



OUTPUT 8:  
TEACHING AQUAPONICS:  
BEST PRACTICE GUIDE



AQU@TEACH:

Innovative educational techniques to promote learning among European students using aquaponics



Erasmus+

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# INTRODUCTION

The Aqu@teach project (2017-2020) was an Erasmus+ Strategic Partnership for Higher Education involving the University of Greenwich (UK), the Zurich University of Applied Sciences (CH), the Technical University of Madrid (ES), the University of Ljubljana and the Biotechnical Center (SI). The partnership was formed as a response to the lack of adequately skilled personnel to design and operate aquaponic systems, with the objective of equipping students with digital, transferrable and entrepreneurial skills that will provide them with a competitive advantage in the labour market, consistent with the European Union's [Agenda for the Modernisation of Europe's Higher Education Systems](#) and [Opening Up Education: Innovative Teaching and Learning for all through new Technologies and Open Educational Resources](#).

The knowledge economy needs people with the right mix of skills: transversal competences, e-skills for the digital era, creativity and flexibility and a solid understanding of their chosen field. But public and private employers increasingly report mismatches and difficulties in finding the right people for their evolving needs. Innovative learning approaches and delivery methods can improve quality and relevance while expanding student numbers, to widen participation to diverse groups of learners, and to combat drop-out. One key way of achieving this, in line with the [EU Digital Agenda](#), is to exploit the transformational benefits of ICTs and other new technologies to enrich teaching, improve learning experiences, support personalised learning, and facilitate access through distance learning and virtual mobility.

Since the 1990s there has been considerable growth in the adoption of technology within higher education. Despite the widespread growth in practice, concerns continue to be expressed about the extent to which it is being used effectively in order to improve the learning experience of students. The sharing of 'good practice' and 'lessons learnt' among members of the higher education community can help teachers to concentrate on effective uses of technology and to avoid the unnecessary duplication of effort and expense. The pilot run of the Aquaponics Curriculum in 2019 was used in order to better understand how technologies are used in practice in online teaching, in order to practise technology enhanced learning more effectively. The pilot run was evaluated on the basis of comprehensive student feedback on each individual module and on the various teaching and learning methods used, and self-evaluation by the tutors. The lessons learnt have been developed into this Best Practice Guide, which provides teachers, instructors and/or tutors with fresh ideas for achieving the best educational results when teaching an interdisciplinary subject such as aquaponics, which requires high-quality knowledge in diverse fields as well as the specifics of interdisciplinary integration. The guide encourages teachers to introduce their students to technical and entrepreneurial skills, and to develop their own professional and transversal competences through the use of innovative teaching methods and tools.

The guide starts with a discussion of the quality assurance measures implemented and the indicators which were used for selecting the 12 best practice case studies. Nine of these focus on how different tools and activities can be used to blend the recommendations of the European Association for

Quality Assurance in Higher Education (ENQA) with the subject-specific requirements of aquaponics, namely high-quality knowledge in diverse fields and the specifics of interdisciplinary integration. The last three case studies illustrate the use of instructional scaffolding, which is a pedagogic practice that enables student-centred learning.

# QUALITY ASSURANCE

The Aquaponics Curriculum and supplementary Entrepreneurial Skills Curriculum were developed in accordance with the recommendations of the [Standards and Guidelines for Quality Assurance in the European Higher Education Area \(ESG\)](#) and [Considerations for Quality Assurance of E-learning Provision](#) issued by the European Association for Quality Assurance in Higher Education (ENQA). According to these recommendations, higher education e-learning programmes should be delivered in a way that encourages students to take an active role in creating the learning process, and this should be reflected in the way that they are assessed. Student-centred learning, teaching and assessment should involve the use of flexible learning paths, different modes of delivery and a variety of pedagogical methods, and students should be given a sense of autonomy. Since digitising content alone does not lead automatically to a successful educational setting, institutions should design their curriculum in such a way that it stimulates and engages students in the learning process, and to reflect best practices and research in teaching and learning. In order to overcome the lack of direct face-to-face interaction, students may need encouragement to engage online with each other. This can be facilitated by the use of online discussion groups for student-to-student contact; however, where peer interactions are essential for the successful completion of a programme, it is essential that institutions make sure to monitor, assess, and inform students of that. There should also be online spaces for communication between teachers and students.

ENQA also recommends that a well-defined educational model can help guarantee that students will achieve the learning outcomes, and that the learning design process should involve a consideration of how the assessment methods are aligned with the learning outcomes. The selection of the e-learning methodology used to assemble the learning model needs to be appropriate to the level and subject domain of the course, and utilising technologies that match the course content will enhance and expand learning for all types of students' needs. Virtual Learning Environments (VLEs), which can be developed based on the pedagogical needs of the course and its learners, offer increased flexibility for teaching, learning, and assessment and can be used to encourage the development of creativity, critical thinking, and in-depth subject knowledge. Regular revision on the basis of learning analytics and learner feedback will help lead to constant improvement.

According to ENQA there are nine indicators of quality assurance in higher education e-learning programmes. Each of these will be discussed briefly in relation to the Aqu@teach Curriculum and the supplementary Entrepreneurial Skills Curriculum.

1. *Teaching methodologies and learning activities are chosen with the aim of achieving the learning outcomes* – The Aquaponics Curriculum and the Entrepreneurial Skills Curriculum both contain clearly stated learning outcomes and the learning activities designed to achieve them. The learning activities were designed using the Learning Designer software (see Output 1 – Toolbox of Innovative Didactic Practices) in order to achieve an appropriate balance between the six types of learning – Acquisition, Inquiry, Practice, Production, Discussion and Collaboration.

*2. Learning materials fit the pedagogical model and facilitate student learning* – The Aquaponics Curriculum and the Entrepreneurial Skills Curriculum adopt the student-centred pedagogy of problem-based learning (PBL) in which students learn about a subject through the experience of solving an open-ended problem found in trigger material. The PBL process does not focus on problem solving with a defined solution, but it allows for the development of other desirable skills and attributes, including knowledge acquisition, enhanced group collaboration, and communication. The PBL tutorial process involves working in small groups of learners, and is focused on the student's reflection and reasoning to construct their own learning, by clarifying terms, defining problems, brainstorming, independent study, and synthesis. The Aquaponics Curriculum and the Entrepreneurial Skills Curriculum were designed as instructor-led, cohort-based e-learning courses which can also be adapted to blended learning. The student is at the centre of the learning, with the instructor playing an advisory and facilitating role through the use of instructional scaffolding. The learning materials are based around the three types of interaction that are required for effective PBL – learner-content, learner-instructor, and learner-learner.

