Virtual education with 3D bread models

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Abstract: *This paper presents how 3D scanning technology can be integrated into food technology education, considering the study of the properties of bread with functional additives included in it. Using a pedagogical approach to apply 3D scanning technology in education leads to increased engagement and formation of critical thinking in students. The proposed methodology is a way to show students how data can be dynamically changed and the results obtained can be evaluated. 3D technology contributes to determining the quality, packaging, and structural changes in food products with sufficiently accurate and reproducible data. Further research aims to integrate with AR (augmented reality), virtual platforms for remote experimentation, and advanced learning resources.*

Keywords: 3D Scanning Technology, Food Technology, Bread Analysis, Pedagogical Strategies.

1. Introduction

The integration of technology with education opens up opportunities for new and interactive learning experiences. Among the innovative technologies is 3D scanning, which has emerged as a tool that allows educators to transport real objects into digital space.

According to a study by Reisoğlu et al. (2017), collaborative and inquiry-based learning strategies are more commonly used in 3D virtual learning environments. Presence, satisfaction, communication skills, and engagement have been repeatedly studied as emotional and cognitive outcomes. Language learning and science are also widely discussed topics.

In the study by Uyar et al. (2009), the authors point out that 3D scanners simplify the geometric characterization of irregularly shaped food products, such as pears and strawberries, by creating accurate digital 3D images. This reduces labor, reduces measurement errors, and improves simulation accuracy when imported into computational fluid dynamics (CFD) programs, making 3D scanning a suitable tool

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for food engineering. This thesis is further developed by Yang et al. (2010), who state that 3D laser scanning technology allows for sufficiently precise, fast, and efficient measurement of food product volumes. By generating 3D data from a point cloud, it simplifies inventory management and provides high accuracy, making it a practical tool for detecting reserves, for example, in granaries.

Rodriguez-Parada et al. (2018) highlight the potential of 3D scanning and reverse engineering in the food industry within the framework of Industry 4.0. By digitizing fresh food, personalized and sustainable packaging can be designed with precision, reducing material use and increasing product safety. The method improves efficiency, supports the development of competitive products, and opens up opportunities for additive manufacturing and augmented reality applications. Gulak et al. (2019) introduce a high-resolution UV laser marking system for plastic products, such as food caps, offering safer, faster, and more precise marking without harmful additives compared to conventional methods. The system enables dynamic, high-speed marking, improves product protection with 3D scanning and dual-lane laser systems, and outperforms traditional printing methods in quality and efficiency.

Bread is an everyday staple that is a hot topic for research. The fact that this product can be transformed into detailed 3D models makes it possible to create tactile and realistic experiences in a virtual learning environment. A particularity of bread is that it is a product with a relatively short shelf life and can hardly be used in education every school year. This is largely true for bread that is under research, for example, with different percentages of functional additives.

Different manufacturers of 3D scanners, such as Matter and Form, Creaform, and Artec 3D, offer a range of educational resources to facilitate the use of their devices. Matter and Form (Matter and Form, 2025) offers a professionally developed curriculum and a library of resources for educators to help learners develop the competencies they need in 3D scanning. Meanwhile, Creaform ACADEMIA (Creaform, 2025) offers a full range of 3D measurement technologies, including e-learning courses for hardware and software. Artec 3D (Artec Europe, 2025) enhances training by providing 3D scanning tools in a variety of applications. Stable Micro Systems (Stable Micro Systems, 2024) offers 3D scanners for measuring bread and bakery products. The manufacturer also offers educational resources related to their devices. Their Volscan Profiler is a desktop laser scanner for volume, density, and dimensions of bakery products; accurate assessments are provided for quality control and product development. The educational materials provided by Stable Micro Systems help users understand the operation and benefits of the Volscan Profiler, thus making it valuable to bakers and food scientists in their goal of high bread quality.

From the analysis of available literature sources, it can be summarized that in most cases, general-purpose 3D scanners are offered, which can be used in bread analysis. There are few manufacturers of specialized devices suitable for solving tasks in this area. Training resources are related to how to work with 3D scanning devices. It is necessary to conduct additional research related to training in the analysis of three-dimensional images of bread, especially in the field of the influence of various additives in the product.

