Revista Española
de Educación Médica

Parasitology curriculum integration and educational innovation at the University of Alcalá.

Integración curricular e innovación educativa en Parasitología en la Universidad de Alcalá.

Antonio Peña-Fernández[1*,2], Jorge Pérez-Serrano[3], Tania Martín-Pérez[3], María de los Ángeles Peña[4]

[1] Department of Surgery, Medical and Social Sciences, Faculty of Medicine and Health Sciences, University of Alcalá, Ctra. Madrid-Barcelona, Km. 33.600, 28871 Alcalá de Henares, Madrid, Spain. https://orcid.org/0000-0002-5690-5445

[2] Leicester School of Allied Health Sciences, De Montfort University, Leicester, LE1 9BH, UK.

[3] Department of Biomedicine and Biotechnology, University of Alcalá, Crta. Madrid-Barcelona Km, 33.6, 28871 Alcalá de Henares, Madrid, Spain. https://orcid.org/0000-0002-4870-8978; https://orcid.org/0000-0001-9499-412X

[4] Department of Biomedical Sciences, University of Alcalá, Crta. Madrid-Barcelona Km, 33.6, 28871 Alcalá de Henares, Madrid, Spain. https://orcid.org/0000-0002-0908-8286

* Correspondencia: Antonio.penafer@uah.es

Recibido: 15/2/26; Aceptado: 11/3/26; Publicado: 13/3/26

Abstract: Parasitology remains a foundational yet increasingly marginalised discipline within modern health and life sciences curricula. At the University of Alcalá (UAH, Spain), parasitology has experienced reduced visibility in undergraduate programmes due to curriculum reforms and its integration into broader (bio)medical modules. This manuscript presents a descriptive institutional case study of parasitology education at UAH and synthesises recent innovations implemented to strengthen teaching across undergraduate and postgraduate programmes. To address declining instructional time and diagnostic training, UAH has adopted active and interdisciplinary learning strategies. These include the integration of parasitology into Chemical, Biological, Radiological, and Nuclear (CBRN) preparedness training, the implementation of scenario-based workshops, and the launch of a summer course focused on advanced diagnostic techniques. Digital innovations, notably the e-Parasitology© platform, have supported self-directed learning and enhanced student engagement in both animal and clinical parasitology. A novel teaching strand in forensic parasitology has also been introduced, supported by virtual case studies and interactive resources. Early implementation signals (participation patterns, structured teaching observations, and non-identifiable student and staff feedback captured during routine delivery) suggest increased engagement and perceived gains in diagnostic reasoning and conceptual understanding, particularly among students without prior exposure to parasitology. Rather than testing effectiveness at UAH using formal outcome measures, we present an implementation-focused account and derive transferable design principles and enabling conditions for adaptation in comparable settings. The UAH experience demonstrates how applied, digital, and interdisciplinary approaches can revitalise parasitology education, ensuring its relevance to One Health and public health priorities. We conclude with practical recommendations to sustain parasitology within integrated curricula and to strengthen alignment with One Health and global health training needs.

Keywords: Parasitology education, Curriculum innovation, Forensic parasitology; Interdisciplinary teaching; CBRN preparedness; e-learning.

Resumen: La Parasitología sigue siendo una disciplina esencial en las ciencias de la salud y de la vida, aunque su presencia curricular se ha visto progresivamente reducida en muchos programas universitarios. En la Universidad de Alcalá (UAH, España), esta pérdida de visibilidad se ha

producido en paralelo a reformas curriculares y a la integración de sus contenidos en asignaturas biomédicas más amplias. En este contexto, el presente trabajo ofrece un estudio de caso institucional descriptivo sobre la enseñanza de la Parasitología en la UAH y sintetiza las principales innovaciones introducidas recientemente para reforzar su presencia en los estudios de grado y posgrado. Para responder a la disminución del tiempo docente y al debilitamiento de la formación diagnóstica, se han incorporado estrategias activas, digitales e interdisciplinares, entre ellas la integración de contenidos parasitológicos en actividades de preparación frente a incidentes QBRN, el desarrollo de talleres basados en escenarios, el uso de recursos digitales como e-Parasitology© y la puesta en marcha de nuevas propuestas formativas en diagnóstico avanzado y parasitología forense. En esta fase, la evidencia disponible procede fundamentalmente de señales tempranas de implementación, incluyendo patrones de participación, observaciones docentes estructuradas y retroalimentación no identificable recogida durante la práctica docente habitual. Más que presentar una evaluación formal de efectividad en la UAH, este trabajo propone una lectura centrada en la implementación y en las condiciones que han favorecido la reintroducción de contenidos parasitológicos en currículos integrados. En conjunto, la experiencia sugiere que los enfoques aplicados, digitales y contextualmente relevantes pueden contribuir a reforzar la visibilidad y la pertinencia formativa de la Parasitología, especialmente en relación con el razonamiento diagnóstico, la salud pública, la salud global y One Health. Asimismo, se identifican principios de diseño potencialmente transferibles a otros contextos universitarios con limitaciones curriculares similares.

Palabras clave: Educación en Parasitología, Innovación curricular, Parasitología forense, Docencia interdisciplinar, Preparación ante riesgos NRBQ, e-learning.

1. Introduction

The significant improvement in sanitary infrastructure and public health measures in developed countries, including those in Europe, has led to a marked reduction in the incidence of parasitic infections in recent decades. However, these infections have not yet been eradicated. In fact, certain parasitic diseases, such as dysentery amebiasis, have shown a concerning upward trend in annual incidence (1-3). This resurgence may be partly explained by increasing global mobility, the globalisation of infectious diseases and changes in dietary habits and sexual behaviours (4). Despite their continued relevance, parasitic infections are increasingly underrepresented in medical education curricula. Consequently, parasitology content is being reduced or removed from health science curricula despite its continued relevance in developed countries. Parasitic infections remain prevalent in high-income countries, highlighting the importance of screening and clinical awareness (5).

In the case of Spain, recent epidemiological evidence highlights the continued relevance of parasitic infections, even among low-risk populations. A recent coproparasitological and nutritional status study conducted among schoolchildren in the Valencian Community revealed that 49.5% of participants tested positive for intestinal parasites (6). A decline in the importance of medical parasitology could reduce healthcare professionals' ability to diagnose parasitic diseases, as well as reducing research into emerging human parasites. One example is *Angiostrongylus cantonensis*, an emerging parasitic zoonosis that has recently been documented as endemic in Spain. Despite representing a public health concern, particularly among children, it remains underrepresented in medical training due to its complex life cycle and potential to cause severe neurological complications (7). Therefore, the strengthening of this discipline in medical and related health sciences degrees has become crucial, as the teaching of medical and veterinary parasitology is key to addressing the increasing number of food- and waterborne parasitic infections reported in Western countries and protecting human and animal health.

The World Association for the Advancement of Veterinary Parasitology (WAAVP) recommends allocating 70-90 contact hours to foundational veterinary parasitology, comprising lectures, practical sessions and tutorials centred on parasite biology, morphology, taxonomy, epidemiology, diagnosis, and control (8-9). This is often complemented by advanced, problem-based and interdisciplinary teaching related to specific animal species or organ systems. However, van Doorn et al. (10) have highlighted that recent curriculum reforms have reduced dedicated teaching time to less than half of this amount in European universities. These reductions, often resulting from integration into broader organ-based or multidisciplinary modules, have made it increasingly difficult to maintain consistent parasitology training. The authors emphasise the importance of modernising veterinary parasitology education through blended learning approaches, such as virtual microscopy, gamification, and online modules. They also propose international cooperation in developing and sharing digital teaching resources, and advocate for flexible teaching formats that could sustain the identity of parasitology in future interdisciplinary curricula. To our knowledge, there are currently no equivalent international guidelines for the teaching of medical parasitology, despite its clinical significance and the persistence of parasitic diseases in both developed and developing countries alike.