*3. Authors of learning materials are relevant for the subject, and the learning materials are reviewed and updated periodically* – The development of the Aquaponics Curriculum and the Entrepreneurial Skills Curriculum involved a consortium of more than twenty individuals with different expertise, including aquaponics, aquaculture, horticulture, agricultural engineering, food safety, marketing, online teaching, and educational theory. The public release of the curricula under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license means that teachers who adopt them will be able to update them as necessary.

*4. The technical infrastructure is aligned with the teaching methodology, learning activities, and e-assessment methods, and it eases the teaching and learning process* – The Aquaponics Curriculum and the Entrepreneurial Skills Curriculum have been designed to be hosted on the Moodle virtual learning environment. Moodle facilitates student-centred learning, by incorporating a variety of different activities – wikis, workshops, glossaries, discussion forums, etc. – designed to encourage students to use different ways to engage with the material in a course, and different ways to interact and express themselves. It facilitates the teaching and learning process because everything – the module guides, the textbook, the assessment e-portfolio – are all readily accessible in the same space. The Aqu@teach Moodle has a Common Room, a space for informal interaction between the students and between them and their tutor.

*5. E-assessment methods are fit for purpose, allowing students to demonstrate the extent to which the intended learning outcomes have been achieved* – The Aquaponics Curriculum and the Entrepreneurial Skills Curriculum have been designed to include numerous opportunities for formative assessment, in the form of interim module quizzes, peer review workshops, and the submission of assignments for feedback from the tutor. Summative assessment is based on a combination of final module quizzes, active engagement with the various teaching and learning tools in Moodle, and e-portfolios. The variety of assessment types is intended to cater for the needs of different types of learners, and the variety of ways in which they may best demonstrate the achievement of the learning outcomes.

6. *Students are clearly informed about e-assessment* – The e-assessments are clearly explained in the Aquaponics Module Guide for Students and the Entrepreneurial Skills Module Guide for Students, and it is recommended that tutors who adopt the curricula set activity completion dates for these assessments in Moodle so that they appear in the course calendar. For the assessments involving peer review, the Moodle Workshops have already been set up with a description of the task, instructions for submission, guidelines for assessment, and guidelines for providing feedback. The Aqu@teach Moodle home page hosts two guides for using e-portfolios – one for Mahara, and the other for alternative e-portfolios.

7. *Students are aware of plagiarism rules* – Students of the Aquaponics Curriculum and the Entrepreneurial Skills Curriculum will be registered at a higher education institution, and therefore their institution's plagiarism rules will automatically apply.

8. *Students are trained in how to appropriately paraphrase, cite, and reference, regarding both online and print sources* – Students of the Aquaponics Curriculum and the Entrepreneurial Skills Curriculum will be registered at a higher education institution, and therefore will already have received training in citation and referencing etiquette.

9. *The institution gives advice on appropriate online behaviour (netiquette rules)* – The Getting Started Guide on the Aqu@teach Moodle home page contains clear guidance on netiquette.



## INDICATORS OF BEST PRACTICE

In order to develop indicators of best practice for teaching aquaponics as a blended learning or e-learning higher education course, it is necessary to merge the recommendations of the European Association for Quality Assurance in Higher Education (ENQA) with the subject-specific requirements, namely high-quality knowledge in diverse fields and the specifics of interdisciplinary integration. Aquaponic production is complex and requires a broad spectrum of knowledge – aquaculture, horticulture, chemistry, biology, food safety, engineering – in order to understand and manage the processes involved. For a student, this means achieving cognitive objectives classified at the top of Bloom’s taxonomy. Given the multidisciplinary nature of aquaponics, it can be taught as an optional module in a wide variety of different degree courses – including agriculture, agronomy, horticulture, aquaculture, landscape architecture, and ecological engineering –, and catering for the variety of backgrounds of the potential students was one of the greatest challenges faced when developing the Aquaponics Curriculum and the supplementary Entrepreneurial Skills Curriculum.

A Toolbox of Innovative Didactic Practices (Output 1) was assembled with a view to exploring and then testing the suitability and effectiveness of different digital tools that could be used for teaching both aquaponics and entrepreneurial skills. The Aquaponics Curriculum was pilot tested as an instructor-led, cohort-based e-learning course at each of the five partner institutions, with students studying very different disciplines: landscape architecture (Greenwich), agricultural engineering (Madrid), natural resource sciences (Zurich), sanitary engineering (Ljubljana) and horticulture (Naklo). The pilot run was evaluated on the basis of comprehensive student feedback on each individual module and on the various teaching and learning methods used, and self-evaluation by the tutors. The experience gained from the pilot run was subsequently used to inform the revision of the textbook, the curriculum and, in particular, the tools used in the student-centred learning activities.

The student evaluation of teaching and learning methods asked the following questions:

- Which of the following activities enhanced the learning process? [5 point Likert scale for each of the 14 activities – Diigo, Flickr groups, Moodle workshops, Moodle wikis, Moodle glossary, Moodle chats, Moodle discussion forums, Mahara e-portfolio, Exercises that involve writing summaries, Exercises that involve making calculations, Internet searches, Intermediate short quizzes, YouTube videos, Module introductory videos]
- Do you think that the time and effort needed to complete these activities was proportionate to the learning benefits? [5 point Likert scale for each of the 14 activities – as above]
- Please provide additional comments about those activities which you think did NOT enhance the learning process
- If your Moodle included H5P exercises, did you find them useful?
- Please comment on what you liked, or didn’t like, about the H5P activities
- Are there any digital tools which we didn’t use which you think would have enhanced the learning experience? If so, please tell us what they are and why you like them

The student evaluation of the individual modules of the curriculum asked the following questions:

- Level – of content, of the final quiz questions, of the assignments [3 point Likert scale for each]
  - Please provide additional comments on the level of content
- The textbook chapter – was clear and well written, was the right length, provided all the information needed to complete the assignments [5 point Likert scale for each]
  - Please provide additional comments about the textbook chapter
- Knowledge gain – I learned new knowledge, I added to my existing knowledge, I could connect new knowledge to previous practical experience [5 point Likert scale for each]
  - Please provide additional comments about knowledge gain
- Teaching methods – the e-learning tools were supportive in the learning process, I had technical problems with the e-learning tools, there is need for more guidelines for the activities which use e-learning tools [5 point Likert scale for each]
  - Please provide additional comments on the teaching methods
- Balance of activities – too much reading, too many solitary e-learning activities, too many interactive e-learning activities [5 point Likert scale for each]
  - Please provide additional comments on the balance of activities
- What did you like most about this module?
- What did you like least about this module?
- How could this module be improved?
- How many hours did it take you to complete the module?