The aim of this work is to integrate 3D scanning technology to improve food technology training. An approach is proposed in which, by integrating the 3D scanning process, realistic models are created and the properties of bread with functional additives are analyzed.

2. Pedagogical approach and didactic solutions in 3D scanning of bread

2.1 Pedagogical approach

Three pedagogical approaches are suitable for teaching 3D bread scanning. The first is multimedia learning (Tee et al., 2019), which improves engagement by incorporating different types of digital resources, such as videos, interactive tutorials, and e-books, that help learners learn how to perform the scanning process in a sufficiently accessible way. An experimental method (Kvittingen et al., 2016) identifies which variables affect scanning accuracy by actively learning the technology. The demonstration method (Bonjour et al., 2014) is visual and interactive. Learners are observers but also participate in the scanning process and thus easily understand the step-by-step actions that need to be performed for a successful 3D scan.

Multimedia learning. Multimedia-based learning uses a combination of video, audio, interactive elements, and other digital resources to enhance the learning process. In 3D bread scanning, multimedia engages students in ways that a traditional lecture cannot. For example, through interactive tutorials, video instructions, interactive e-books, and e-tests.

Experimental method. This method involves testing hypotheses and exploring new theories. When using this approach to 3D bread scanning, an experiment is structured that allows students to hypothesize about the factors affecting the accuracy of 3D bread scanning. Also, to plan an experiment, such as evaluating the impact of different additives on the geometric characteristics of bread. Scanning the bread, collecting the resulting data, and processing it using various algorithms to process the 3D images of bread. The final step is analyzing the results obtained.

Demonstration method. This method involves showing objects and materials to students while explaining. In 3D bread scanning, a demonstration is used to visually understand the scanning process and how this technology is applied to bread. The demonstration of the scanning process discusses the capabilities of different types of 3D scanners and their applicability according to the texture and shape of the bread. The steps that are performed to realize the scanning of the bread are indicated sequentially. The scanning process is demonstrated in real time (scanning of a loaf of bread). Interactive demonstration—the students take part in the individual stages of scanning the bread.

2.2 Didactic challenges and solutions

The complexity of geometric modeling training stems from the requirements for mastering mathematical shapes and transformations, which can be difficult for learners. Also, limited training time leads to insufficient practical exercises, which further complicates the process (Pisarova, 2024). These challenges can be overcome by simplified 3D scanning workflows and the use of pre-prepared models.

An interdisciplinary approach is important in education, uniting different scientific fields (Neminska, 2023). In the case of 3D scanning of bread, it is demonstrated how food science, computational modeling, and technological education are connected, which is facilitated by studying algorithms for processing 3D images of bread (Uyar et al., 2009).

Assessing learners' skills in problem solving, collaboration, and digital literacy is an important part of the educational process (Neminska, 2023). In this regard, the use of 3D scanning for educational purposes provides an opportunity to develop and assess these skills.

Table 1 summarizes the didactic challenges and their solutions from the perspective of education through 3D scanning of bread.

Table 1. Didactic challenges and solutions

Challenge Solution	Challenge Solution
Complexity of 3D Modeling Training	Using simplified 3D scanning workflows and pre-prepared models
Short Shelf Life of Bread as a Learning Material	Creating reusable 3D printed models
Interdisciplinary Integration	Demonstrating how 3D scanning connects food science, computational modeling, and technology education and learning algorithms for processing 3D images of bread
Evaluation of Learning Outcomes	Assessing learners' problem-solving, collaboration, and digital literacy skills

3. Results

As a result of the studies and summaries, an algorithm and procedure for 3D scanning of bread with functional additives was created.

The flour bread was prepared according to technology based on the approved standard US02/2011 (Approved Standard "Bulgaria," "white" bread). The main raw material, wheat flour, was replaced with 3,7% pigweed flour and 7,1% purslane flour.

The amount of additives was determined through preliminary studies.

