Discovery Learning Meets Gamified Quizzing: Teaching the Law of Light Reflection in Optometry Education

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ABSTRACT

This research intends to describe the application of the Discovery Learning model, with the help of the Quizizz interactive quiz tool, as a medium for formative assessment in one class session on the Law of Light Reflection. The research adopted a descriptive case study design where a class of second-semester students in a D3 Optometry program, taking a Physics of Optics course, is studied. Data were gathered using structured observation throughout six Discovery Learning syntax stages, portfolio assessment, and real-time cognitive assessment of each learner through Quizizz. The result of the research indicates that Discovery Learning was a catalyst for encouraging the engagement of students in an active learning process through the simple inquiry and group discussions comparing regular reflection in a flat mirror with diffuse reflection on a wall. The formative assessment conducted through Quizizz reveals the relatively high level of conceptual knowledge among the learners, which included the competence of working out the geometric-mathematical problem on reflection angles. However, the common misconception (confusing the angle of the mirror surface with the angle of incidence) was detected and corrected in real-time formative assessment. Since this is a case study of one class session without a comparison class and the number of enrolled learners, the results have no generalization value but have a high practical value of preparing optometrists to deal with the geometry of instruments like retinoscope, ophthalmoscope, and trial lenses.

Keywords: *Discovery Learning, law of light reflection, Quizizz, optometry education, descriptive case study.*

INTRODUCTION

Physics of Optics is an obligatory subject in the program of studies for a D3 Optometry major. It follows a previously taken introductory course on physics taught in the first semester. In general terms, the subject covers advanced topics in geometrical optics: the law of reflection and refraction, image formation in mirrors and different lenses, and their application to the visual system of human beings, including detection of such refractive errors as hyperopia, myopia, and astigmatism, as well as colour vision disorders. The course is strategically located to provide a disciplinary basis for developing clinical skills of optometrists in conducting refractive examinations and prescribing corrective lenses.

Among the topics that must be mastered by the optometry students in the early stage of geometrical optics is the Law of Light Reflection, taught in the second session of the semester. It is impossible to learn image formation in the flat and curved mirrors or refraction through lenses without mastering this topic first. The correct understanding of the geometry of light reflection processes is a key point to foster analytical skills in optical simulation and in the laboratory practice. The accurate examination of eye disorders relies much on correctly calculating the angle of reflection of the light when diagnosing a refractive error.

Though this topic seems simple, the literature review reveals the fact that this topic possesses a surprisingly high level of abstraction when connected to the geometric-optic analysis and problem-solving. For example, according to the systematic review and meta-analysis by Pacaci, Ustun, and Ozdemir (2024), on the methods of fostering conceptual change in science education, the learners frequently do not manage to correlate the formal concepts of geometrical optics with the observed phenomena after the instruction, and that misconceptions related to confusing the reflecting surface angle with the angle of incidence (instead of measuring from the normal line) can resist a one-directional teaching method. That is why the transition from conventional lecturing to student-centered educational approach is required.

Moreover, it is a typical finding of science-education research that learners build misconceptions before being confronted with the empirical evidence, and such misconceptions can be successfully restructured only if learners have a chance to experience discovery and proper scaffolding (Pacaci, Ustun, & Ozdemir, 2024). In this connection, a meta-analysis conducted by Kalemkuş and Kalemkuş (2022) on technology-assisted visual interventions in science education has revealed that the effectiveness of the discovery approach is contingent upon whether learners are actively guided in the process of visualizing the abstract phenomena. Furthermore, as Djudin (2023) demonstrated, the students' problem-solving skills in physics depend on their ability to interpret the mathematics representations physically, which can be evaluated through numerical reflection-geometry items, such as the Item 5 of the Quizizz quiz that was used in this study.

These observations formed the basis of the pedagogy design of the lesson presented in this paper, in which discovery has been followed by verification and formative assessment. In order to solve the problem of scaffolding discovery and making sure that learners acquire new knowledge, the Discovery Learning model has been applied as the main instructional approach. In accordance with this model, students become active investigators and observe phenomena, define problems, collect data, process their findings, verify their conceptual conclusions in relation to scientific theory and make generalizations. In order to scaffold discovery learning and provide learners with instant feedback, Quizizz, which is a platform for digital quizzes, has been used as a formative-assessment tool.