The following indicators, aligned with the ENQA quality assurance recommendations, have been used for selecting the 12 best practice case studies presented in this document:

- Usefulness of the tools/activities for teaching the different aspects of aquaponics at higher education level [*ENQA – the e-learning methodology needs to be appropriate to the level and subject domain*]
- Impact of the tools/activities on student learning, based on an analysis of the end of module quiz results, peer evaluations, and e-portfolios [*ENQA – course content and technologies need to be matched in order to enhance and expand learning, the e-assessment methods need to be aligned with the learning outcomes*]
- Student evaluation of the teaching and learning methods [*ENQA – student-centred learning, teaching and assessment should involve the use of different modes of delivery and a variety of pedagogical methods*]
- Student engagement with the tools/activities [*ENQA – the curriculum should be designed in such a way so as to stimulate and engage students in the learning process*]
- Teacher experience of using the tools/activities

## CASE STUDY 1 | MOODLE GLOSSARY

Moodle Glossary is an activity which encourages students to create and maintain a communal alphabetical list of specialised or technical terms and their definitions, and is appropriate for learning objectives at the lowest level of the cognitive domain of Bloom's taxonomy:

- Remember

In terms of transferable skills, the main aim of the Moodle Glossary activity is to develop:

- Teamwork

### Teaching aquaponics and entrepreneurial skills using Moodle Glossary

Moodle Glossary activities occur throughout the Aquaponics Curriculum and the Entrepreneurial Skills Curriculum. Aquaponic production is complex and requires a broad spectrum of knowledge – aquaculture, horticulture, chemistry, biology, food safety, engineering – in order to understand and manage the processes involved. This means that there will be many terms with which the students will be unfamiliar. The same is true for the Entrepreneurial Skills Curriculum.

### Advantages

- It helps students get used to new terminology
- Familiarity with new terminology helps students to acquire a better understanding of the related concepts
- When students are responsible for creating the definitions, they are more likely to remember the word and the correct definition
- It ensures that students have a handy source for the definitions of terms
- It is a handy revision tool

### Disadvantages

- Students may not be motivated to add definitions
- Students may make errors in their entries

### Recommendations for teachers

Linking Glossary activities to external motivators, such as assessments and quizzes, might be needed in order to encourage its use and therefore support active and independent learning. The input of the teacher through the editing function is vital to ensure that entries are of good quality, and feedback or a discussion around the entries is helpful for students to understand mistakes. It may also be a good idea to ask the students to include examples of uses of the new words in context.

## CASE STUDY 2 | MOODLE DATABASE

Moodle Database was implemented as a new activity after the pilot run of the Aquaponics Curriculum. The students were overwhelmingly not in favour of the Diigo social bookmarking and Flickr image sharing activities, because they preferred to have all their activities within Moodle, rather than being directed to external sites where they then had to register to be a user. The Database activity enables the students to build, display and search a bank of record entries about a particular topic. In so doing they create a communal resource for the benefit of themselves and their peers. The format and structure of these entries can be almost unlimited, and they can include images, files, URLs, and text. Database therefore acts as an adequate substitute for social bookmarking and image sharing activities, though with limitations (see below). Moodle Database is appropriate for learning objectives in the lower half of the cognitive domain of Bloom's taxonomy:

- Remember
- Understand

In terms of transferable skills, the main aim of Moodle Database activity is to develop:

- Teamwork

### Teaching aquaponics using Moodle Database

Image sharing activities are particularly useful for topics such as plant pests and diseases and nutrient deficiencies, where different databases can be used to store a handy reference source of photos for each topic. The webpage sharing activities are mainly geared towards finding and storing pages relating to equipment and consumables, so that the students can start to get an idea of what is available, and what it costs. The Database activity is used in the following modules:

#### Module 1 – Aquaponic technology

- Share images of aquaponic system for commercial crop production, domestic production, education, social enterprise, greening and decoration

#### Module 2 – Aquaculture

- Share the websites of five aquaculture production companies in different regions of the world, and comment on the annual production and total size of the systems

#### Module 3 – Fish anatomy, health and welfare

- Share images of fish from cartoons, movies or other media, and comment on any anatomical aspects which are false or exaggerated
- Share webpages on fish welfare

#### Module 4 – Fish feeding and growth

- Share images of fish feeding and annotate with three keywords, including species
- Share the websites of companies that sell fish feeders that could be suitable for aquaponics

#### Module 5 – Nutrient water balance

- Share images of nutrient deficiencies for all essential elements on plants that are commonly grown in aquaponic systems, and provide information on the species/variety, the nutritional disorder of which element, and the name of the symptom

#### Module 6 – Hydroponics

- Share webpages of different types of substrate that are commercially available in your country
- Share webpages of hydroponic fertilizers that are commercially available in your country
- Share webpages of different types of hydroponic lighting systems that are commercially available in your country

#### Module 7 – Plant varieties

- Share the websites of seed companies in your country

#### Module 8 – Integrated pest management

- Share webpages of pest and disease control substances sold by hydroponic retailers in your country that you think would be safe to use in an aquaponic system
- Share images of damage caused by pests on plants commonly grown in aquaponics systems, and label them with the type of pest and the type of plant

#### Module 12 – Design and build

- Share the websites of companies that sell aquaponic systems and fish farm equipment that would be suitable for a developing country
- Share images of fish tanks, solids removal devices, biofilters and grow beds
- Share webpages of different types of water and air pumps for aquaponics systems

#### Module 15 –Social aspects of aquaponics

- Share images of herbs with a very pronounced fragrance which are suitable for growing in an aquaponics unit, and Label them with the species names and a short description of their properties

### Teaching entrepreneurial skills using Moodle Database

Moodle Database is used in the following units:

#### Unit 5 – Marketing and pricing

- Share images of packaging of aquaponics produce
- Share webpages and prices for competitor products and substitute products

### Advantages

- The communal building of the database reduces the amount of time that each student needs to spend searching the Internet for images or websites
- It is a useful tool for sharing resources
- The ability to search the database makes it a handy reference tool
- It is a handy revision tool

### Disadvantages

- It cannot compare with the image gallery facility of Flickr
- It does not have the collaborative annotation facility of Diigo, and therefore it lacks the higher order facility of critical evaluation

### Recommendations for teachers

Templates can be created for the Database activities in order to guide the students towards providing the required accompanying information with their entries, and also to control their visual layout. For example, each database can include fields for contributor name (i.e, the student who uploaded the figure or link), open text fields to comment on the entry, and open text fields for other students to comment on the entries made by their peers. In order to detect non-compliance with the instructions in a timely manner and to prevent such practices being continued by others, 'Approval required' can be activated during database set up, which means that the instructor needs to approve an entry before it becomes available for others to see. Teachers should make clear to the students how they will be graded on their database activities and how the activity enhances their knowledge on that topic.

