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D3.4 First run of MSc programme

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## About TeachHy

As the FCHT industry gradually emerges into the markets, the need for trained staff becomes more pressing. TeachHy2020, or short TeachHy, specifically addresses the supply of undergraduate and graduate education (BEng/BSc, MEng/MSc, PhD etc.) in fuel cell and hydrogen technologies (FCHT) across Europe.

TeachHy2020 will take a lead in building a repository of university grade educational material, and design and run an MSc course in FCHT, accessible to students from all parts of Europe. To achieve this, the project has assembled a core group of highly experienced institutions working with a network of associate partners (universities, vocational training bodies, industry, and networks). TeachHy offers these partners access to its educational material and the use of the MSc course modules available on the TeachHy site. Any university being able to offer 20 to 30% of the course content locally, can draw on the other 80 to 70% to be supplied by the project (and its successor entity that will support the platform post-project).

This will allow any institution to participate in this European initiative with a minimised local investment. TeachHy will be developing solutions to accreditation and quality control of courses, and support student and industry staff mobility by giving access to placements. Schemes of Continuous Professional Development (CPD) will be integrated into the project activities. We expect a considerable leverage effect which will specifically enable countries with a notable lack of expertise, not only in Eastern Europe, to quickly be able to form a national body of experts.

TeachHy will offer some educational material for the general public (e.g. MOOC's), build a business model to continue operations post-project, and as such act as a single-stop shop and representative for all matters of European university and vocational training in FCHT. The project partnership covers the prevalent languages and educational systems in Europe. The associated network has over 70 partners, including two IPHE countries, and a strong link to IPHE activities in education.



## Deliverable Abstract

This deliverable describes the implementation of the TeachHy MSc programme at the University of Birmingham for the 2<sup>nd</sup> programme delivery in the academic year 2022/23.

## 1 Approach to implementation

### 1.1 Teaching approach and background

TeachHy modules have from the start (2017) been set up as ‘blended learning’, i.e. as a mix of online and in-person teaching. Covid has taught us that this approach is the most sustainable under all conditions, as it offers the highest level of flexibility and resilience. In practical terms we have used the approach post-Covid as a ‘flipped classroom’ model.

Flipped Classroom means that students receive the lecture material upfront of the interactions with the lecturers in order to prepare, read, and formulate any questions they might have. In-person lectures and tutorials are then located towards the end of the course and do not serve the purpose of transferring knowledge, but rather as Q&A sessions, exercises, and additional information events. In the context of the arrangements found at University of Birmingham (UBHAM) for the Covid Years 2020 & 2021 this meant that students were given access to the online material one week ahead of the timetabled module (‘Release Week’). The following week (‘Support Week’) opened with an Induction Tutorial on the Monday morning (in hybrid mode, i.e. in-person attendance with the option to participate online), followed by two online-only tutorials on Thursday and Friday morning, and two mainly in-person (hybrid if feasible) tutorials on the Thursday and Friday afternoons. This format has now been adopted for all TeachHy MSc modules at UBHAM.

In order to support student time management, the sub-units of a modules are structured such that one unit approximates one regular teaching day (3 to 4 lectures of 90 minutes). Students can only pass from one unit to the next when they have concluded the previous unit, i.e.

- visited all lecture pages, and
- completed all quizzes.

Originally, we also required a participation in the Discussion Board exchange (posting remarks, feedback, questions etc.) but as many students did not want to participate or had nothing to contribute, we dropped this requirement.

Details of the implementation on the Learning Management System (LMS) CANVAS are reported in Deliverable D5.4.

### 1.2 Curriculum development

All modules listed in Table 1 have now been fully implemented for use in teaching. Modules O6 ‘Advanced electrochemical characterisation’, O7 ‘High temperature electrochemistry for SOFCs/SOEs’, and O12 ‘Fuel Cell Design’ were shelved for the time being as there was no activity of the respective partners Ecole Polytechnique de Lausanne (EPFL) and Technical University of Delft (TUD) (tasks in the future to be fulfilled by Rijksuniversiteit Groningen, RUG).

Modules O1 ‘Life Cycle Assessment’ and O11 ‘Advanced Modelling Tools’ will be fully developed at a later point in time.