This descriptive case study is aimed at describing and analyzing in detail how the Discovery Learning model, enhanced with Quizizz, was implemented in one session on the Law of Light Reflection in a D3 Optometry program and how the pedagogical observations made during the session can be associated with the students' readiness for the clinical competencies as future optometrists. As the session is limited in scope (one class only) and no number of enrolled students is mentioned, this study does not pretend to provide statistical evidence of any instructional method's effectiveness; it rather represents the documentation of one particular instructional practice.

LITERATURE REVIEW

The Discovery Learning Model

The Discovery Learning model is a type of instructional design that encourages learners to develop their own conclusions based on their activity and observation, rather than the one-directional explanation of the content by the instructor. Students are put in situation, where they can try to experiment by themselves: asking questions, conducting simple researches, searching for answers, making connections between different bits of knowledge and comparing their findings with other students' findings. Generally speaking, there are six stages of discovery learning: (1) stimulation the initial stimulus, problem or phenomenon that triggers learners' curiosity; (2) problem statement learners formulate their question or initial hypothesis; (3) data collection learners search for information to check the hypothesis from different sources; (4) data processing collected data is organized, classified and analyzed; (5) verification the processed data is compared to the scientific theory and (6) generalization drawing broader conclusions from the discovery process.

There is some disagreement regarding the effectiveness of discovery learning; however, it seems like the quality of the scaffolding provided alongside with it is the decisive factor. The meta-analysis of conceptual change strategies in science education conducted by Pacaci, Ustun, and Ozdemir (2024) proves that discovery without proper scaffolding is usually less effective than discovery, where learners are provoked into cognitive conflicts and guided verification. The same observation can be made on the basis of the meta-analysis of technology-based visual interventions in science education conducted by Kalemkuş and Kalemkuş (2022): discovery without instructor's scaffolding is not more effective than the discovery with instructor's facilitation. This is why Discovery Learning is an appropriate choice for the Law of Light Reflection: the basic idea of the equality of the angle of incidence and the angle of reflection in relation to the normal line is easier to understand through learners' verification than through memorizing the formula i = r.

Quizizz as a Gamified Formative-Assessment Medium

Formative assessment helps constantly track the learning process, provide feedback, and timely intervene before the concepts are misinterpreted and get fixed in the student's mind. Systematic Review of Evidence of Causal Links Between Formative Assessment Interventions and Higher Education Student Outcomes by Morris, Perry, and Wardle (2021) identifies low-stakes quizzing as one of the most effective forms of formative assessment, more so than others, including feedback via praise or just using summative assessment. It corresponds with results of meta-analysis by Yang, Luo, Vadillo, Yu, and Shanks (2021) involving 222 independent studies and over 48,000 learners, confirming that classroom quizzing effectively improves learning outcomes, and this effect gets increased with corrective feedback. Similar conclusions about positive impact of quizzes were reached in systematic review by Agarwal, Nunes, and Blunt (2021) of the benefits of retrieval practice in various settings and at different education levels. Quizizz is one of the interactive quiz applications based on the principles of gamification popular for such purposes due to ease of use, immediate feedback, and automated item analysis allowing to identify gaps in knowledge quickly. Gamification elements of scoring, leaderboards, and slight competition in Quizizz were proven in the meta-analysis by Yıldırım and Şen (2021), based on analysis of dozens of experimental studies, to contribute significantly to academic performance compared with traditional evaluation tools.

Specific to the use of Quizizz, Zhang and Crawford (2023) discovered that gamification in Quizizz positively affected motivation and reduced evaluation anxiety, making learners more ready to express their true level of knowledge. Systematic review of Ratinho and Martins (2023) involving 40 studies on gamification at the secondary and higher education levels found that game elements like points, badges, and ranking are commonly used to motivate students, but need to be carefully managed, as their effectiveness decreases with time. In this regard, systematization of Zeybek and Saygı (2024) on gamification in education says that success of gamification depends on matching of game elements with learning objectives rather than on adding fun elements alone.

The Law of Light Reflection and Its Clinical Relevance in Optometry

Law of Light Reflection, also known as Snell's law of reflection, says that incident ray, reflected ray, and normal lie in the same plane, and that angle of incidence (i) equals angle of reflection (r) measured from the normal, an imaginary perpendicular line to the reflecting surface. Depending on the properties of the reflecting surface, light reflection may be specular (regular) that happens on smooth and flat surfaces like mirrors and creates an image, and diffuse reflection, happening on rough surfaces and scattering light in all directions without creating an image. Simple though the concept is mathematically, systematic review by Pacaci, Ustun, and Ozdemir (2024) shows that misunderstanding of image formation by a flat mirror is one of the most common geometrical-optics misconceptions even among formally instructed learners.