## CASE STUDY 3 | ACTIVITIES THAT INVOLVE WRITING SUMMARIES

Writing summaries involves identifying key elements and condensing important information into a student's own words in order to solidify meaning. Activities that involve writing summaries are appropriate for learning objectives in the lower half of the cognitive domain of Bloom's taxonomy:

- Understand

In terms of transferable skills, the main aim of the Internet search and research activities is to develop:

- Communication skills

### Teaching aquaponics using activities that involve writing summaries

In the Aquaponics Curriculum the students are regularly tasked with writing summaries of about 500 words in order to give them an opportunity to determine what is important about the new knowledge that they have just acquired, and then express those important ideas in their own words. Activities that involve writing summaries occur in the following modules:

#### Module 2 – Aquaculture

- Summarise the history of aquaculture
- Summarise the desirable ranges for different physical and chemical water quality parameters in a RAS

#### Module 3 – Fish anatomy, health and welfare

- Summarise the operational welfare indicators that could be used in an aquaponic unit

#### Module 4 – Fish feeding and growth

- Summarise the problems of formulating feed for fish used in aquaponics, and the importance of feeding time

#### Module 5 – Nutrient water balance

- Summarise the differences between the nitrogen cycle in general and the nitrogen cycle in aquaponic systems

#### Module 6 – Hydroponics

- Summarise the influence of light on plant physiology
- Summarise the things that would be needed to start hydroponic production of lettuce in a small greenhouse

#### Module 7 – Plant varieties

- Summarise the reasoning behind your selection of species and cultivars for growing as a commercial polyculture of leafy greens, herbs and flowers, and create a crop schedule

#### Module 9 – Monitoring of parameters

- Summarise why monitoring in aquaponics is important and identify some pointers for monitoring

#### Module 10 – Food safety

- Summarise the potential foodborne pathogens related to the water source, and make a table showing the advantages and disadvantages of each type of water treatment applicable to

aquaponics

- Summarise the working procedures of GAP/GHP
- Summarise the initial steps of a food safety plan following the principles of the HACPP system

Module 11 – Scientific research methods

- Summarise a peer-reviewed scientific paper on the relationship between fish stocking density and plant yield in aquaponics systems, and the methodology used

Module 12 – Design and build

- Summarise the aquaponic systems and fish farm equipment that would be suitable for improving food security in developing countries

Module 13 – Urban agriculture

- Summarise the results of the analysis of competitors; the rationale for the choice of crop(s); the target customers; your USP; the type of growing system (hydroponic vs aquaponic) and the type of farm; the list of anticipated capital and operational costs; your notes on the relevant legislation; and the kind of business model you are going to adopt according to van der Schans' typology

Module 14 – Vertical aquaponics

- Summarise your calculations of production, revenue and seedling estimates for a 32 m<sup>2</sup> aquaponic greenhouse growing leafy greens and herbs in a ZipGrow towers, including the justification for your choice of crop
- Summarise the various pros and cons of using the four main types of vertical growing system for aquaponic cultivation

Module 15 – Social aspects of aquaponics

- Summarise how aquaponics might be used to improve food security and food sovereignty in the Za'atari refugee camp
- Summarise your idea for a social enterprise involving aquaponics

### Teaching entrepreneurial skills using activities that involve writing summaries

In the entrepreneurial skills summaries are used for a different purpose. They follow on from team brainstorming activities, and are used to provide a record of these so that the students may refer back to them as the module progresses. Activities that involve writing summaries occur in the following units:

Unit 2 – Lean start-up methodology

- Summarise the different building blocks of your 5 Bold Steps Vision Canvas
- Summarise the different building blocks of your Context Map Canvas

Unit 3 – St Gallen Business Model Navigator

- Summarise the outcome of the SWOT analysis of your business model

Unit 4 – Business Model Canvas

- Summarise the different building blocks of your Business Model Canvas

Unit 5 – Marketing and pricing

- Summarise the outcome of the Porter's Five Forces Model exercise
- Summarise the outcomes of the Six Thinking Hats exercise
- Summarise the different building blocks of your Value Proposition Canvas



## Unit 6 – Funding your start-up

- Summarise the different building blocks of your Storytelling Canvas
- Summarise the different building blocks of your Pitch Canvas

### Advantages

- Students have to select the most important information, which motivates them to read the text closely
- Students learn to organize their ideas, to determine their point of view, and to consider their audience
- In a cohort-based e-learning course such as Aqu@teach, summary writing is one of the few activities that the students undertake independently. It is therefore important for giving the students a sense of autonomy
- Summary writing is a valuable exercise in critical and reflective thinking, and also strengthens transversal skills such as written communication

### Disadvantages

- Students may struggle to read a lot of text and then condense the words into an appropriate summary
- If students do not receive proper feedback from their teacher or their peers, it is likely that they will not develop a good summary writing technique
- Because of the word limit, students may focus more on the number of words than on the contents of their summary
- If the text they need to summarise is not written in their native language, they may have difficulties understanding and/or summarising the key points
- It can be a time consuming activity, especially if the text they need to summarise is not written in their native language
- Since it can be time consuming, students may be tempted to copy and paste from the internet, resulting in plagiarism

### Recommendations for teachers

Like other writing activities, summary writing needs appropriate feedback. It is important that the instructor is actively involved, by sharing examples of good and bad practice. Respecting the word limit should be more a recommendation than an exact line which should not be crossed. The summaries can be run through plagiarism detection software such as Turnitin, which is a Moodle plugin.

## CASE STUDY 4 | ACTIVITIES THAT INVOLVE PRACTICAL TASKS

Activities that involve practical tasks are appropriate for learning objectives in the lower half of the cognitive domain of Bloom's taxonomy:

- Apply

In terms of transferable skills, the main aim of the activities that involve practical tasks is to develop:

- Problem solving
- Innovation

### Teaching aquaponics using activities that involve practical tasks

Students need to be made aware of the wide range of practical tasks that are involved in every aspect of aquaponics, from designing systems to monitoring parameters, and be provided with the necessary skills. Activities that involve practical tasks occur in the following modules:

Module 7 – Plant varieties

- Create a crop schedule for a 300 m<sup>2</sup> polyculture of leafy greens, herbs and flowers

Module 8 – Integrated pest management

- Draft a step-by-step integrated pest management programme for the biological control of aphids on sweet peppers in an aquaponic system

Module 9 – Monitoring of parameters

- Identify the parameter that is causing abnormal behaviour in fish, estimate the value of the parameter causing stress based on the data provided, and propose an action for remediation
- Draft a monitoring plan for an aquaponic system, with a description of the system and an annotated sketch showing the sampling points

Module 10 – Food safety

- Prepare a procedure for good agricultural practice (GAP) and good hygiene practice (GHP)