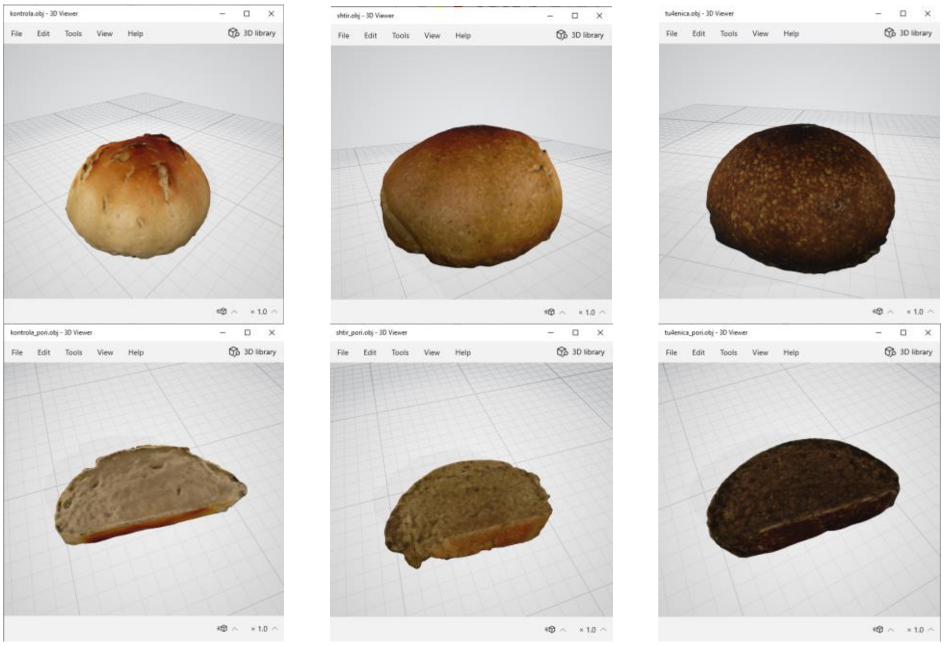
The resulting floor bread was scanned with a 3D scanner, model SOL CA73A (Scan Dimension, Alleroed, Denmark), with a working rotary table. The scanning was done with the software SOL Creator Ver.22 (Scan Dimension, Alleroed, Denmark).

The three-dimensional images of the object — bread — are stored in the .OBJ file format. Its conversion to .STL was done with the online tool ImageToSTL (ImageToStl, 2025).

In the STL file, a 3D object is represented as a series of connected triangles (Lee et al., 2019). Each triangle is defined by its three vertices and a normal vector. These triangles describe the surface of the object with a sufficiently high level of detail.

Figure 1 displays three-dimensional (3D) scanned images of bread samples made from the addition of pigweed and purslane flour. Each sample is represented in two perspectives: the whole loaf (top row) and cross-section of the crumb structure (bottom row). The images were captured with the bread placed upon a flat horizontal surface and visualized with imposed texture to facilitate close-up surface inspection. The products are placed in the middle of the frame and observed at a slightly slanted angle, having complete view of their structure and form.

For the control sample (a), the bread is uniform in color with pale golden brown color, smooth with fine texture, even crumb structured with porous and soft touch. Upon the addition of 3.7% pigweed flour (b), the bread is darker in color and has some roughness on the exterior, and the crumb also becomes denser in appearance with a firmer texture. The differences are most evident in the instance of 7.1% purslane flour sample (c), where the bread takes on a far darker color with the exterior possessing a rough, nonglossy surface. The texture of the crumbs appears coarser and more dense than in the remaining samples.



a) control sample b) 3,7% pigweed c) 7,1% purslane

Figure 1. Three-dimensional (3D) images of floor bread with the addition of pigweed and purslane flour

Table 2 presents an algorithm for processing STL files with 3D scanned floor bread. This algorithm works on an STL file by calculating its geometric and physical properties. First, the STL file is imported, and then the user specifies the mass of the object before the algorithm orients the object along its main axes using PCA (Principal Component Analysis). The volume and surface area of the object are then calculated using a function, and the density, which is the mass divided by the volume, is calculated. The algorithm calculates the dimensions of a bounding hemisphere — diameter, radius, and height — as well as the diffusion coefficient as the ratio of the height to the diameter. The results are in terms of volume, surface area, density, H/D ratio (height over diameter), and properties of the hemisphere. The object and the minimal hemisphere are plotted on a common 3D coordinate system.

