–158. http://dx.doi.org/10.1016/j.edurev.2017.09.003

[10] SUSTAINABLE DEVELOPMENT GOALS – GOAL #2. Available online at: https://sdgs.un.org/goals/goal2 (accessed on 15 December 2023).

[11] FAO 'Climate-smart Agriculture Sourcebook'. 2013. Available online: http://www.fao.org/3/i3325e/i3325e.pdf. (accessed on 20 November 2021).

[12] Y. Liu, X. Ma, L. Shu, G. P. Hancke and A. M. Abu-Mahfouz, From industry 4.0 to agriculture 4.0: current status, enabling technologies, and research challenges, IEEE Trans. Ind. Informat., 2020. https://doi.org/10.1109/TII.2020.3003910

[13] D. Bochtis, L. Benos, M. Lampridi, V. Marinoudi, S. Pearson and C. G. Sørensen, Agricultural Workforce Crisis in Light of the COVID-19 Pandemic. Sustainability 2020, 12, 8212. https://doi.org/10.3390/su12198212

[14] W. Ridley and S. Devadoss, (2021). The Effects of COVID - 19 on Fruit and Vegetable Production. Applied Economic Perspectives and Policy, 43(1), 329-340.

[15] M. Javaid, A. Haleem, R. P. Singh and R. Suman, (2022). Enhancing smart farming through the applications of Agriculture 4.0 technologies. International Journal of Intelligent Networks, 3, 150-164.

[16] L. B. Sørensen, L. B. Germundsson, S. R. Hansen, C. Rojas and N. H. Kristensen, What Skills Do Agricultural Professionals Need in the Transition towards a Sustainable Agriculture? A Qualitative Literature Review. Sustainability 2021, 13, 13556. https://doi.org/10.3390/su132413556

[17] C. M. Cunningham and G. J. Kelly, Epistemic practices of engineering for education. Sci. Educ. 2017, 101, 486–505. https://doi.org/10.1002/sce.21271

[18] E. A. Siverling, E. Suazo-Flores, C. A. Mathis and T. J. Moore, Students' use of STEM content in design justifications during engineering design-based STEM integration. Sch. Sci. Math. 2019, 119, 457–474. https://doi.org/10.1111/ssm.12373

[19] D. Loukatos, M. Kondoyanni, I.-V. Kyrtopoulos and K.G. Arvanitis, Enhanced Robots as Tools for Assisting Agricultural Engineering Students' Development. Electronics 2022, 11, 755. https://doi.org/10.3390/electronics11050755

[20] PBL (2020) What is PBL. Available online at: https://www.pblworks.org/what-is-pbl (accessed on 1 December 2021)

[21] B. L. Smith and J. T. MacGregor, What is collaborative learning? In Collaborative Learning: A Sourcebook for Higher Education; Goodsell, A.S., Maher, M.R., Tinto, V. Eds.; National Center on Postsecondary Teaching, Learning, & Assessment, Syracuse University: Syracuse, NY, USA, 1992.

[22] Euclidean distance metric description on wikipedia. https://en.wikipedia.org/wiki/Euclidean_distance (accessed on 1 December 2023)

[23] Arduino Uno board description on the official Arduino site. Available online at: https://store.arduino.cc/arduino-unorev3 (accessed on 1 December 2023)

[24] Arduino IDE software description. Available online at: https://www.arduino.cc/en/Guide/Environment (accessed on 2 December 2023)

[25] APDS-9960 multifunction sensor description provided by Broadcom. Available online at: https://www.broadcom.com/products/optical-sensors/integrated-ambient-light-and-proximity-sensors/apds-9960 (accessed on 2 December 2023)

[26] R. Likert, A Technique for the Measurement of Attitudes. Arch. Psychol. 1932, 140, 1–55.

[27] Google Forms (2021). Repository of guidance and tools for the Google Forms. Available online at: https://www.google.com/forms/about/ (accessed 28 September 2021).

[28] M. Cardín Pedrosa, M. Marey-Perez, T. Cuesta and C. J. Álvarez, Agricultural Engineering Education in Spain. Int. J. Eng. Educ. 2014, 30, 1023–1035.

[29] Y. He and L. Liang, Application of Robotics in Higher Education in Industry 4.0 Era. Univers. J. Educ. Res. 2019, 7, 1612–1622.

[30] D. Loukatos, M. Kondoyanni, and K. G. Arvanitis. 2022. Automatic Fruit Picking: An Entry-level, in Scale, Approach for Cyber Physical Systems Understanding. In Proceedings of the 25th Pan-Hellenic Conference on Informatics (PCI '21). ACM, New York, NY, USA, 167–171. https://doi.org/10.1145/3503823.3503855