Module 12 – Design and build

- Design a small-scale aquaponic system for improving food security in developing countries: define its location (e.g. indoors, outdoors, rooftop) and make a list of all the factors that you will need to consider, such as the type and size of the system, the types and quantities of fish and plant species that you will use
- Draw a diagram of your small-scale aquaponic system and describe all the elements of your system (fish tank, filtration system, hydroponic component, etc.) in detail (size, materials, costs etc.)
- On the diagram of your small-scale aquaponic system, mark the points for taking water samples. Make a table of the parameters you would monitor in your system, and the frequency of monitoring

### Teaching entrepreneurial skills using activities that involve practical tasks

The activities that involve practical tasks occur in the following units:

#### Unit 2 – Lean start-up methodology

- Design experiments to test and measure your team’s riskiest assumptions in a quantitative way

#### Unit 5 – Marketing and pricing

- Define your brand identity and sketch some ideas for conveying it to your customers

#### Unit 6 – Funding your start-up

- Design a campaign page for a crowdfunding campaign for your start-up

### Advantages

- Students strengthen the connection between theory and practice through the application of theoretical principles to practical tasks
- In a cohort-based e-learning course such as Aqu@teach, practical tasks are one of the few activities that the students undertake independently. They are therefore important for giving the students a sense of autonomy

### Disadvantages

- Students may struggle to perform a task if previous and content-related activities were not completed successfully
- Some students may prefer more theoretical learning than practical tasks

### Recommendations for teachers

Open-ended tasks or problems with no easily defined solution are recommended. Teachers should therefore anticipate the different ways that a practical task could be completed, and should avoid those where only one outcome is possible. Teachers should make it clear to the students how they will be graded, and should promote process writing, whereby each student writes down the steps they used to reach their final answer so as to be able to verify their problem solving process and explain it to others. Practical tasks need appropriate and timely feedback.

## CASE STUDY 5 | ACTIVITIES THAT INVOLVE MAKING CALCULATIONS

Activities that involve making calculations are appropriate for learning objectives at the higher levels of the cognitive domain of Bloom's taxonomy:

- Analyze

In terms of transferable skills, the main aim of the activities that involve making calculations is to develop:

- Analytical skills
- Problem solving
- Numeracy

### Teaching aquaponics using activities that involve making calculations

There are many aspects of aquaponic food production that require accurate calculations to be made, from the relative size of the various parts of the system to the revenue costs that can be generated. Activities that involve making calculations occur in the following modules:

Module 1 – Aquaponic technology

- Calculate the current hype ratio for 'aquaponics', 'hydroponics' and 'aquaculture'

Module 2 – Aquaculture

- Dimension the recirculating aquaculture part of an aquaponic system

Module 4 – Fish feeding and growth

- Calculate fish feed and TAN

Module 5 – Nutrient water balance

- Calculate the nutrient balance of an aquaponic system

Module 6 – Hydroponics

- Calculate the fertilizer additions for a sample of local tap water

Module 7 – Plant varieties

- Calculate the required growing area, fish biomass and amount of feed needed in order to be able to harvest 50 heads of leafy greens per week
- Calculate the number of plants, the fish biomass and the amount of feed needed to grow two fruiting crops in Bato buckets in an area of 16 m<sup>2</sup>
- Calculate the fish biomass and the amount of feed needed to grow a polyculture of leafy greens, herbs and flowers in an area of 300 m<sup>2</sup>

Module 14 – Vertical aquaponics

- Calculate production, revenue and seedling estimates for a 32 m<sup>2</sup> aquaponic greenhouse growing leafy greens and herbs in a ZipGrow towers

### Advantages

- Calculation activities help to strengthen the connection between theory and practice
- They add a numerical dimension to problem solving that would otherwise be neglected

- By making calculations, students get a better understanding of the interconnectivity between different parameters and the complexity of aquaponic systems
- In a cohort-based e-learning course such as Aqu@teach, practical tasks are one of the few activities that the students undertake independently. They are therefore important for giving students a sense of autonomy

### Disadvantages

- Some students may struggle with tasks that involve making calculations, depending on their background
- If students do not get appropriate feedback from their teacher or their peers, it is more likely they will not understand the importance of making accurate calculations

### Recommendations for teachers

Calculations should not be an isolated activity, but rather an integral part of other tasks. It is recommended that whenever possible, calculations should be made using data from real aquaponic systems rather than hypothetical cases. If applicable the teacher should also predict different possible outcomes for a calculation. Exercises involving calculations need appropriate feedback, either from the teacher or from the other students as part of a Workshop activity. Teachers should make it clear that students need to explain their calculation process, not just provide the final result.

## CASE STUDY 6 | MOODLE WORKSHOP

Moodle Workshop is a powerful peer assessment activity. Students submit their own work and then receive one or more submissions from a fellow student which they must assess according to a predetermined list of criteria set by the teacher. Peer assessment is appropriate for learning objectives at the higher levels of the cognitive domain of Bloom's taxonomy:

- Analyse
- Evaluate

In terms of transferable skills, the main aim of peer assessment is to develop:

- Teamwork
- Decision making
- Communication skills

### Teaching aquaponics using Moodle Workshop

Peer review is used to assess the work of one other student in the following modules:

Module 1 – Aquaponic technology

- Calculate the hype ratio for 'aquaponics', 'hydroponics' and 'aquaculture'

Module 3 – Fish anatomy, health and welfare

- Identify two operational welfare indicators for fish, and explain why they could be useful

Module 4 – Fish feeding and growth

- Calculate fish feed and TAN

Module 5 – Nutrient water balance

- Calculate the nutrient balance of an aquaponic system

Module 6 – Hydroponics

- Summarise the influence of light on plant physiology

Module 7 – Plant varieties

- Calculate fish biomass and feed for a 300 m<sup>2</sup> polyculture of leafy greens, herbs and flowers, and create a crop schedule

Module 8 – Integrated pest management

- Create tables of different types of beneficial insects and mites, nematodes and biopesticides, and pest monitoring products

Module 9 – Monitoring of parameters

- Identify the parameter causing abnormal behaviour in fish, estimate the value of the parameter, and propose an action for remediation

Module 10 – Food safety

- Prepare a procedure for good agricultural practice (GAP) and good hygiene practice (GHP)

Module 12 – Design and build

- Design a small-scale aquaponic system suitable for improving food security in a developing country

Module 13 – Urban agriculture

- Justify your choice of type of commercial indoor farm, and list the anticipated capital and operational costs

#### Module 14 – Vertical aquaponics

- Calculate production estimates for growing towers

#### Module 15 –Social aspects of aquaponics

- Devise a primary school lesson plan using aquaponics to teach Science, Maths, or Design and Technology

### Teaching entrepreneurial skills using Moodle Workshop

In the optional Entrepreneurial Skills module, in which the students work together in small teams to develop a business idea, most of the Moodle Workshop activities have been designed so that each student assesses the work of all of the other members of their team. The exception is Unit 4, where each student assesses the work of one other student, since this exercise is unrelated to the development of the team’s business idea.