To determine the main characteristics of a floor bread based on data from a *.STL file, available mathematical relationships were used.

The diameter of the loaf D, mm is determined by the following relationship:

$$D = x_{max} - x_{min} \tag{1}$$

where x_{max} and x_{min} are the maximum and minimum values along the x-axis of the 3D image of the loaf (the lower part of the loaf can be conditionally assumed to be a circle).

The height of the loaf H, mm is determined by the following relationship:

$$H = z_{max} - z_{min} \tag{2}$$

where z_{max} and z_{min} are the maximum and minimum values along the z-axis of the 3D image of the bread.

The spread factor SF (a dimensionless quantity) is determined by the following relationship:

$$SF = \frac{H}{D} \tag{3}$$

where H, mm is the height of the loaf; D, mm – its diameter.

The center of the minimum hemisphere is determined by:

$$C = \left(\frac{x_{min} + x_{max}}{2}, \frac{y_{min} + y_{max}}{2}, z_{min}\right) \tag{4}$$

where x, y and z are the coordinates of the object (bread) in the 3D image.

The volume V, mm^3 of the minimal hemisphere is determined by:

$$V = \frac{2}{3}\pi r^3 \tag{5}$$

where r, mm is the radius of the base (r=D/2).

Area A, mm^2 of the minimal hemisphere is determined by:

$$A = 2\pi r^2 \tag{6}$$

where r, mm is the radius of the base.

The surface area of the loaf and its volume are defined by the tetrahedra formed by the triangles and their vertices, by which the object is represented. Each triangular face in the STL mesh is treated as part of a tetrahedron, where one vertex is at the origin (0,0,0), and the other three vertices are the vertices of the triangle from the STL file.

The volume of the ith tetrahedron Vi, mm^3 is defined by:

$$V_i = \frac{1}{6}|v_0(v_1 \times v_2)| \tag{7}$$

where v_0, v_1 and v_2 are the three vertices of the triangular face of the object (bread); x is a cross multiplication, which results in a vector perpendicular to the triangle.

The total volume of the bread V, mm^3 is determined by:

$$V = \sum_{i=1}^{N} V_i \tag{8}$$

where N is the total number of triangular faces in the STL file.

The surface area of a tetrahedron A_i, mm^2 is defined by:

$$A_i = \frac{1}{2} \|(v_1 - v_0)(v_2 - v_0)\| \tag{9}$$

where v_0, v_1 and v_2 are the three vertices of the triangular face of the object (bread).

The total surface area of the entire loaf is given by:

$$A = \sum_{i=1}^{N} A_i \tag{10}$$

where N is the total number of triangular faces in the STL file.

The PCA method was used to align the 3D object because the STL file contains 3D points without a predefined orientation. PCA finds the natural principal axes of the object and aligns it. This ensures that the diameter is correctly measured in the X-Y plane. The height is correctly measured along the Z axis. The object is in a standardized position for the following calculations.

The command *[coeff, ~, ~] = pca(vertices)* was used. *pca(vertices)* calculates the principal components of the vertex coordinates. coeff contains the eigenvectors of the vertex covariance matrix. These vectors define the two principal axes of the object.

The data is centered (the mean of each coordinate is subtracted). The covariance matrix C of the centered data is calculated:

$$C = \frac{1}{N} \sum_{i=1}^{N} (v_i - v_m)(v_i - v_m)^T \tag{11}$$

where v_i is the i^{th} vertex; v_m is the average over all vertices.

The eigenvectors and eigenvalues of C are calculated. The eigenvectors are obtained in the coeff matrix.

The rotation of the object using the principal components is obtained with the command *rotatedVertices = (vertices * coeff).* The original coordinates of the vertices are transformed by multiplying them by the coefficient of the principal components matrix. This aligns the object so that its longest dimension lies along one of the principal coordinate axes. The new coordinate system makes it easier to analyze properties such as height, width, and depth.

The characteristics of the bread are calculated after it is oriented relative to the X-Y surface, as shown in Figure 2.