In optometric training, knowing the above law is not only basic physics knowledge, but also fundamental concept underlying several eye examination procedures. Equality of angles of incidence and reflection makes possible the work of a retinoscope used in static retinoscopy for determination of the refractive error. Estay, Plaza-Rosales, Torres, and Cerfogli (2023) proved that mastering of retinoscopy takes relatively long time and depends on precise understanding of the direction of reflection of light from retina. Hollis, Allen, and Heywood (2022) say about learning retinoscopy that "it is a journey through problem space" that presupposes the mastery of basic reflection concepts as a prerequisite. Consequently, the level of understanding of the law of light reflection, gained in geometrical optics classes, will affect the effectiveness of learning the clinical skills as an eye care professional.

METHODS

This research used qualitative approach and a descriptive case study design. As Greenhalgh (2025) mentions in his recently published methodology guide for researchers and educators, case study designs are especially suitable for in-depth exploration of implementation of an intervention in a real world environment and providing practical insights to be used by other educators a perfect choice to document the implementation of the instructional model in a real world environment of a single Physics of Optics class without control group and experimental manipulation. The main aim of this case study was observation of interaction, independent and group learning processes and students' cognitive dynamics in implementing the six stage Discovery Learning model supported by Quizizz in a single course session.

The participants in this study were second-semester students of the D3 Optometry major, currently taking the course Physics of Optics. Specifically, the exact number of participants enrolled in the course is not specified in the available source documents, which is considered a limitation (see Section 4.4). The class was held in person, with in-class hours allocated according to the national requirements of higher education for a two-credit course of 100 minutes of theoretical teaching in class.

Among the research instruments utilized in this study were a structured observation sheet of students' activities designed based on the six stages of Discovery Learning syntax and a rubric for the evaluation of the quality of group data processing and verification, as well as Quizizz formative assessment platform to measure students' cognitive success in real time. The instruction was designed in the context of the theories of Discovery Learning and formative assessment covered above in the Literature Review section.

The assessment framework was designed to cover three domains equally: (1) individual cognitive assessment through the Quizizz interactive quiz score – 50% of the total session score; (2) the quality of group data processing and verification, measured through discussion-report portfolio – 30%; and (3) student participation in discussion and presentation – 20%. This weighting was done purposefully, in order to put most weight on the individual formative assessment as recommended by Morris, Perry, and Wardle (2021), who stated that fast, low-stakes individually targeted quizzing is among the best-supported levers of improving learning outcomes in higher education. This assessment strategy was introduced into the semester learning plan from the very beginning, therefore the assessment procedure was an integral part of the unfolding instruction syntax.

Data gathering was performed simultaneously qualitatively and quantitatively. The quantitative data from Quizizz was gathered as response-accuracy patterns for each item of the quiz and used for analysis of the location of common misconceptions. The qualitative data from group discussion was analyzed descriptively, following the steps of data reduction, data display, and conclusion drawing with the use of reflection theory. Methodological note: Since this is a case study of a single-class, single-session type, the conclusions will be of descriptive-contextual nature, and are not intended for statistical generalization. Instead, the validity of the findings will be guaranteed by the level of process description ("thick description") and triangulation of observation, portfolio, and Quizizz data. Interrater reliability check was not performed for observation coding, which is recognized as another limitation.

Table 1:
Discovery Learning Syntax Framework Applied to the Law of Light Reflection

DL Syntax	Instructor/Facilitator Activity	Student Response and Activity
1. Stimulation	Demonstrating the reflection of a flashlight beam on a flat mirror and on the classroom wall.	Visually observing the demonstration and identifying the difference in reflection effects (glare vs. no glare).
2. Problem Statement	Posing trigger questions about the rule governing the direction of the reflected ray on the mirror and the wall.	Formulating group research questions on the characteristics of light reflection on smooth and rough surfaces.
3. Data Collection	Guiding students to consult reference optics texts and other literature.	Conducting independent and group literature study on regular reflection, diffuse reflection, and Snell's law.
4. Data Processing	Dividing the class into two focused discussion groups (Group 1: mirror; Group 2: wall) and monitoring the discussion.	Discussing in small groups to formulate the characteristics of light reflection, the physical properties of the reflecting surface, and the direction of the reflected ray.
5. Verification	Presenting a scientific explanation via slides and guiding students to match their discussion findings with physics theory.	Matching group findings with the instructor's explanation and reference material to verify the law of reflection (i = r).
6. Generalization	Assessing cognitive understanding through the Quizizz interactive quiz and providing conceptual reinforcement plus an independent take-home task.	Presenting group discussion results, responding to other groups' presentations, and completing the Quizizz assessment items.