#### Unit 1 – Introduction

- Identify the political, economic, social, technological, environmental and legal factors that might affect the viability of your team’s business idea

#### Unit 2 – Lean start-up methodology

- Design experiments to test and measure your team’s riskiest assumptions in a quantitative way

#### Unit 3 – St Gallen Business Model Navigator

- Choose a business model and identify WHO, WHAT, HOW, and WHY/VALUE

#### Unit 4 – Business Model Canvas

- Make a proposition for a business innovation that changes 3 out of 4 basic aspects of the EKAG Business Model Canvas

#### Unit 5 – Marketing and pricing

- Build a Value Proposition Canvas for your team’s business idea

#### Unit 6 – Funding your start-up

- Develop a script and slides for a 10 minute start-up pitch

### Advantages

- Predetermined assessment criteria means that there can be little confusion about assignment outcomes and expectations
- It encourages collaborative learning
- It increases student responsibility
- It develops a better understanding of a student’s own subjectivity and judgement
- It develops critical thinking
- It exposes students to solutions, strategies, and points of view that they would not see otherwise
- Students can produce more effective feedback than tutors by providing explanations in terms that their peers understand best and according to their level of understanding
- It shifts the role of the student from passive learner to active learner, which encourages a

deeper approach to learning

### Disadvantages

- Students may have had little prior exposure to peer assessment, and so may feel they lack the necessary skills
- Students may feel reluctant to evaluate the work of their peers
- Students may feel unconfident about the strengths of their own work, which will make them question their ability to evaluate the same assignment produced by someone else

### Recommendations for teachers

While Moodle Workshop is primarily a student-focused activity, the reluctance of students to judge their peers and their lack of confidence in doing so could be alleviated by the teacher providing guidance in the form of example submissions for them to try out beforehand, and by publishing some good (or less good) examples at the end of the workshop.



## CASE STUDY 7 | MOODLE FORUM

The Forum activity enables students and teachers to engage in asynchronous discussion by posting comments as part of a 'thread'. Discussion threads are presented in a chronological order – the thread that receives the latest reply automatically goes to the top of the forum. Moodle Forum is appropriate for learning objectives in the top half of the cognitive domain of Bloom's taxonomy:

- Evaluate

In terms of transferable skills, the main aim of discussion forums is to develop:

- Teamwork
- Communication skills

### Teaching aquaponics using Moodle Forum

In the Aquaponics Curriculum the discussion activity is used in the following modules to enable students to critically evaluate the knowledge that they have acquired from their reading, watching or searching activities:

Module 1 – Aquaponic technology

- Which institutions, NGOs or businesses are doing serious research in the field of aquaponics?
- What topic in the field of aquaponics do you find particularly interesting?

Module 2 – Aquaculture

- What are the possible environmental, economic and other disadvantages of RAS?

Module 3 – Fish anatomy, health and welfare

- How can fish live in an environment with very little oxygen, and how much energy do they spend for respiration compared to reptiles and mammals?
- Do fish feel pain?

Module 4 – Fish feeding and growth

- What qualities would a sustainable feed need to have?

Module 7 – Plant varieties

- Which variety would be suitable for growing as a monocrop in a small commercial greenhouse?
- Which varieties would be suitable for growing as a polycrop in a small commercial greenhouse?

Module 8 – Integrated pest management

- Which pest and disease control substances sold by hydroponic retailers in your country would be safe to use in an aquaponic system?

Module 9 – Monitoring of parameters

- What causes necrotic patches on leaves and young leaves to appear white, and how can this be remediated?

Module 10 – Food safety

- Which microbiological, chemical, physical hazards and allergens are most likely to be expected in aquaponic food production?

#### Module 11 – Scientific research methods

- What is the most appropriate methodology for researching the fish and plant yield in an aquaponic system?

#### Module 12 – Design and build

- Which systems and fish farm equipment would be suitable for aquaponics in a developing country?

#### Module 13 – Urban agriculture

- Which urban agriculture enterprises are operating in your city, what is their business model, and can you identify a gap in the market?

#### Module 14 – Vertical aquaponics

- Given the levels of investment required, what sort of crops and fish would you need to grow to make vertical aquaponics commercially viable?

#### Module 15 – Social aspects of aquaponics

- How could aquaponics be used to improve food security in the Za’atari refugee camp?
- How could you use aquaponics for a social enterprise – who would your customers be, and how would you measure the social impact?

### Teaching entrepreneurial skills using Moodle Forum

In the optional Entrepreneurial Skills module, in which the students work together in small teams to develop a business idea, the discussion activities are used for brainstorming:

#### Unit 1 – Introduction

- Discuss and agree on an initial business idea
- Based on the results of the PESTEL analysis, revise and refine your business idea

#### Unit 2 – Lean start-up methodology

- Brainstorm the different blocks of the 5 Bold Steps Vision Canvas
- Brainstorm the different blocks of the Riskiest Assumption Canvas

#### Unit 3 – St Gallen Business Model Navigator

- Decide on one business model to take forward

#### Unit 5 – Marketing and pricing

- Discuss how to include experience in what you are proposing to offer your customers
- How do aquaponics farms use package design to draw their customers to their brand identity? What type of customers are they trying to attract?

#### Unit 6 – Funding your start-up

- Where would your start-up be positioned on the investor matrix model, and what funding path might you adopt in order to scale your business?
- What factors might have contributed to the relative success of three crowdfunding campaigns?

### Advantages

- Asynchronous discussion forums allow learners to participate without the limits of time and space
- Asynchronous communication gives the participants more time to reflect, and interact with

each other, which provides potential for more in-depth discussion

- It promotes collaborative learning
- It promotes higher order thinking
- It promotes critical thinking

### Disadvantages

- Students have a tendency to make a posting and then not return to the forum, thus precluding the possibility of any real discussion taking place
- It may be difficult to keep the discussions focused because of the chronologically organized structure
- The poorly interrelated structure of postings may be inefficient in promoting interactive dialogues
- It may be difficult for ideas to be synthesized because of the hierarchically structured threads
- One or two individuals may dominate the discussion

### Recommendations for teachers

Active engagement of the tutor in the discussion forum is needed in order to keep the momentum going, and also to correct any misconceptions or prevent the discussion from straying off topic. In order to encourage more effective discussion, a teacher could also require that each student responds to a minimum number of postings made by others.