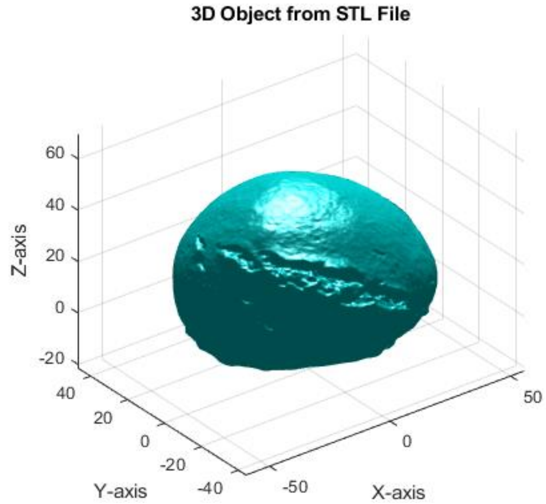


Figure 2. Bread position after alignment relative to the X-Y surface

Table 2. Algorithm for processing 3D images of bread

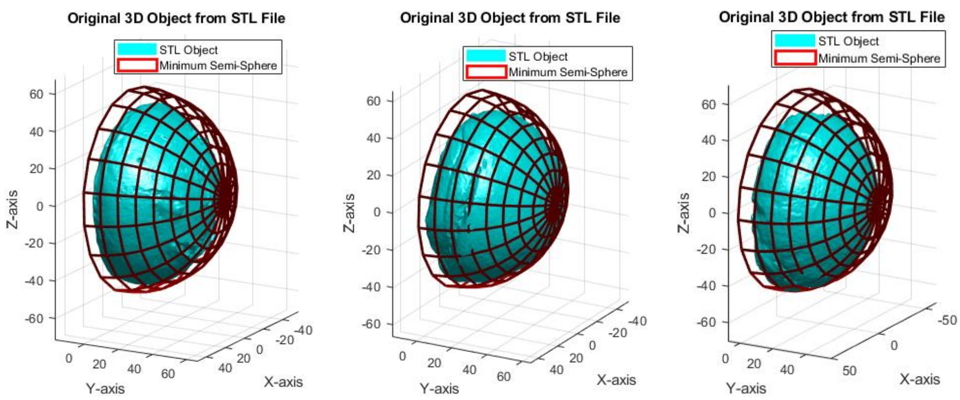
Stage	Step	Description
1	**Input variables**	**STL file; Bread mass, g**
2	Calculating the principal axes	Use PCA to determine the principal axes of the object
3	Calculating volume and surface area	Calculate the volume and surface area of the aligned object using the function (stlVolume).
4	Calculating density	Calculate the density of the object using the formula Density=Mass/Volume
5	Minimum hemisphere and geometric properties	Calculate the dimensions of the minimum hemisphere, diameter, radius and height of the object
6	Calculating the spreading factor	Calculate the spreading factor (H/D) as the ratio of height to diameter
7	Drawing a hemisphere	Overlay the original object with the minimum hemisphere and visualize on a 3D coordinate system
8	**Output variables**	**Volume, surface area, density, spreading factor, hemisphere properties**
9	STL volume function (*stlVolume*)	Function that calculates the volume and surface area of the STL object using its vertices and faces

The STL Volume Function (*stlVolume*) is presented in Table 3. The volume and surface area of a 3D object, which are calculated from the vertex and face data from the STL file. The volume and surface area variables are initialized, and then for each face of a triangle in the object, the algorithm extracts the vertices for each triangle, then calculates the volume of the tetrahedron forming that triangle and its surface area, summing them into a current total volume and surface area. At the end, an absolute value is calculated to ensure that the sign of the result is positive.

Table 3. Algorithm of STL Volume Function (*stlVolume*)

Stage	Step	Description
1	**Input variables**	**Vertices and faces from STL file**
2	Initialize volume and surface area	volume = 0; surfaceArea = 0
3	Traverse each triangular face	Extracting the vertices of a triangle
3.1	Calculate the volume of the tetrahedron	-
3.2	Calculate the area of the triangle	-
3.3	Add to volume and surfaceArea	-
3.4	Finally - take the absolute value of the volume	-
4	**Output variables**	**Volume, Surface Area**