At the University of Alcalá (UAH, Spain), parasitology has traditionally formed a core part of the Biology and Pharmacy curricula and has more recently been incorporated into postgraduate programmes in scientific and public health contexts (11). However, changes to the curriculum, greater integration of biomedical subjects, and limited teaching hours have made it difficult to maintain parasitology as a distinct discipline within undergraduate programmes. Logistical constraints and the need to balance theoretical instruction with practical, hands-on experience, such as microscopy and specimen analysis, further complicate this situation. In response to these challenges, our academic group has introduced a series of educational innovations aimed at preserving and revitalising the teaching of parasitology at UAH. These include the adoption of blended learning and virtual formats, designing active learning strategies such as workshops and case-based discussions, and developing a specialised summer course to reinforce applied parasitology skills. Additionally, we have drawn on our previous collaborative experience at De Montfort University (DMU, UK), where digital resources such as e-Parasitology©, which is described later in this manuscript, were found to be valuable in supporting flexible, student-centred learning (12).

This paper presents a descriptive institutional case study of parasitology curriculum integration and educational innovation at the University of Alcalá (UAH, Spain). Our purpose is **i)** to characterise the local curriculum context and the current positioning of parasitology across undergraduate and postgraduate provision; **ii)** to describe and synthesise the main teaching innovations implemented since 2023 to strengthen applied parasitology and diagnostic training; and **iii)** to derive transferable instructional design principles and enabling conditions that may support parasitology teaching in similarly integrated health-science curricula. Evidence is drawn from programme documentation and teaching materials, implementation descriptors (*e.g.*, delivery formats, reach, and participation), and structured reflections embedded in routine teaching practice (including non-identifiable classroom observations and qualitative feedback from learners and staff). At this stage, we do not evaluate effectiveness at UAH using formal outcome measures; instead, we report implementation and early signals to inform a planned next phase of structured evaluation.

1.1. Conceptual and evaluation framework

Parasitology teaching innovations at UAH were designed and interpreted using a pragmatic medical-education framework combining constructive alignment, self-determination theory (SDT), and Kirkpatrick's evaluation model, with the current phase limited to early-level evidence (13-18).

Constructive alignment informed the explicit linkage between intended learning outcomes, the learning activities implemented, and the forms of assessment or performance demonstration available within routine delivery (16). In practice, this involved aligning parasitology-related knowledge and skills with case-based activities, digital learning resources, practical diagnostic tasks, and applied classroom exercises. Self-determination theory informed the design of learning environments intended to support autonomy, competence, and relatedness, particularly in student groups with limited prior exposure to parasitology (14-15). This perspective guided the development of activities intended to enhance perceived relevance, support progressive skill development, and encourage collaborative engagement, in line with recent evidence linking need-supportive teaching practices to student motivation and engagement (17,19).

To avoid over-interpretation of early-stage implementation, the current UAH-based evidence is situated primarily at Kirkpatrick levels 1–2, focusing on learner engagement, qualitative feedback, and early learning signals arising from routine teaching practice (18). At this stage, the manuscript does not claim changes in assessment performance, behavioural transfer, or institutional impact at UAH. Rather, it presents an implementation-oriented institutional case study and identifies priorities for future structured evaluation. Table 1 summarises how each intervention strand maps onto its intended mechanism of action and the evidence currently available, and it outlines concrete next steps for structured evaluation (*e.g.*, pre/post measures, validated instruments, learning analytics, and anonymised analysis of assessment data where appropriate).

Table 1. Conceptual and evaluation framework mapping intervention strands to intended mechanisms, current evidence, and next evaluation steps.

Intervention strand	Intended mechanism (Constructive Alignment + SDT)	Evidence currently available (UAH + partner contexts)	Next evaluation step (planned)
e-Parasitology© integration (virtual microscopy, mini-videos, case studies)	Aligns outcomes (diagnostic reasoning, parasite identification) with digital activities; supports autonomy (self-paced learning) and competence (repeated practice).	Partner sites: questionnaire-based perceived gains and/or module mark analyses; UAH: participation patterns, structured classroom observations, and non-identifiable qualitative feedback captured during routine delivery.	Pre/post knowledge quiz; learning analytics (completion, time-on-task); brief validated engagement/self-efficacy instrument; anonymised assessment data analysis (where feasible).
Scenario-based CBRN workshops / outbreak simulations	Strong alignment: outcomes (outbreak-response reasoning, prioritisation) ↔ activities (simulated incidents) ↔ performance outputs; supports relatedness via team decision-making and interdisciplinary facilitation.	UAH: observed completion of response plans and prioritisation outputs; repeated delivery across cohorts; participation patterns and descriptive field notes.	Rubric-based scoring of scenario outputs; implementation fidelity checklist; pre/post confidence scale; OSCE-style station (optional).

Forensic parasitology virtual case strand	Aligns outcomes (forensic interpretation and reasoning) with interactive cases; supports competence via guided case progression and feedback.	UAH: pilot delivery descriptors; non-identifiable qualitative feedback and task completion signals during routine delivery.	Case-based rubric (critical reasoning); short reflective prompt (thematic coding); pre/post vignette-based test.
Summer course: Advanced diagnostic techniques (hands-on + molecular/serological methods)	Alignment of outcomes (diagnostic laboratory skills) with intensive practical activities; supports competence through hands-on mastery and feedback; increases perceived relevance and autonomy.	Implementation descriptors (reach/participation); routine feedback; practical demonstrations embedded in course delivery.	Skills checklist/competency log; pre/post practical knowledge test; structured satisfaction survey; follow-up survey.
Outreach (secondary school activity)	Supports early interest via authentic, hands-on experience; boosts relatedness (university context) and competence (microscopy basics).	Participation and informal feedback captured during delivery; implementation description (reach).	Short age-appropriate pre/post quiz; structured teacher feedback form; implementation metrics (reach/adoption).

1.2. Design, context, and sources of evidence.

This manuscript is presented as a descriptive institutional case study situated within curriculum development and quality improvement in higher education. The unit of analysis is the set of parasitology teaching interventions and their implementation across programmes (rather than individual learners). Evidence is drawn from **a)** programme documentation and teaching materials (module structures, learning activities and resources), and **b)** implementation descriptors captured during routine delivery at UAH (delivery formats and participation patterns), alongside non-identifiable qualitative feedback and structured teaching reflections recorded as part of standard educational practice. In addition, we draw on published outcome evaluations from partner contexts using the same core educational resources (e-Parasitology©) to triangulate plausibility and interpretability of mechanisms. At this stage, we do not report formal effectiveness outcomes at UAH (*e.g.*, validated questionnaires, controlled comparisons, or systematic analysis of assessment performance). Instead, we provide an implementation-focused synthesis and outline concrete next steps for structured evaluation and implementation monitoring (Table 1). All the educational resources referred to in this study, including e-Parasitology©, the scabies application, and the forensic case-based materials, were available in English and were used in either English or Spanish, depending on the programme and educational setting.

2. Teaching Status of Parasitology at the University of Alcalá before 2023

At the University of Alcalá (UAH), parasitology is included in the undergraduate curricula of human health and science programmes (11). Within the health-related degrees, it is taught as a stand-alone module in the BSc in Health Biology and as part of broader modules in the MPharm

Pharmacy and Medicine programmes. By contrast, no specific teaching hours in parasitology were identified in the BSc in Nursing. Within the science degrees, parasitology is offered as an optional stand-alone module in the BSc in Biology. This distribution reflects the increasing integration of parasitology into broader biomedical and multidisciplinary curricula, a process that has reduced its visibility as an independent discipline.