## CASE STUDY 8 | MOODLE WIKI

Moodle Wiki is a report on a single topic which contains enough complexity to allow individual students to contribute, review, and edit a section or part of an entry. Moodle Wiki is appropriate for learning objectives in the top half of the cognitive domain of Bloom's taxonomy:

- Evaluate
- Create

In terms of transferable skills, the main aim of Moodle Wiki is to develop:

- Teamwork
- Communication skills

### Teaching aquaponics using Moodle Wiki

In the Aquaponics Curriculum the wiki activity is used in the following modules:

Module 1 – Aquaponic technology

- Aquaponic systems in Africa and Latin America

Module 3 – Fish anatomy, health and welfare

- Abnormalities in the external anatomy of fish

Module 4 – Fish feeding and growth

- Minerals and their normal range of concentration in feed for salmonids and tilapia

Module 6 – Hydroponics

- Different types of substrate that are commercially available in your country, and how they compare in terms of cost
- The range of hydroponic fertilizers that are commercially available in your country, and how they differ in terms of their constituent elements and their price
- Different types of lighting system and how they compare in terms of function and cost

Module 8 – Integrated pest management

- The five stages of an integrated pest management programme

Module 10 – Food safety

- The legislation relevant to aquaponic food production in your country

Module 12 – Design and build

- Different types of fish tanks, solids removal devices, biofilters and grow beds
- Different types of water and air pumps

Module 13 – Urban agriculture

- The legislation pertinent to indoor urban farming in your city

Module 15 – Social aspects of aquaponics

- The different activities carried out in an aquaponics unit and their associated therapeutic benefits

## Teaching entrepreneurial skills using Moodle Wiki

In the optional Entrepreneurial Skills module, in which the students work together in small teams to develop a business idea, the wiki activities are used for brainstorming:

### Unit 2 – Lean start-up methodology

- Brainstorm the different blocks of the Context Map Canvas

### Unit 3 – St Gallen Business Model Navigator

- Brainstorm all the different business models that could be applied to your team's business idea
- Brainstorm the strengths, weaknesses, opportunities and threats related to your business model

### Unit 4 – Business Model Canvas

- Brainstorm the different blocks of the Business Model Canvas

### Unit 5 – Marketing and pricing

- Brainstorm your customer segments using the Persona Canvas

### Unit 6 – Funding your start-up

- Brainstorm the different blocks of the Pitch Canvas

## Advantages

- It encourages collaboration
- It is easy to use
- It provides a useful forum for sharing the results of a research exercise

## Disadvantages

- Students may misunderstand that the document is meant to be both collaboratively produced and edited
- Students may be reluctant to edit the work of their peers
- Students may feel unqualified to edit the work of their peers
- It can become chaotic and muddled
- One or two individuals can dominate it

## Recommendations for teachers

For a wiki to work well as a learning space, one which is characterized by genuinely collaborative writing and collective meaning-making, it is necessary to nurture among students a sense in which it is acceptable to be ruthless – to edit, amend and challenge each other via the direct manipulation of each other's text. For the teacher in the Wiki, the key challenge is to nurture in students this sense that to do so is not a breach of trust but an act of responsibility and mutuality.

## CASE STUDY 9 | E-PORTFOLIO

E-portfolio is a digital collection which students can use to record and demonstrate their life-long learning, skills and development over time to selected audiences. E-portfolio is appropriate for learning objectives at the top of the cognitive domain of Bloom's taxonomy:

- Create

In terms of transferable skills, the main aim of e-portfolio is to develop:

- Communication skills

E-portfolio forms part of the summative assessment for both the Aquaponics Curriculum and the Entrepreneurial Skills Curriculum. Mahara is the suggested e-portfolio, because it enables different 'artefacts' (text, images, video, etc.) to be placed together on a page, and for different pages to then be grouped together to form a thematic collection. For example, the pages relating to the practical tasks in the various modules of the Aquaponics Collection could all be grouped into a 'Practical Skills' collection, and thus serve as a useful reference source. While the Module Guides for Students for both curricula contain frequent prompts for them to upload assignments to their e-portfolio, it is also explicitly stated in the Mahara e-portfolio Guide and Alternative e-portfolio Guide (located on the Aqu@teach Moodle home page) that the e-portfolio should show active engagement with the teaching/learning tools in the Moodle course, and that students can use their e-portfolio to collect other information which is pertinent to the course, without being prompted to do so.

### Advantages

- It facilitates the formation of thematic links between the content of different modules
- It documents the student's accomplishments during the learning process, which in turn can provide motivation to keep studying
- It helps learners to set personal goals related to their learning, and to identify short and long-term goals which are necessary to achieve their individual goals
- It can be used as a formative and/or summative assessment tool
- It helps students to reflect on their skills, appreciate their own knowledge base, and gain confidence in their ability to find a job
- It can be updated and incorporated into professional networking platforms as a job search tool
- Employers are increasingly aware of and willing to accept e-portfolios to evaluate job applicants

### Disadvantages

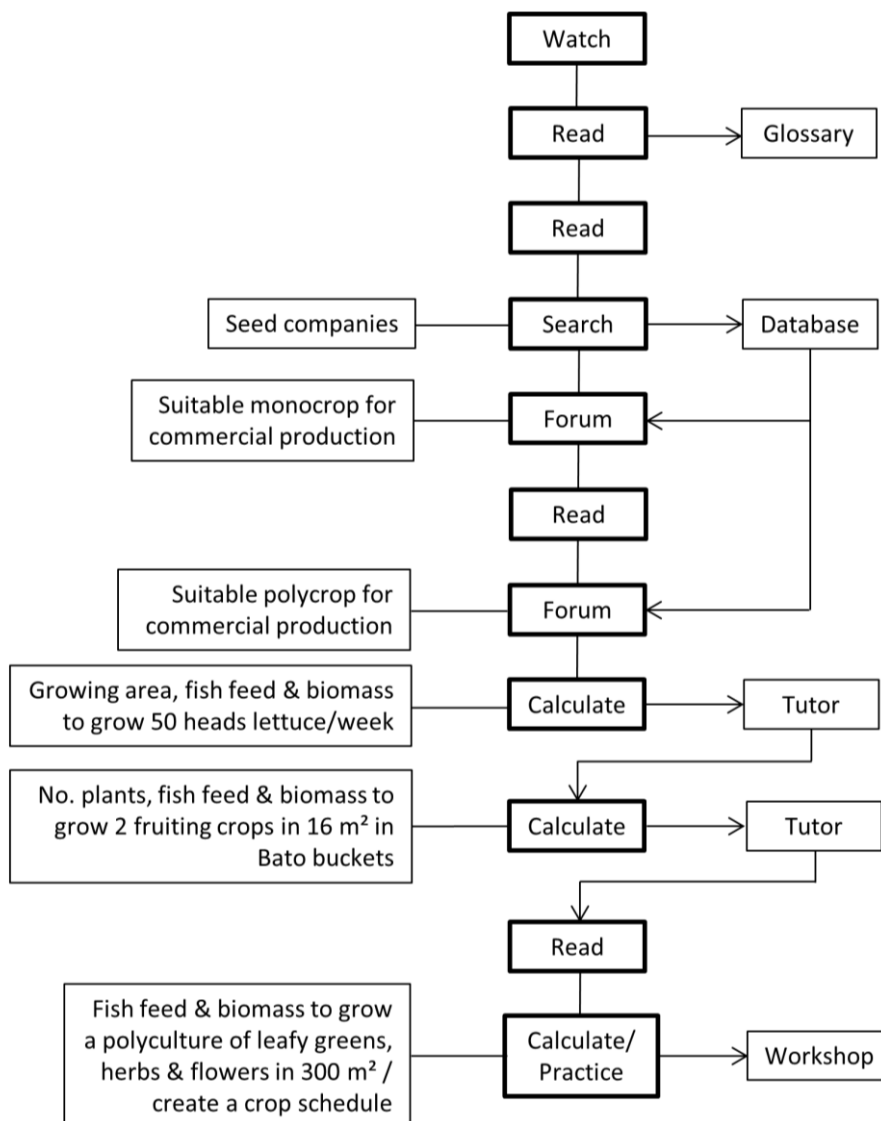
- Students often live in the moment, and only recognise what a tool can do for them now (satisfy the course requirements) rather than what it could do for them in the future (help them to get a job)