Figure 3 illustrates three-dimensional (3D) images of bread enriched with pigweed and purslane flour, along with the minimal hemisphere outlined around each of them. Among the samples, the control has the largest volume and is quite uniform in surface and shape. Minimal deviations from the hemispherical shape and volume are observed for the sample with 3,7% pigweed content. The most significant difference occurred for the sample containing purslane flour (7,1%), which had the lowest volume and shape deviations compared to the other samples.



a) control sample b) 3,7% pigweed c) 7,1% purslane

Figure 3. 3D images of a floor bread with a minimal semi-sphere circumscribed around it

Table 4 presents measurements of floor bread with additives. A comparative analysis was made of the three types of bread Control, Pigweed and Purslane in terms of volume, area, density, spread factor and measurements of the minimum hemisphere. Purslane bread has the largest volume and area compared to the other samples, while pigweed bread has the smallest values, especially for volume and area of the hemisphere. The density of all breads is similar, but Pigweed bread contains the highest spread factor, indicating greater spreadability of the dough.

Table 4. Bread measurements

Bread type / Characteristic	Control (Mean ± SD)	Pigweed (Mean ± SD)	Purslane (Mean ± SD)
V of bread, mm^3	211760.34 ± 5000	209970.74 ± 4800	219020.27 ± 5200
A of bread, mm^2	20479.20 ± 450	19386.53 ± 430	20523.38 ± 470
Density D, g/mm^2	0.00042 ± 0.00001	0.00042 ± 0.00001	0.00041 ± 0.00001
Spread factor SF	0.52 ± 0.02	0.56 ± 0.02	0.50 ± 0.02
V of semi-sphere, mm^3	315913.88 ± 7000	266340.54 ± 6500	323540.30 ± 7200
A of semi-sphere, mm^2	17805 ± 400	15889.09 ± 350	18089.49 ± 420

4. Discussion

The work related to 3D scanning of bread can significantly support and diversify the learning strategies of students. The visualization and analysis of bread with functional additives is an example of the application of modern technologies in education. The results obtained in this work complement those of Uyar & Erdogdu (2009), according to which the use of 3D scanning in food technology removes the complexity of traditional teaching methods and provides easily digestible modular elements. This is also emphasized by Minchev & Pisarova (2024), according to whom the integration of new technologies such as 3D scanning in geometric modeling training makes concepts more understandable for students. The authors of the material believe that the application of 3D scanning promotes student engagement and leads to deeper learning. Neminska (2023) points out that the interdisciplinary integration of new technologies such as 3D scanning helps students to connect scientific and practical applications. Lee et al. (2019) noted that visualizations obtained from 3D scanning stimulate interest in food science and increase digital literacy. In the case of bread, with functional additives, learners can visually assess and analyze changes in the texture and structure of the product, which improves their analytical approach. Future directions for the development of 3D scanning of bread are related to the integration of augmented reality (AR) and the creation of virtual platforms for food product analysis. Artec 3D (Artec Europe, 2025) suggests that the application of AR can provide new methods of visualization and interaction. Virtual platforms would allow learners to access resources remotely and experiment with different models and methods. Improving training resources, including the development of detailed manuals and training videos, would facilitate the understanding and application of 3D scanning in food technology (Creaform, 2025).

It can be summarized that:

- 3D scanning allows better visualization and analysis of bread with functional additives, which is better for learning and more interesting and interactive;

- The technology simplifies intricate food science concepts into something less complex and more applicable;
- Future advancements can even include augmented reality (AR) and virtual spaces to provide an enhanced food product discovery;
- Even more smooth training tools, such as textbooks and videos, can even help to make 3D scanning more adoptable in education for food technology.

5. Conclusion

This paper investigates and integrates 3D scanning technology in food technology education, applied to bread analysis. The application of 3D scanning to create realistic models and analyze the properties of bread with functional additives is analyzed.

3D scanning in scientific research is used to measure the quality indicators of bread with higher accuracy and higher reproducibility compared to traditional methods, customize packaging, and analyze structural changes in food products.

From a teaching perspective, 3D scanning offers the learner the opportunity to visualize abstract concepts, manipulate variables during scanning, and then analyze the result of these manipulations in an appropriate way.

Algorithms and procedures are adapted that are suitable for teaching 3D scanning technologies in food sciences.