2.1. MPharm Pharmacy

In the MPharm Pharmacy programme, parasitology content is mainly delivered through two compulsory modules (20): *Parasitología y Virología* and *Métodos biológicos de diagnóstico en el laboratorio de microbiología y parasitología*. Together, these modules provide students with core training in the morphology and biology of major human parasites, the diseases they cause, and their diagnosis, treatment and control. Practical teaching includes laboratory sessions focused on morphological identification, basic diagnostic procedures, and interpretation of parasitological findings. Although parasitology retains a relevant place in this curriculum, it is taught within a broader framework shared with other disciplines, particularly virology and microbiology. As a result, teaching tends to prioritise the most clinically relevant parasites, while broader environmental or animal-health aspects receive less attention. In the final-year diagnostic module, parasitology is addressed alongside microbiology, with an emphasis on the analysis of infectious biological samples and the interpretation of laboratory results.

2.2. BSc in Health Biology

In the BSc in Health Biology, parasitology is taught through the compulsory third-year module *Parasitología Sanitaria* (21). This module focuses on human parasitic diseases and addresses the morphology and biology of medically relevant parasites, the pathology and clinical manifestations associated with infection, and the principles of diagnosis, treatment and control. Among the undergraduate programmes at UAH, this degree offers the clearest example of parasitology being preserved as a distinct subject with a direct health-oriented focus.

2.3. Medicine (MBChB)

In the Medicine degree, parasitology content is included within the core third-year module *Microbiología Médica* (22). Here, parasitology is taught as part of a broader approach to infectious diseases, covering biological characteristics, pathogenesis, epidemiology, diagnosis and prevention. The module also places emphasis on the selection and processing of clinical specimens and the interpretation of laboratory findings, so parasitology is presented within a clinically oriented diagnostic framework rather than as a separate discipline.

2.4. BSc in Biology

In the BSc in Biology, parasitology is offered as an optional module, *Parasitología* (23). This subject provides training in parasite biology, diversity and medical relevance, integrating theoretical and practical perspectives. Students are introduced to the morphology, life cycles, transmission pathways and pathogenesis of key parasitic taxa, together with diagnostic approaches, control measures, and ecological and epidemiological principles. This broader framing gives the module a multidisciplinary character and links parasitology to both animal and human health contexts.

2.5. Postgraduate and Continuing Education

UAH has also incorporated parasitology into postgraduate and continuing education through a range of applied and interdisciplinary initiatives. These include formal taught programmes, specialist residency-based training, summer courses, and lifelong learning activities.

2.5.1. Integration of Parasitology into the Industrial and Galenic Pharmacy Specialisation

Since 2013, our group has delivered specialist training in clinical and environmental parasitology to pharmaceutical residents within the *Farmacia Industrial y Galénica* programme, a postgraduate professional training pathway in industrial and formulation-oriented pharmacy (24). Developed in collaboration with Public Health England, now the UK Health Security Agency, and academic partners in the United Kingdom and Spain, this initiative linked parasitology training to preparedness for chemical and biological incidents through the use of the UK Recovery Handbooks for Chemical (25) and Biological Incidents (26). Following initial work on chemical incidents, a biological response strand was introduced in 2014 using outbreak scenarios involving emerging human parasites. This approach enabled trainees to apply parasitological knowledge within emergency preparedness and public health response contexts. Although the original specialisation was discontinued at UAH in 2016/17, related training was later reintroduced through the Lifelong Learning Master's Degree in Industrial and Galenic Pharmacy (27,28).

2.5.2. Parasitology in Postgraduate Taught Programmes

Parasitology has also been represented in several postgraduate taught programmes at UAH. The *Máster Propio en Enfermedades Infecciosas* included practical training relevant to parasitology (29), and the now-discontinued Master's in Applied Microbiology for Public Health and Infectious Disease Research also contributed to postgraduate teaching in this area (30). Building on this experience, parasitology is currently included in the Master's in Humanitarian Health Action, where it is taught in relation to global health threats, migration, vulnerable populations, and outbreak prevention and response (31).

2.5.3. Summer Schools and Continuing Professional Development

Parasitology has also been supported through UAH summer schools and continuing professional development initiatives. These short-format activities have been designed for healthcare professionals, laboratory scientists and early-stage researchers, and have focused on applied parasitology and public health issues. A representative example is the 2023 summer course *Parásitos humanos: un problema sanitario de índole global*, which addressed emerging parasitic threats and their wider health implications.

2.5.4. Lifelong Learning and Public Engagement through the Universidad de Mayores

Finally, parasitology also forms part of UAH's broader lifelong-learning and public-engagement mission through the *Universidad de Mayores*. Within the *Programa de Ciencias Naturales*, parasitology is taught as a distinct second-year module (32), introducing adult learners to parasite–host relationships, zoonotic transmission and the public health relevance of parasitic diseases. This initiative extends parasitology teaching beyond conventional degree programmes and contributes to scientific literacy across generations.

3. Current strategies for strengthening Parasitology teaching at the University of Alcalá

The initiatives described in this section correspond to different stages of development and should be interpreted accordingly. For clarity, we distinguish between: **i)** interventions formally implemented within the undergraduate curriculum from the 2023/24 academic year onwards; **ii)** pilot or early-phase innovations introduced from 2024 onwards in selected teaching contexts; and **iii)** more recent specialist, short-course, or outreach activities developed to extend applied parasitology training beyond the core curriculum.

The evidence presented is likewise stage-specific. First, we draw on previously published mixed-method evaluations of e-Parasitology© (33) and related teaching activities conducted at partner institutions in different national contexts, namely De Montfort University (DMU, Leicester,

UK), Universidad Miguel Hernández de Elche (UMH, Alicante, Spain), and the University of Makeni (UniMak, Makeni, Sierra Leone), where anonymous questionnaires, optional written comments, and analysis of examination and module marks were used to assess perceived learning gains and academic performance following the introduction of the digital resource (34-36). These studies had received formal ethical approval from the relevant research ethics or institutional review bodies, including the Research Ethics Committee at DMU (Ref. 1851; initial approval 8 December 2016, with an amendment approved on 20 April 2021). All procedures were conducted in accordance with the principles of the 1964 Declaration of Helsinki and its later amendments, or comparable ethical standards. In the present manuscript, these previously published data are used only as contextual and comparative evidence to inform interpretation of the early implementation experience at the University of Alcalá, rather than as directly transferable outcome evidence for the local context.

Second, at the University of Alcalá, the current work was conducted as part of routine curriculum development and educational quality-improvement activity. Only non-identifiable qualitative information arising from normal teaching delivery (*e.g.*, classroom observations, informal oral feedback, and structured teaching reflections) was considered. No research questionnaires were administered at UAH, no assessment structures were altered for research purposes, and no individual student grades were collected or analysed as research data. Accordingly, these early UAH-based activities were not treated as formal human-participant research requiring separate research ethics committee approval. Any future phase involving systematic data collection, pre/post measures, or anonymised analysis of assessment outcomes will be submitted for institutional ethics review as required.

To facilitate interpretation, Sections 3.1–3.5 are organised according to the stage and context of implementation: formal curricular incorporation in undergraduate programmes, pilot innovation in forensic parasitology teaching, specialist short-course provision, and outreach activity for pre-university students. This distinction is important because not all initiatives are equally mature, and the current manuscript does not claim equivalent levels of evidence across them.