### Recommendations for teachers

Unless a student personally invests in the tool, it is unlikely that it will be utilised to its full potential. The challenge for instructors is therefore to adopt strategies which motivate the students to readily engage in the e-portfolio process by highlighting its value and usefulness, both for the task at hand, and in the future. Teachers should share examples of best practice with their students, so that they are clear what is expected of them, and should recommend that the students start planning the layout of their e-portfolio at the beginning of the course, rather than at the end, so as to prevent them from trying to create order out of chaos.

## CASE STUDY 10 | INSTRUCTIONAL SCAFFOLDING IN MODULE 7

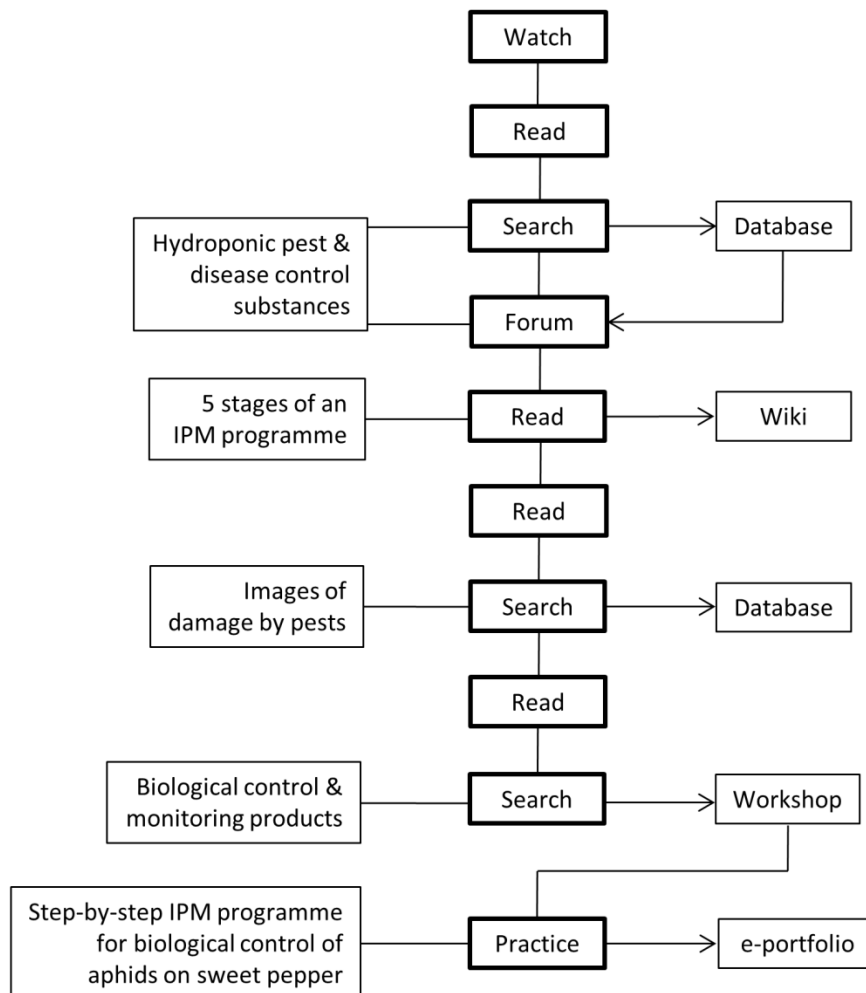
This case study illustrates the use of instructional scaffolding in Module 7 – Plant varieties. Instructional scaffolding is the support provided by the tutor throughout the learning process. This support is specifically tailored to each student, which enables student-centred learning. In this example the support from the tutor is provided in the discussion forums and in the formative feedback that is provided after the first two calculation exercises, so that any misunderstandings may be rectified before the final exercise. Instructional scaffolding provides sufficient support to promote learning when concepts and skills are being first introduced to students. Sharing definitions in the Glossary and resources in the Database, and the use of Forum and Workshop activities, creates a community of learning which further supports the student as they progress through the module. The activities have been designed to develop the commercial awareness of the student in terms of what plant cultivars are available in their country which might be suitable for commercial production.





## CASE STUDY 11 | INSTRUCTIONAL SCAFFOLDING IN MODULE 8

This case study illustrates the use of instructional scaffolding in Module 8 – Integrated Pest Management. As in the previous case study, the activities in the module have been designed to develop the commercial awareness of the student – in this case the various hydroponic pest and disease products that are commercially available in their country which might be suitable for aquaponics, as well as the different types biological pest and control and monitoring products. The tutor provides support by guiding the discussion in the Forum and by correcting any misconceptions in the Wiki. Sharing resources in the Database and the collaborative construction of a Wiki creates a community of learning. In this module formative assessment is provided in the form of peer review. The various activities gradually build up the knowledge needed for the final activity, which is a practical task.



## CASE STUDY 12 | INSTRUCTIONAL SCAFFOLDING IN MODULE 13

This case study illustrates the use of educational scaffolding in Module 13 – Urban Agriculture. Over the course of the module the students are tasked with developing a concept for a commercial indoor urban farm selling fresh, local produce. They are told that they will develop their ideas in a series of distinct stages, and that they can change their mind at any time during the process – about the produce they will grow, their target customers, their USP, the type of system they will use, and the type of farm – based on the feedback they receive along the way. The first formative feedback comes from the tutor, and the second from their peers. The Workshop activity, along with the Forum and Wiki activities, creates a community of learning which supports the students. The activities in the module were designed to develop their entrepreneurial skills.