The results of the study on 3D scanning of bread can be applied to improve pedagogical strategies and overcome didactic challenges in this field. Through effecttive integration of these technologies, learners can acquire in-depth knowledge and skills about the technical process of bread production and related scientific concepts, developing skills in data and results analysis, as well as forming critical thinking.

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REFERENCES

Artec Europe (2025) *Learning Center.* https://www.artec3d.com/learning-center. [Accessed 9th January 2025].

Bonjour, J., Hass, A., Pollock, D., Huebner, A. & Frost, J. (2014) Bringing NMR and IR spectroscopy to high schools. *Journal of Chemical Education*. 94, 38–43.

Creaform (2025) *Creaform ACADEMIA*. https://www.creaform3d.com/en/products/creaform-academia. [Accessed 8th January 2025].

Gulak, S. V., Cherkashin, A. I., Balashov, I., Zarytskyi, V. I., Kurskoy, Yu. S. & Zhdanova, Yu. V. (2019) Development of a high-resolution laser marking system for plastic and food industry applications. *In 2019 IEEE 8th International Conference on Advanced Optoelectronics and Lasers* (CAOL) (pp. 1–7). IEEE. doi: 10.1109/CAOL46282.2019.9019422.

ImageToStl (2025) *Convert OBJ to STL*. https://imagetostl.com. [Accessed 25th January 2025].

Kvittingen, E., Kvittingen, L., Sjursnes, B. & Verley, R. (2016) Simple and Inexpensive UV-Photometer Using LEDs as Both Light Source and Detector. *Journal of Chemical Education*. 93, 1814–1817.

Lee, G.-H., Nam, J.-H., Han, H.-S. & Kwon, S.-C. (2019) A study on 3D file format for web-based scientific visualization. *International Journal of Advanced Culture Technology*. 7(1), 243–247. doi: 10.17703/IJACT.2019.7.1.243.

Matter and Form (2025) *The Best 3D Scanner in Education*. https://www.matterandform.net [Accessed 12th January 2025].

Minchev, D. & Pisarova, I. (2024) Technical Means for Teaching “Computer Modelling and Information Technology” at Lower Secondary Education. *2024 23rd International Symposium on Electrical Apparatus and Technologies (SIELA), Bourgas, Bulgaria*. pp. 1–6. doi: 10.1109/SIELA61056.2024.10637814.

Neminska, R. (2023) Interdisciplinary education for modernization. *Pedagogika-Pedagogy*. 95(3s), 18–26. (in Bulgarian).

Pisarova, I. (2024) Identification of the most effective pedagogical approaches for teaching students in the field of computer modeling and information technologies in junior high school. In Proceedings of the *International Scientific Conference "Multidisciplinary Innovations for Social Changes: Educational Transformations and Entrepreneurship", Burgas, Bulgaria*. pp. 680–687.

Reisoğlu, I., Topu, B., Yılmaz, R., Karakuş Yılmaz, T. & Göktaş, Y. (2017) 3D virtual learning environments in education: a meta-review. *Asia Pacific Education Review*. 18(1), 81–100. doi: 10.1007/s12564-016-9467-0.

Rodriguez-Parada, L., Pardo Vicente, M. Á., & Mayuet Ares, P. F. (2018) Digitizing fresh food using 3D scanning for custom packaging design. *Dyna (Spain)*. 93(1), 681–688. doi: 10.6036/8784.

Stable Micro Systems (2024) *Measuring the Volume, Density and Dimensions of Bakery Products*. [Accessed 28th December 2024]. https://www.stablemicrosystems.com/MeasuringVolumeBakery.html.

Tee, N., Gan, J., Li, J., Cheong, B., Tan, H., Liew, O. & Ng, T. W. (2018) Developing and Demonstrating an Augmented Reality Colorimetric Titration Tool. *Journal of Chemical Education*. 95(3), 393–399. doi: 10.1021/acs.jchemed.7b00618.

Uyar, R. & Erdogdu, F. (2009) Potential use of 3-dimensional scanners for food process modeling. *Journal of Food Engineering*. 93(3), 337–343.

Yang, F., Zhang, A., Dai, Y. & Li, K. (2010) Application of three-dimensional laser scanning technology in granary reserve detection. *Chinese Journal of Lasers*. 37(S1), 317.