3.1. Curriculum modifications in Environmental Health, Environmental Sciences and Criminalistics

Since the 2023/24 academic year, parasitology content has been formally incorporated into selected undergraduate modules at UAH that previously contained little or no explicit parasitology content: the second-year module *Toxicología Ambiental y Salud Pública* (Environmental Toxicology and Public Health) in the BSc in Environmental Sciences, and the third-year module *Toxicología Forense* (Forensic Toxicology) in the BSc in Criminalistics: Sciences and Forensic Technologies, an interdisciplinary undergraduate programme combining applied forensic science, laboratory analysis, and criminal investigation. We have also enhanced the current teaching status of the MPharm Pharmacy program by incorporating parasitology content into the final-year optional module of Sanidad Ambiental. This initiative consisted of a shared teaching intervention based on the biological response training. In brief, we introduced theoretical sessions on emerging parasitic diseases and two innovative practical seminars simulating the management of a zoonotic protozoan outbreak (biological incident), with different levels of difficulty based on the students' background in parasitology and infectious diseases. The virtual resource e-Parasitology© (http://parasitology.dmu.ac.uk/), which was designed at De Montfort University (DMU, UK), was used to overcome time constraints and to enhance the clinical practical aspect of these modules and to facilitate the acquisition of diagnostic parasitological skills (33). This open-access virtual package includes theoretical content, virtual labs and microscope, and clinical case simulations designed to support parasitology teaching (12). e-Parasitology© was originally developed at De Montfort University (DMU, UK), with contributions from several collaborating universities, including UAH, Universidad Miguel Hernández de Elche (UMH), and CEU San Pablo University (12). It should

therefore be understood as an international digital educational resource rather than as a tool associated with a single institutional partnership. Within this broader initiative, the UAH team contributed to the adaptation, implementation, and pedagogical integration of the resource across undergraduate and postgraduate teaching contexts. Across previous implementations of e-Parasitology© in Higher Education programmes at DMU (BSc Biomedical Science, third-year Medical Microbiology module; n = 72 respondents out of 194 students), UMH (MPharm Pharmacy, second-year Parasitology module), and the University of Makeni in Sierra Leone (BSc Public Health program, second- and fourth-year cohorts; n = 31 respondents (34,35)), questionnaire-based evaluations consistently showed high levels of perceived learning gain. Briefly, in the Microbiology cohort, 95.8% of respondents reported appropriate acquisition of knowledge on the pathology, prevention and treatment of parasitic diseases and 91.7% indicated that they had learnt basic investigative skills, while 95.8% agreed that e-Parasitology© helped them with their studies (36). At UMH, preliminary analysis of grades in the second-year Parasitology module across two pre-implementation and two post-implementation cohorts (2015/16–2018/19) showed statistically significant increases in both exam and overall module marks after the introduction of e-Parasitology© (p-value< 0.001 (12)). These data, although generated in partner institutions with different curricular structures and evaluation designs, provide contextual support for the educational potential of the virtual resource now embedded in our curriculum at UAH. However, they should not be interpreted as direct evidence of equivalent outcomes in the local UAH setting (36).

The package was developed in the belief that technology could address several challenges in current medical and health education, such as large student numbers and a shortage of health professionals. It can also meet the future requirements of Education 2030 (37). Studies have suggested that virtual laboratories and simulations can enhance student learning, intrinsic motivation and self-efficacy, particularly among those with prior knowledge (38). The introduction of this package at various universities, including UAH, has supported new ways of delivering parasitology teaching, while in other settings it has also contributed to strengthening teaching and research capacity in this field, including at two African universities (Ernest Bai Koroma and Makeni) (36).

Despite the different academic backgrounds of the students enrolled in the Environmental Sciences, Criminalistics and Pharmacy programmes at the University of Alcalá, exploratory classroom observations suggested broadly similar patterns of engagement and task completion across cohorts. In exploratory classroom observations, students across these cohorts appeared able to engage with the proposed parasitic outbreak scenarios, identify relevant recovery options (ROs), and discuss measures to protect human health, reduce exposure, and support environmental decontamination. Among students from the Environmental Sciences (n=61) and Criminalistics programmes (n=41), many who had not previously studied parasitology were also able, during routine teaching activities, to select appropriate laboratory techniques for the parasites addressed and to prioritise ROs for different urban scenarios in ways broadly comparable to final-year Pharmacy students (n=40). These observations further suggested that students could discuss issues of capacity, preparedness, and resource allocation in response to a simulated parasite outbreak (39). In addition, students from the two undergraduate science programmes were able to use the virtual slides available in the e-Parasitology© package to support parasite recognition during the sessions. These qualitative classroom outcomes are broadly aligned with the direction of findings reported in more formal evaluations of the same virtual package in other settings, although differences in institutional context, student profile, curriculum structure, and evaluation design limit direct comparison. For instance, in the Sierra Leonean Universiy of Makeni, Public Health students in second and fourth year (n=31 respondents out of 367 enrolled; 2018/19) reported that 100% had gained appropriate knowledge of the parasitic diseases studied after using e-Parasitology©, while

93.5% and 90.3% indicated that the diagrams and mini-videos facilitated their learning and helped them to perform specific diagnostic techniques. A subsequent practical session in the Medical Laboratory Sciences pathway (*n*=18) showed that only one participant (11.1%) felt insufficiently prepared to perform the Kinyoun stain (35,36). Together with the grade improvements observed in Pharmacy and Biomedical science cohorts at UMH and DMU, reported in a multi-site evaluation of e-Parasitology© (12,36), these observations suggest that even limited curricular time and resources may support meaningful engagement with outbreak-response tasks involving human parasites in an urban environment. However, in the case of UAH, this interpretation should be regarded as exploratory because no formal local outcome measures were collectedThese outbreak-response sessions were repeated with new cohorts from the same three programmes at the University of Alcalá in the 2024/25 academic year, and informal classroom observations suggested similar patterns of participation and discussion of appropriate recovery options, although no formal quantitative evaluation was conducted in this iteration. This is a very relevant result considering the growing concern about the declining ability of healthcare professionals to diagnose parasitic diseases, due to the reduction in instructional hours devoted to parasitology in human health education programmes worldwide (3).

Moreover, informal in-class feedback suggested that students enrolled in the science programmes showed clear interest in, and positive reception of, the medical parasitology content included in their programmes. As part of the third and final block on public health in the second-year *Environmental Toxicology and Public Health* module, students worked in small groups to develop a research project or proposal addressing an environmental risk of their choice over six two-hour sessions. Many groups chose to focus on emerging parasites, such as those causing food contamination. During a dedicated session at the end of the course, the students presented their proposals, which their peers then evaluated as highly relevant (39). Although these impressions are based on informal in-class feedback rather than a formal survey at UAH, they are broadly consistent with the high levels of satisfaction reported in structured questionnaires completed by Pharmacy, Biomedical science and Public health students at partner universities following e-Parasitology©-supported activities (36). At UAH, e-Parasitology© was integrated operationally through selected components of the platform, particularly virtual microscopy, virtual laboratory resources, and case-based materials, which were used to complement theoretical classes, practical seminars, and outbreak-response activities in Environmental Sciences, Criminalistics, and Pharmacy teaching; these applications are described in more detail in the following sections.

3.2. CBRN curriculum development.

In response to increasing global threats, UAH and the UKHSA have recently updated the CBRN training course to significantly enhance the integration of parasitology training. This uses an applied, scenario-based approach to develop students' practical and decision-making skills (40). A series of three 2-hour workshops was introduced to support active learning and foster emergency preparedness competencies. Mini case studies in clinical parasitology were used to train students in diagnosing emerging zoonotic pathogens (CDC Categories B and C), which could be used in bioterrorism events. Students also designed tailored protection and decontamination interventions in response to simulated chemical and biological incidents, and presented and critically evaluated their plans. These workshops were supported by open-access tools developed by UKSHA for first responders and the e-Parasitology© package, which further supports parasitology-specific learning. Furthermore, the CBRN course has been expanded to include real-world case studies based on documented incidents. This training has been embedded across several UAH programmes: Environmental Sciences (*Environmental Toxicology and Public Health* module), Criminalistics: Sciences and Forensic Technologies (*Forensic Toxicology*), and the recently launched MSc in *Industrial Pharmacy and Galenics*. Notably, content on environmental and clinical parasitology was introduced to help students develop effective decontamination and diagnostic strategies for biological

incidents. This innovative pedagogical approach provided students with valuable insight into the intersection of parasitology with emergency preparedness, environmental decontamination, and public health protection.