RESULTS AND DISCUSSION

Reconstructing the Learning Process and Group Discussion Findings

It seemed that the use of the Discovery Learning model stimulated active participation of the students in each stage of instruction. In particular, during the stimulation stage, the demonstration using the mirror and flashlight became a spontaneous point of attraction for the students. When the flashlight beam was pointed at a flat mirror, students noticed that the light reflects directly, creating glare. In comparison, when the flashlight beam was pointed at the classroom wall, students reported that the light did not reflect concentratedly, therefore no glare occurred.

After this stimulation stage observation, the students were divided into two small discussion groups to look into the physical mechanism behind this phenomenon. First of all, Group 1, represented by one of its members, discussed the features of light reflection on a mirror surface. According to the results of the discussion, the interaction of the flashlight beam and a flat mirror gives rise to the regular reflection, since the surface of the latter is very smooth, flat, and shiny. The parallel incident rays are reflected parallel to each other, giving birth to a clear image that, however, leads to the glare when observed directly along the reflected beam. Group 1 suggested that the direction of the reflected ray is dependent upon the angle of the incident beam and the position of the mirror itself, which corresponds to the physical principle of the law of reflection.

Secondly, Group 2 investigated the light reflection on the rough classroom wall. It came to the conclusion that reflection on the wall should be regarded as the diffuse reflection, since the wall surface is rough, uneven, and irregular, so the parallel incident rays are reflected in different directions. Although the diffuse reflection does not produce an image and does not create glare, Group 2 highlighted that this phenomenon plays an ecological role in the room, reflecting light everywhere, illuminating non-lighted areas and providing comfortable visibility of objects in the room.

The relationship between the two groups is the example of one of the main advantages of the Discovery Learning method coupled with proper guidance, which is that students did not learn the definitions of regular and diffuse reflection, but rather built the definitions based on their observations, defending their group's argument in front of another group. Thus, the process of inter-group argumentation is likely to train scientific communication and collaboration teamwork skills, which are the soft skills essential for eye-care professionals working in clinical settings.

In the end, the teacher performed as a facilitator to verify and consolidate the concepts discovered into the scientifically sound formulation. Students were introduced to the concept of Snell's law of reflection, stating that: (1) the incident ray, the reflected ray, and the normal line pass through one point and lie in one plane, and (2) the angle of incidence (i) is equal to the angle of reflection (r), both measured from the normal line, an imaginary line perpendicular (90°) to the reflecting surface. The verification stage was significant, since it allowed students to consolidate their qualitative findings into the scientifically sound and quantitative knowledge. In fact, this can be considered the process of the instructional scaffolding, which, according to Pacaci et al. (2024), makes the Discovery Learning more effective than the unguided independent discovery.

Qualitative-Quantitative Analysis of Cognitive Performance via Quizizz

As the last step of the session, the formative assessment using the Quizizz interactive quiz was conducted to validate the conceptual mastery of students. The analysis of their answers helped to have a relatively clear picture of the conceptual understanding in the class. In general, the students performed well on the basic conceptual items (Items 1 to 4 and 6).

It is, however, more interesting to notice the way some students performed in answering Item 5, which was an analytical-mathematical problem: "The incident ray makes a 60° angle with the reflecting surface. What is the angle of reflection with respect to the normal line?" Many students were confused in their answers and chose 60° as the answer. Such mistakes appeared due to the fact that students did not take into consideration the mathematical definition of the angle of incidence and assumed immediately that the 60° angle made by the incident ray and the surface of the mirror was the angle of incidence (i). It is confirmed by the results of the systematic review by Pacaci, Ustun, and Ozdemir (2024), in which it is claimed that such mistakes are very common and difficult to correct.