Similar trends were observed in the results from 2023/24 and 2024/25 for students enrolled in human health and science programmes. Specifically, they demonstrated their ability to propose effective intervention plans for complex biological events and were able to identify the emerging parasites. Thus, while further and quantitative analysis is needed, e-Parasitology© appears to support learning about zoonotic parasites relevant to bioterrorism, enabling students with no prior parasitology experience to engage meaningfully. These results are consistent with recently reported findings from parasitology education research in Japan, which emphasised that students' prior interest and motivation before attending lectures significantly impacted their understanding and engagement with the subject (41). Notably, this study found that students who had previously received some parasitology instructions were sometimes less engaged than those encountering the subject for the first time. This suggests a potential mismatch between course delivery and student expectations. Sekine (41) therefore emphasises the importance of designing parasitology courses that actively foster curiosity and provide meaningful learning experiences early on, particularly for students with limited or no prior exposure to the field.

Our findings also align with previous research in veterinary parasitology education, which highlights that prior exposure to the discipline does not necessarily translate into increased engagement or perceived relevance. For example, Strube et al. (42) found that almost a quarter of veterinary students rated fundamental aspects, such as parasite biology, as "not very relevant" or "irrelevant", and only around half expressed interest in receiving further parasitology training. The authors also noted that students tended to focus primarily on exam preparation rather than on developing a deeper conceptual understanding, particularly when the subject was not perceived as directly applicable to their future professional practice. Similar trends were observed among pharmacy and science students at the UAH, where prior disciplinary background did not appear to significantly influence learning outcomes. These findings could also reinforce our innovative, applied teaching strategies, such as interactive workshops, clinical case studies, and digital platforms like e-Parasitology©, to promote meaningful engagement with parasitology in diverse educational settings.

Using digital learning tools alongside in-person sessions improved student engagement and learning in clinical modules that included parasitology (43). Students particularly valued digital resources that supported practical sessions and reinforced laboratory skills. However, Kelly et al. (43) also noted that poorly integrated or excessive digital content could reduce motivation, particularly among students with limited prior knowledge. These findings emphasise the importance of aligning online materials with students' needs, ensuring they complement interactive teaching approaches rather than replacing them.

3.3. Forensic Parasitology: An Emerging Educational Field

Parasitology is increasingly recognised as a valuable tool in forensic investigations, particularly for post-mortem analysis and environmental casework (44). Our teaching innovation group at UAH is pioneering the development of forensic parasitology training, integrating it into science degree programmes. In 2024, new educational materials were developed as part of a dedicated innovation project entitled *Virtual resources for teaching and learning forensic parasitology* (45). The aim of this project was to create virtual case studies on forensic parasitology, with forensic scenarios involving protozoa, helminths, and arthropods.

The first case study, which describes a post-mortem diagnosis of *Ascaris lumbricoides* in a child, is available through the e-Parasitology© Case Studies module. Designed to enhance students' diagnostic reasoning and critical thinking skills, this case has initially been tested with third-year students enrolled on the Criminalistic degree program. Preliminary feedback indicates that Forensic Toxicology students were able to engage with parasitic evidence in a forensic context (46).

3.4. Teaching Emerging Diagnostic Techniques

As a more recent specialist initiative beyond the core undergraduate curriculum, a new summer course on diagnostic techniques, entitled *Advanced Diagnosis of Emerging Parasites in Humans and Animals*, was launched in 2025 (47). The course is designed to equip students and professionals with the practical skills needed to detect and manage parasitic infections, placing a strong emphasis on diagnostic innovation. Delivered over eight intensive days, the program combined theoretical instruction with hands-on laboratory work using real clinical and veterinary samples. Participants were trained in conventional diagnostic procedures (*e.g.*, sedimentation and flotation) and advanced techniques such as PCR and monoclonal antibody development. The curriculum also included a theoretical session dedicated to the control of emerging and re-emerging parasitic diseases, reinforcing the importance of preparedness and coordinated responses. Additionally, students explored the design and formulation of medicinal products, soaps, and topical lotions for treating parasitic infections, thereby linking parasitology, public health preparedness, and pharmaceutical development within a One Health framework. These theoretical sessions were complemented by practical workshops on designing, preparing and quality-controlling active pharmaceutical ingredients and formulations for treating parasitic diseases in both human and animal contexts. The curriculum also integrated One Health approaches, environmental decontamination strategies, and pharmaceutical development to highlight the multifaceted nature of parasite control.

A cross-programme synthesis of the intervention profile is presented in Table 2. As shown, the most transferable components across settings were the use of e-Parasitology© and scenario-based CBRN activities, whereas diagnostic intensification, One Health framing, and forensic case-based work were incorporated more selectively according to programme aims and learner profile. This distribution reinforces the implementation logic described above: a common digital and scenario-based core was adapted to different curricular needs, while more specialised strands were introduced selectively where disciplinary relevance and teaching context made them feasible.

Table 2. Implementation profile of parasitology teaching interventions across undergraduate, postgraduate, and short-course settings at UAH.

Programme	Parasitology teaching innovations				
	e-Parasitology	**CBRN Workshops**	**Diagnostic Training**	**One Health Focus**	**Forensic Case Studies**
Pharmacy (UG)	Yes	Yes	Yes	Yes	No
Environmental Sciences (UG)	Yes	Yes	Yes	Yes	No
Criminalistics: Sciences and Forensic Technologies (UG)	Yes	Yes	No	No	Yes
Industrial Pharmacy (PG)	Yes	Yes	Yes	Yes	No
Summer Course	Yes	Yes	Yes	Yes	No

3.5. Promoting Early Scientific Interest: Introducing Parasitology to Secondary School Students

As part of our commitment to widening participation and fostering early scientific vocations, our group has introduced medical parasitology to the *4º ESO + Empresa* outreach program for secondary school students at the UAH, which is supported by the Community of Madrid, during the 2024/25 academic year. This programme is a pre-university outreach initiative, supported by the Community of Madrid, for secondary school students aged 15–16. Our activity offered participants an immersive experience in the biomedical sciences. It was developed in collaboration with colleagues from Human Anatomy and Embryology, Legal and Forensic Medicine, and Pharmacy and Pharmaceutical Technology, highlighting its interdisciplinary nature and its alignment with the broader aims of health-science education.

During structured rotations in university laboratories, students learnt to identify parasites under the microscope, understand basic transmission mechanisms, and explore the public health significance of parasites. Sessions were integrated with pharmaceutical formulation and public health activities. Teachers and students provided informal positive feedback, particularly valuing the opportunity to handle laboratory equipment and to link parasite biology with real-world prevention strategies; formal evaluation of this outreach activity is planned for future editions.

Following the success of this pilot, we expanded and formally incorporated the malaria case study into the 2025 *Madrid Science and Innovation Week* (48), under the event *Jóvenes Científicos en Acción: Tu futuro en la salud* (49). This wider implementation included students from four secondary schools—IES Alonso Quijano, IES Antonio Machado and IES Lázaro Carreter (Alcalá de Henares, Madrid region) and IES Ana María Matute (Cabanillas del Campo, province of Guadalajara)—thus reaching a broader and more diverse cohort. A total of 59 students from Years 10–11 (equivalent to 3º and 4º ESO) and sixth-form level (equivalent to 1º de Bachillerato) attended a three-hour workshop on 12 November 2025, in which they worked through an adapted malaria clinical scenario using high-quality digital images of thick and thin blood films from the e-Parasitology© virtual microscope and guided prompts to identify *Plasmodium* infection, relate it to the patient's symptoms, and discuss transmission and prevention. Classroom observations indicated high engagement and collaboration; most groups correctly recognised malaria, explained key diagnostic features, and articulated the basic transmission cycle. Teachers highlighted that the activity filled a gap in school curricula where microscopy-based learning is limited and expressed interest in adapting the materials for future classroom use.

By incorporating parasitology into this early-exposure programmes, the UAH aims to support foundational scientific literacy and promotes awareness of neglected tropical diseases, highlighting their relevance to the One Health and environmental health frameworks. This initiative takes an innovative approach to engaging future students with parasitology well before they enter university, thereby reinforcing its societal relevance and educational value.

3.6. Cross-cutting instructional design principles

Across intervention strands, several shared instructional design principles were intentionally prioritised to sustain parasitology teaching within constrained, integrated curricula. First, learning activities were anchored in authentic, problem-centred scenarios (*e.g.*, outbreak response and forensic casework) to strengthen perceived relevance and transfer. Second, the curriculum emphasised diagnostic reasoning as a unifying competency, linking parasite identification to decision-making about appropriate laboratory methods and public health actions. Third, learning tasks were scaffolded from guided identification and interpretation towards more complex, open-ended problem solving. Fourth, a blended and resource-efficient delivery model was adopted,

combining open-access digital resources (*e.g.*, virtual microscopy and case simulations) with targeted hands-on training when feasible. Fifth, learning design incorporated feedback-rich practice (iterative tasks, facilitated discussion, and structured teaching reflection) to support competence development. Sixth, interdisciplinary facilitation (*e.g.*, public health, environmental, forensic and laboratory perspectives) was used to align parasitology with One Health priorities and workforce-relevant skills. Seventh, interventions were designed to be inclusive for learners with heterogeneous backgrounds, offering multiple entry points and flexible pacing. Finally, the programme was implemented with a view to progressive evaluation maturity, starting with implementation descriptors and early learning signals and progressing towards structured outcome evaluation in subsequent phases.

4. Emerging Teaching Resources and Future Steps

Recognising the importance of enhancing the teaching status of medical and veterinary parasitology, our group has set up a Teaching Innovation Group (GID, in Spanish acronym) at UAH called Responding to Chemical, Biological, Radiation and Nuclear Incidents (UAH-GI23-205, (50)). The future objectives of the GID include strengthening of our virtual offerings by developing mini-games integrated into applications in collaboration with multimedia developers, to support the teaching and learning in medical parasitology. Another objective is to generate 3D-printed models from two-dimensional images of helminth eggs and other parasitic structures, based on their real morphological and morphometric characteristics. These models will enrich the teaching and learning process in both face-to-face and distance learning contexts.

Building on the success of the e-Parasitology Game Collection© app created by DMU graduate James Sampson-Brindley, who was recruited through the Graduated Champion scheme, we are developing further games based on an app for Smartphones (51). The new app was developed by Samuel Cochrane during his 2024 Graduate Champion internship at DMU using Unity (Unity Technologies, San Francisco, CA) and the C# programming language. It was produced in three sprints following an agile scrum framework (52) and is depicted in figure 1.

This game app includes mini-games to teach you how to prevent and treat scabies, as well as how to diagnose it. Scabies is transmitted through human contact with ectoparasites, particularly *Sarcoptes scabiei* var. *hominis*. It is becoming a public health concern in Europe and developed countries due to a significant increase in cases among different population groups (*e.g.*, men who have sex with men), as well as following the implementation of containment measures after the 2019-23 coronavirus pandemic. The mini-games share a common architectural foundation and contain different exercises, questions and information about scabies, covering key topics on prevention, management, treatment and diagnosis.

Figure 1. Overview of the new game on scabies, which will be accessible from the Google Play Website (Artwork courtesy of DMU, Peña-Fernández A.).

Across the different interventions, several common instructional principles emerged: the use of applied and professionally relevant contexts, the combination of digital and practical learning resources, and the adoption of flexible formats that can be accommodated within time-constrained curricula. These features appeared to support student

engagement, although implementation remained constrained by limited curricular space, uneven prior knowledge, reliance on staff expertise, and the current absence of structured local evaluation.

Although institution-specific, this case study may still be informative for other higher-education systems in which parasitology has lost visibility within increasingly integrated curricula. Its main transferable value lies not in the replication of individual modules or activities, but in the underlying design principles: embedding parasitology in professionally meaningful contexts, combining digital and applied practical resources, and using flexible teaching formats that preserve disciplinary visibility despite limited teaching time. Their adoption elsewhere will depend on local contextual conditions, including curricular space, staff expertise, infrastructure, institutional support for cross-disciplinary teaching, and evaluation capacity. In this sense, the present study is intended not as a prescriptive model, but as an example of how parasitology teaching can be re-positioned within constrained contemporary curricula.

5. Conclusions.

- Parasitology remains a crucial yet vulnerable discipline within health and life sciences education. At the University of Alcalá, significant steps have been taken to address its reduced visibility in undergraduate and postgraduate curricula through interdisciplinary and applied teaching strategies. Implementing digital tools such as e-Parasitology© alongside scenario-based workshops, CBRN training, forensic case studies, and advanced diagnostic summer courses has given students accessible, contextually relevant resources with which to develop essential diagnostic and analytical skills.
- Early implementation signals suggest high learner engagement across diverse academic backgrounds, including students without prior parasitology training, and indicate perceived gains in foundational competencies relevant to parasitic threats in public health, forensic science, and environmental contexts. Participation patterns and observed performance in simulated outbreak scenarios support the feasibility and potential educational value of integrated, applied pedagogical approaches for revitalising parasitology within constrained curricula.
- As parasitic diseases continue to pose global health threats, it is essential to strengthen teaching provision and reaffirm the relevance of parasitology within contemporary biomedical and environmental science education. Our early implementation experience suggests that similar integrative and digital strategies may be worth considering in other institutions seeking to preserve parasitology teaching within integrated curricula, although their adoption and impact will necessarily depend on local curricular conditions, available teaching time, staff expertise, and evaluation capacity. Future work will prioritise structured evaluation of these approaches at UAH (*e.g.*, pre/post measures, validated instruments where appropriate, anonymised analysis of assessment data, and implementation metrics such as reach and fidelity) and the broader implementation of open-access digital tools and interdisciplinary training models, ensuring that parasitology remains an essential and resilient component of health sciences curricula.

Acknowledgments. This research was funded at De Montfort University's (DMU) Teaching Innovation Project Fund (Scheme 2015-16) and two DMU's Quality Research Global Challenges Research Fund (QR GCRF; Schemes 2018-19 and 2020). The funding included various schemes designed to promote employability, such as two DMU SAAS-funded internal placements (Schemes 2018-19 and 19/20) and three Graduate Champions positions (Scheme 2020-21), all of which were awarded to Dr. Peña-Fernández's team. The novel resources described were produced by Samuel Cochrane and James Robison during their 2024 Graduate Champions internship at DMU. Additionally, a teaching innovation project at the University of Alcalá (UAH), led by the same team, supported the design and implementation of new parasitology teaching activities. Although this UAH project did not receive specific financial support, it was recognised within the institutional framework

for educational innovation and contributed significantly to the development of the pedagogical strategies and digital resources described in this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Author Contributions: Conceptualization, APF; methodology, APF, JPS, TMP, MAP; software and re-sources, APF, DMU; implementation, APF, JPS, TMP, MAP; formal analysis, APF, JPS, TMP, MAP; data curation, APF, MAP; investigation, APF, JPS, TMP, MAP; writing—original draft preparation, APF; writing—review and editing, APF, JPS, TMP, MAP; project administration, APF; funding acquisition, APF. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported with internal funds from Leicester School of Allied Health Sciences, De Montfort University (UK) and the University of Alcalá (*Proyectos para el Fomento de la Innovación en el proceso de enseñanza-aprendizaje*).

Ethical approval: Ethical approval was provided by the Research Ethics Committee at De Montfort University (Ref. 1851; 8th December 2016; amendment approved on 20th April 2021).

Informed Consent Statement: Written informed consent was obtained from all participants through the questionnaires administered in each referenced study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to further processing for a future submission as a manuscript.