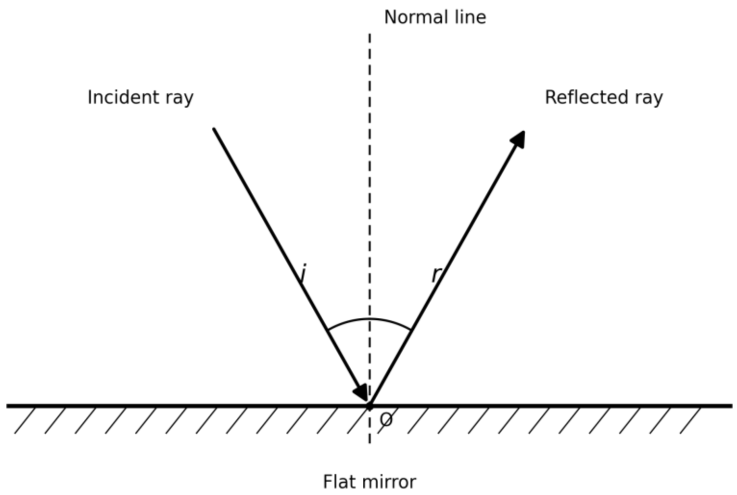

Figure 1: Schematic representation of the geometrical configuration involved in the law of reflection of light from a plane mirror: Angle of incidence (i) = Angle of reflection (r), both being taken with respect to the normal to the surface - the principle behind the misconception that has been identified on item number 5.

Through direct instructions and schematics provided by the teacher, this misconception was discussed and clarified in class. The students were made to realize that the normal line, by definition, is always perpendicular to (that is, at 90° to) the plane mirror. Hence, if the incident ray is at 60° to the mirror, the angle of incidence (i) will be the complement of the right angle and hence i = 90° – 60° = 30°. According to Snell's law of reflection, the angle of incidence has to be equal to the angle of reflection (i = r); thus, the angle of reflection (r) is also 30° from the normal line.

This phenomenon is in line with research on interactive quizzes as a medium of formative assessment in higher education, where the immediacy of the feedback provided by the tool helps the instructor detect high-error questions immediately, rather than waiting for the feedback generated manually after the end of class (Morris, Perry, & Wardle, 2021; Yıldırım & Şen, 2021). In other words, it could be considered what differentiates a Quizizz quiz from the traditional quiz, in which case correction of the misconception does not wait until the error is "inactive" in the mind of the learner.

Table 2:
Item-Level Analysis of the Quizizz Formative Assessment

Item	Key Concept Tested	Correct Answer	Pedagogical Note
Item 1	Physical definition of light reflection	Light travels in a straight line and is reflected upon striking a surface	High apparent accuracy. Students grasped the condition for reflection when light strikes a different medium.
Item 2	Characteristics of reflection on a smooth, flat surface	Regular (specular) reflection	High apparent accuracy. Students correctly identified the smooth, flat, glossy properties of a plane mirror.
Item 3	Reference line for measuring the angle of incidence and reflection	The normal line (perpendicular to the reflecting surface)	Strong theoretical understanding observed. The normal line was understood as an imaginary line perpendicular (90°) to the mirror.
Item 4	Formulation of Snell's law of reflection	i = r (angle of incidence equals angle of reflection, coplanar)	Strong grasp of the basic mathematical postulate of equal incidence and reflection angles.
Item 5	Numerical geometric-optics problem	30° (derived from 90° minus 60° = 30°)	High difficulty. Initially triggered a misinterpretation of the mirror-surface angle as the angle of incidence; resolved through guided instruction.
Item 6	Characteristics of the image formed by a plane mirror	Virtual, upright, and the same size as the object	High apparent accuracy. Students connected the physical theory to their everyday experience of looking in a mirror.

Linking Physical-Pedagogical Findings to Clinical Competence in Optometry

In this case study, there exists an evident link between the ability to comprehend reflection optics and the acquisition of clinical skills in optometry. Knowing the fact that the angle of incidence equals the angle of reflection (i=r), in addition to the importance of the normal line, is more than just physics formula memorization, as it is part of the mechanical principles used in several optometric diagnostic devices.

To consider a concrete example, in the objective refraction test using retinoscopy, the optometrist shines a light into the pupil of a patient's eye in order to see the reflection of the light coming from the retina (fundus reflex). The movement direction of the reflected light coming back to the eye of the examiner (with-motion or against-motion) depends entirely upon the principles of the law of reflection and refraction geometry. As Hollis, Allen, and Heywood (2022) explain, mastering the technique of retinoscopy is a process of problem-solving based on the development of the necessary conceptual foundations in the reflection geometry, which must be built from the very beginning of this process; according to the empirical study conducted by Estay et al. (2023), retinoscopy performance improved linearly with the increase in hours of practice, and learners with immature conceptual foundation demonstrated significantly lower initial performance level. Therefore, if prospective optometrists have a misconception regarding calculation or analysis of the angle of incidence and reflection, as evidenced in Item 5 of the Quizizz quiz, their learning of this clinical technique will take more time. In other words, correcting even a small misconception at the introductory course stage may play a significant role later on, as it will influence the quality of patients' lens prescription.