6. References.

1. Roure, S., Valerio, L., Soldevila, L., Salvador, F., Fernández-Rivas, G., Sulleiro, E., ... & Clotet, B. Approach to amoebic colitis: Epidemiological, clinical and diagnostic considerations in a non-endemic context (Barcelona, 2007-2017). *PLoS One*. **2019**, 14(2), e0212791. https://doi.org/10.1371/journal.pone.0212791

2. Cooney, J., Siakavellas, S. I., Chiodini, P. L., Mahadeva, U., Godbole, G., Pollok, R. C., & Smith, P. J. Recent advances in the diagnosis and management of amoebiasis. *Frontline Gastroenterology*. **2025**, 16(1), 37-50. https://doi.org/10.1136/flgastro-2023-102554

3. Kanahashi, T., Yamada, M., Ibuki, K. et al. Construction of a preliminary digital parasite specimen database for parasitology education and research. *Sci Rep*. **2025**, 15, 20711. https://doi.org/10.1038/s41598-025-07673-4

4. Comelli, A., Oliva, E., Bernieri, F., Zammarchi, L., Clemente, L., Petrullo, L., Calleri, G., Bruschi, F., & Raglio, A. Screening and Diagnosis Access for Neglected and Tropical Parasitic Diseases in Italy: A National Survey. *Tropical Medicine and Infectious Disease*. **2025**, 10(6), 153. https://doi.org/10.3390/tropicalmed10060153

5. Moniot, M., Nourrisson, C., Bailly, E., Lambert, C., Combes, P., & Poirier, P. Current status of intestinal parasitosis and microsporidiosis in industrialized countries: Results from a prospective study in France and Luxembourg. *PLOS Neglected Tropical Diseases*. **2024**, 18(12), e0012752. https://doi.org/10.1371/journal.pntd.0012752

6. Tapia-Veloz, E., Guillén, M., Trelis, M., Carpio-Arias, T. V., & Gozalbo, M. Assessment of the Health Status of Spanish Schoolchildren Based on Nutrimetry, Lifestyle and Intestinal Parasites. *Nutrients*. **2023**, 15(12), 2801. https://doi.org/10.3390/nu15122801

7. Jaume-Ramis, S., Rivory, P., Velázquez, I. S., Šlapeta, J., & Paredes-Esquivel, C. Neuroangiostrongyliasis Infection Risk Near Preschool Centres in Mallorca, Spain: A Pilot Micro-Epidemiological Study. *Zoonoses and Public Health*. **2025**. https://doi.org/10.1111/zph.13228

8. Krecek, R. C. Resolution on teaching veterinary parasitology: World Association for the Advancement of Veterinary Parasitology (WAAVP). *Veterinary parasitology*. **2002**, 108(4), 333-335. https://doi.org/10.1016/S0304-4017(02)00233-9

9. Vercruysse, J., & Eckert, J. Teaching of undergraduate veterinary parasitology in some European countries. *Veterinary parasitology*. **2002**, 108(4), 309-315. https://doi.org/10.1016/S0304-4017(02)00230-3.

10. van Doorn, D. C. K., Nijsse, E. R., & Ploeger, H. W. Pitfalls and opportunities of teaching veterinary parasitology within an integrated curriculum. *Veterinary Parasitology*. **2018**, 252, 85-88. https://doi.org/10.1016/j.vetpar.2018.01.036
11. UAH. *Undergraduate degrees*. **2025**. Available at: https://uah.es/es/estudios/estudios-oficiales/grados/ (accessed 20/07/2025).
12. Peña-Fernández, A., Acosta, L., Fenoy, S., Magnet, A., Izquierdo, F., Bornay, F. J., ... & Del Aguila, C. Evaluation of a novel digital environment for learning medical parasitology. *Higher Education Pedagogies*. **2020**, 5(1), 1-18. https://doi.org/10.1080/23752696.2019.1710549
13. Biggs, J. Enhancing teaching through constructive alignment. *Higher education*. **1996**, 32(3), 347-364.
14. Ryan, R. M., & Deci, E. L. *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. **2017**. The Guilford Press. https://psycnet.apa.org/doi/10.1521/978.14625/28806
15. Vansteenkiste, M., Ryan, R. M., & Soenens, B. Basic psychological need theory: Advancements, critical themes, and future directions. *Motivation and emotion*. **2020**, 44(1), 1-31. https://doi.org/10.1007/s11031-019-09818-1
16. Biggs, J., Tang, C., & Kennedy, G. *Teaching for quality learning at university 5e*. **2022**. McGraw-hill education (UK). https://www.iberlibro.com/Teaching-Quality-Learning-University-5e-Biggs/31578584556/bd
17. Wang, Y., Wang, H., Wang, S., Wind, S. A., & Gill, C. A systematic review and meta-analysis of self-determination-theory-based interventions in the education context. *Learning and Motivation*. **2024**, 87, 102015. https://doi.org/10.1016/j.lmot.2024.102015
18. Sturm, H., Brown, G., & Gantwerker, E. A. Evaluating Medical Education Escape Rooms: A Scoping Review Using the Kirpatrick Model. *MedEdPublish*. **2026**, 15(28), 28. https://mededpublish.org/articles/15-28
19. Howard, J. L., Slemp, G. R., & Wang, X. Need support and need thwarting: A meta-analysis of autonomy, competence, and relatedness supportive and thwarting behaviors in student populations. *Personality and Social Psychology Bulletin*. **2025**, 51(9), 1552-1573. https://doi.org/10.1177/01461672231225364
20. UAH. *Subjects. Degree in Pharmacy*. **2025**. Available at: https://uah.es/en/estudios/estudios-oficiales/grados/asignaturas/index.html?codPlan=G577 (accessed 20/07/2025).
21. UAH. *Subjects. Degree in Health Biology*. **2025**. Available at: https://uah.es/en/estudios/estudios-oficiales/grados/asignaturas/index.html?codCentro=102&codPlan=G651 (accessed 20/07/2025).
22. UAH. *Subjects. Degree in Medicine*. **2025**. Available at: https://uah.es/en/estudios/estudios-oficiales/grados/asignaturas/index.html?codCentro=101&codPlan=G215 (accessed 20/07/2025).
23. UAH. *Subjects. Degree in Biology*. **2025**. Available at: https://uah.es/en/estudios/estudios-oficiales/grados/asignaturas/index.html?codCentro=102&codPlan=G650 (accessed 20/07/2025).
24. Peña-Fernández, A., González-Muñoz, M. J., & de los Ángeles Peña, M. Designing training for teaching environmental toxicology to specialized pharmacists. *Currents in Pharmacy Teaching and Learning*. **2015**, 7(6), 864-868. https://doi.org/10.1016/j.cptl.2015.08.015
25. Wyke, S., N. Brooke, A. Dobney, D. Baker, V. Murray. *The UK Recovery Handbook for Chemical Incidents*. **2020**. Version 1.1, 2020. PHE publications, Gateway number: GW-1451. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/912808/UKRHCI_2019_Update_v1.1__2_.pdf (accessed 20/07/2025).
26. Pottage, T., E. Goode, C. Shieber, S. Wyke, S. Speight, A. M. Bennett. *UK Recovery Handbook for Biological Incidents*. **2015**. Version 1. PHE publications gateway number 2015406. https://www.gov.uk/government/publications/uk-recovery-handbook-for-biological-incidents (accessed 20/07/2025).
27. Royal Decree 2708/1982, of 15 October, which regulates specialisation studies and the awarding of the title of Specialist Pharmacist. «*BOE*». **1982**, No. 261, dated 30 October 1982, pages 29994 to 29997. Available at: https://www.boe.es/eli/es/rd/1982/10/15/2708 (accessed 20/07/2025).