Similarly, the use of an ophthalmoscope for the examination of the patient's internal anatomical structures (fundus) involves the ability to capture the reflection of light from the retina without the interference of the light from the corneal reflex. To do this successfully, an optometrist must have a clear understanding of the principles of regular reflection of light on a flat surface. Edgar, Ainge, Backhouse, and Armitage (2022) emphasize the role of diagnostic reasoning in optometric practice, one of the bases of which is the understanding of the principles of geometrical optics. In this case, this finding agrees with the results of the scoping review conducted by Elvén, Welin, Wiegleb Edström, Petreski, Szopa, Durning, and Edelbring (2023), according to which robust clinical reasoning should be explicitly built throughout the education of healthcare professionals from the early stages, as opposed to implicit development of this skill. In line with this, the recommendations of Gordon, Rencic, Lang, Thomas, Young, and Durning (2022) state that clear definitions of clinical reasoning should be established in all health professional education programs, including optometry programs, for systematic tracking of conceptual learning outcomes, such as the law of reflection. An optometrist should be able to adjust the angle of incidence of the ophthalmoscope's light in such a way that the corneal reflection does not interfere with the examination.

Pedagogically, the combination of Discovery Learning and Quizizz seemed to move the classroom from passive transfer of knowledge towards active evidence-based concept building. This learning became more meaningful as students were able to connect the simple physical phenomenon (mirror vs wall reflection) to the clinical challenges that they would need to overcome in their future work as optometrists. This finding is consistent with one of the characteristics of the well-guided discovery learning described by Pacaci, Ustun, and Ozdemir (2024) – knowledge that is gained through observation and verification of the learner becomes more durable and easily transferrable to new contexts of application, in this case to clinical application in the optometry practice. At the same time, this result is consistent with a number of reports on the effectiveness of gamified formative assessment in health education (Arruzza & Chau, 2021; Huang, Loid, & Sung, 2024; Nylén-Eriksen et al., 2025), and with the observation that efforts of technology integration in vocational education are most likely to succeed when closely aligned with practical competencies that define this area (Suarta, Suwintana, Sudhana, & Hariyanti, 2023).

Limitations

First of all, as a descriptive case study of a single class and a single session, this study has its own limitations that should be kept in mind. For instance, no comparison group was available (e.g., a class taught by traditional lecture), so any claim of superiority of the Discovery Learning method over others cannot be checked statistically in this study. Furthermore, the exact number of participating students is not reported in the source material for this account – an issue that should be corrected in any further, full version of the report since it limits the interpretation of the class-level accuracy patterns in Table 2. Additionally, the available data is merely descriptive, class-level accuracy patterns per item rather than individual-level scores for statistical analyses, and no interrater reliability check was performed for the qualitative observation coding. Moreover, the observation was conducted in a single session, and the study cannot provide information about the long-term retention of the concept – for instance, whether students remember and apply this knowledge when performing retinoscopy in later semesters. Finally, the instructor being at the same time the author and the only observer of the session may imply some unnoticed positionality bias; the presence of an independent observer/co-rater would improve future work. However, these limitations are inherent to the design of a case study and do not limit its value as a documented description of how a specific active learning model worked in a real classroom, but readers should evaluate them when considering the scope of the findings, and they should not be treated as a proof of effect.

CONCLUSION

Based on the qualitative-quantitative analysis conducted in this descriptive case study, the Discovery Learning model, supported by the Quizizz medium, seemed to be implemented consistently in a single session of the Law of Light Reflection lesson in a D3 Optometry program. Six structured stages of Discovery Learning, together with the guidance and verification of the instructor at key moments, seemed to foster active participation, scientific curiosity, and collaborative teamwork while students investigated the regular reflection on a flat mirror and diffuse reflection on a rough wall.

The integration of the Quizizz platform as a formative assessment method seemed to assist in assessing the individual cognitive skills of students. Using Quizizz, a misunderstanding concerning the reference line used to measure the angle of incidence (the 60° against the mirror case) was detected and resolved in class by the lecturer. It also seems that there is a relationship between the law of reflection and the practical competences an optometry student requires to use retinoscopes, ophthalmoscopes, and trial lenses in clinical practice. This is a description of a single class, which means there is no sample size or control in this case study.

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