28. UAH. *Farmacia Industrial y Galénica*. **2025**. Available at: https://www.uah.es/es/estudios/Farmacia-Industrial-y-Galenica/ (accessed 20/07/2025).
29. UAH. *Master's degree en Enfermedades Infecciosas*. **2025**. Available at: https://posgrado.uah.es/en/oferta/Enfermedades-Infecciosas/ (accessed 20/07/2025).
30. UAH. *Microbiology Applied to Public Health and Infectious Diseases Research*. **2025**. Available at: https://posgrado.uah.es/es/oferta/Microbiology-Applied-to-Public-Health-and-Infectious-Diseases-Research/ (accessed 20/07/2025).
31. UAH. *Master's Degree in Health Humanitarian Action*. **2025**. Available at: https://posgrado.uah.es/en/oferta/Accion-Humanitaria-Sanitaria/ (accessed 20/07/2025).
32. UAH. *Programa de Ciencias Naturales- Campus Alcalá*. **2025**. Available at: https://posgrado.uah.es/es/universidad-de-mayores/oferta-academica/Programa-de-Ciencias-Naturales-Campus-Alcala/# (accessed 20/07/2025).
33. Peña-Fernández, A., & De Montfort University. *e-Parasitology©: Open-access digital resources for parasitology education*. **2024**. Available at: http://parasitology.dmu.ac.uk/ (accessed 20/07/2025).
34. Peña-Fernández A., Guetiya Wadoum RE., Izquierdo F., Anjum U., Acosta L., Fenoy S., Peña MA., Berghs M., Koroma S. Use of DMU e-Parasitology in a West African university. In: *"Dando la vuelta a los procesos de enseñanza y aprendizaje: Aula invertida y otros retos de la Educación Superior. XI Encuentro de Innovación en Docencia Universitaria"*. **2020**. Eds. Del Castillo & Gómez. Servicio de Publicaciones de la Universidad de Alcalá, 2020: pp 1-187. ISBN: 978-84-18254-74-1. Available at: https://publicaciones.uah.es/ (accessed 20/07/2025).
35. Peña-Fernández, A., Anjum, U., Wadoum, R. E. G., Koroma, S., & Berghs, M. Competing ethics in a pilot strategy to implement parasitology training and research in post-Ebola Sierra Leone. *International health*. **2020**, 12(6), 509–514. https://publicaciones.uah.es/colecciones/libro/?id=2060
36. Peña-Fernández A, Acosta L, Escalera B, Peña MÁ. Strengthening the teaching status of parasitology at an English university: approaches and long-term analysis. In: Satorre Cuerda R, Menargues Marcillas A, Díez Ros R, editors. XARXES-INNOVAESTIC 2021. Llibre d'actes / REDES-INNOVAESTIC 2021. Libro de actas. Alicante: Universidad de Alicante; 2021. p. 264-265. https://rua.ua.es/server/api/core/bitstreams/6659d5a6-2c90-4a5c-ba6a-b99e9bb951b8/content
37. Simpson, D., Sullivan, G. M., Artino Jr, A. R., Deiorio, N. M., & Yarris, L. M. Envisioning graduate medical education in 2030. *Journal of graduate medical education*. **2020**, 12(3), 235-240. https://doi.org/10.4300/JGME-D-20-00292.1
38. Makransky, G., Thisgaard, M. W., & Gadegaard, H. Virtual simulations as preparation for lab exercises: Assessing learning of key laboratory skills in microbiology and improvement of essential non-cognitive skills. *PloS one*. **2016**, 11(6), e0155895. https://doi.org/10.1371/journal.pone.0155895
39. Peña-Fernández, A., et al. Introducing case scenarios from real CBRN events to train future science and healthcare professionals. En: Satorre Cuerda, Rosana (coord.). *Redes de Investigación e Innovación en Docencia Universitaria. Volumen 2024*. **2024**. Alacant: Institut de Ciències de l'Educació (ICE) de la Universitat d'Alacant. ISBN 978-84-09-66090-2, pp. 159-171. https://dialnet.unirioja.es/servlet/articulo?codigo=9825346
40. Peña-Fernández, A. and Peña M.A. Block versus traditional teaching for proper learning of medical parasitology. In: *Formación docente, fundamentos metodológicos y evidencias empíricas*. **2024**. Aura L. López de Ramos, Gustavo Quintero Barreto and Belka Bonnett Bogallo (coords). Barcelona: Octaedro, 2024, pp. 241-251. ISBN 978-84-1079-036-0. http://doi.org/10.36006/16443-1
41. Sekine, S. Pre-graduate teaching of human parasitology for medical laboratory technologist programs in Japan. *Humanities and Social Sciences Communications*. **2022**, 9(1), 1-6. https://doi.org/10.1057/s41599-022-01246-w
42. Strube, C., Raue, K., & Janecek, E. Simple, but not easy–Opportunities and challenges from teachers' and students' perspectives in the 21st century of veterinary parasitology teaching. *Veterinary parasitology*. **2018**, 252, 74-79. https://doi.org/10.1016/j.vetpar.2018.01.034

43. Kelly, R. F., Mihm-Carmichael, M., & Hammond, J. A. Students' engagement in and perceptions of blended learning in a clinical module in a veterinary degree program. *Journal of veterinary medical education*. **2021**, 48(2), 181-195. https://doi.org/10.3138/jvme.2019-0018
44. Kwak, M. L., Wallman, J. F., Yeo, D., Archer, M. S., & Nakao, R. Forensic parasitology: a new frontier in criminalistics. *Forensic Sciences Research*. **2024**, 9(2), owae005. https://doi.org/10.1093/fsr/owae005
45. UAH. *Proyectos para el Fomento de la Innovación en el proceso de enseñanza-aprendizaje*. **2025**. Available at: https://ideo.uah.es/es/innovacion-docente/proyectos-innovacion/#historico (accessed 20/07/2025).
46. Peña MA. and Peña-Fernández A. Developing training on forensic parasitology at the University of Alcalá, Spain. In: Antolí Martínez JM., Mengual-Andrés S., López-Padrón A., Lorenzo Álvarez C., Onrubia Martínez V. (eds.). *Libro de Actas. 3rd International Congress: Education and Knowledge*. **2024**. Ediciones Octaedro, 2024, pp. 369. ISBN: 978-84-10282-32-2. Available at: https://octaedro.com/libro/actas-proceedings-actes-3nd-international-congress-education-and-knowledge/ (accessed 20/07/2025).
47. UAH. *Curso de Verano en Diagnóstico avanzado de parásitos emergentes en humanos y animales*. **2025**. Available at: https://posgrado.uah.es/es/extension-universitaria/Diagnostico-avanzado-de-parasitos-emergentes-en-humanos-y-animales./# (accessed 20/07/2025).
48. Semana de la Ciencia y la Innovación. *Inicio. Fundación para el Conocimiento madri+d*. **2025**. https://www.semanacienciamadrid.org/ (accessed 09/03/2026).
49. Fundación para el Conocimiento madri+d. *Jóvenes científicos en acción: tu futuro en la salud*. **2025**. https://www.semanacienciamadrid.org/actividad/jovenes-cientificos-en-accion-tu-futuro-en-la-salud (accessed 09/03/2026).
50. UAH-GI23-205. *Grupo de Innovación Docente: Responding To Chemical, Biological, Radiation And Nuclear Incidents*. **2023**. Disponible en: https://ideo.uah.es/es/innovacion-docente/grupos-innovacion/RESPONDING-TO-CHEMICAL-BIOLOGICAL-RADIATION-AND-NUCLEAR-INCIDENTS/ (accessed 20/07/2025).
51. Peña-Fernández, A., Ukaegbu, E., Peña, M. A. Clinical parasitology education in Sierra Leone: a game experience approach. In: Carolina Gonzálvez Maciá, Ricardo Sanmartín López, María Vicent Juan. *Nuevos retos educativos e investigación interdisciplinaria*. **2022**. Editorial Aula Magna - McGraw Hill, 2022. ISBN 9788419544513, pp. 295-312. Available at: https://libros.cc/Nuevos-retos-educativos-e-investigacion-interdisciplinaria.htm?isbn=9788419544513 (accessed 20/07/2025).
52. Przybyłek, A., Albecka, M., Springer, O., & Kowalski, W. Game-based Sprint retrospectives: multiple action research. *Empirical Software Engineering*. **2022**, 27(1), 1. https://doi.org/10.1007/s10664-021-10043-z