Currently, an intensive exchange and co-development with two other initiatives, the Joint European Summer School on Fuel Cell, electrolyser, and Battery Technology (JESS) and the EIT-KIC funded project KICStarH2 is taking place.

Table 1: Modules offered in the academic year 2022/23 TeachHy MSc programme at UBHAM.

Section	No.	Title
Core / Mandatory	C1	Introduction to Electrochemistry
	C2	Fuel Cell Technologies and Applications
	C3	Hydrogen and hydrogen-based fuels
	C4	Fuel cell modelling tools and control
	C5	Characterisation methods
	C6	Fuel Cell and Hydrogen Lab
	C7a	Principles of Hydrogen safety
	C7b	Hydrogen safety
Optional / Elected	O2	Low temperature fuel cells
	O3	High temperature fuel cells
	O4	Fuel Cell systems
	O5	Advanced electrochemical applications
	O8	Fuel cell electric vehicles
	O9	Hydrogen Markets and Policies
	O10	Energy systems and storage

JESS is a private initiative of UBHAM, Forschungszentrum Jülich, and the Danish Technical University (DTU), with support from Ulster University (UU).

KICStartH2 overlaps with the TeachHy consortium via members UBHAM and UPB.

The Module C7b ‘Hydrogen Safety’ has been developed between the three projects and initiatives as a module for initial instruction for students as well as for Continuous Professional Development (CPD) use. More details are reported in Section 1.3. It is expected that this cooperation, hopefully adding further projects and groupings, will lead to an extensive body of teaching material and expertise that will be shared in this network.

### 1.3 Upgrades following the 1<sup>st</sup> trial run

Table 2 shows the full list of modules intended for the fully developed TeachHy MSc programme.

Three new modules have been added which were or are being developed between UBHAM and RUG, in cooperation with the EIT-KIC funded project KICStartH2, and with the JESS Summer School. JESS was initiated within the FCH JU funded project TrainHy, and since has been organised privately funded between DTU, FZ Jülich (RWTH), UBHAM, and UU. All of these modules (O13 to O15) are intended as optional modules in the MSc programme and specifically for CPD delivery. KICStartH2 was created in order to produce 4 modules for university and CPD use, that have also been incorporated into the TeachHy optional modules

list, i.e. C7b (alternative 10 credit/5 ECTS version to the UU 20 credit/10 ECTS module C7a), C14, C15, and a modified version of O9 concentrating on RCS alone and to be used for CPD purposes.

Module C7b Hydrogen Safety is a version akin to the JESS module (which is taught fully live) with UU contributions largely replaced by UBHAM and Bundesanstalt für materialforschung (BAM, Berlin) contributions as UU is not partner to KICStartH2. The module is meant as a shorter (and less credit carrying) version of the more expansive UU version C7a Principles of Hydrogen Safety.

Module O9b will in its KICStartH2 version be more focused on RCS. This will not be offered for the MSc programme, but there is a demand for such information to be conveyed in CPD.

The material for the optional module O11 Advanced Modelling was updated and uploaded. The developed material has the aim to introduce fuel cells modelling focusing on a macroscopic, physically based approach. The module contains the following list of lectures:

1. Transport phenomena (advanced)
2. Electrochemical modelling (advanced)
3. SOFC heterogeneous chemistry
4. SOFC multidimensional modelling (advanced)
5. Insights on charge transfer and kinetics
6. Image analysis and EIS for SOFC
7. Seminar on Power-to-power

This material still requires formatting and peer review and has thus not yet been implemented for the current TeachHy MSc programme delivery (academic year 2022/23).

Module O13 Electrolysis is felt to meet a need for more information on electrolysis that is currently not well represented in the TeachHy curriculum. It is in the process of being designed between RUG and UBHAM, with a distinctive need for such a module for CPD implementation.

Module O14 Hydrogen Infrastructure meets a similar need in the desire of students as well as companies to understand the hydrogen supply chain. This module is being developed together with UPB within the KICStartH2 project.

Module O15 is a JESS module that has been upgraded to an online module within KICStartH2 and is led by the Swiss SME Future.Solutions. The module is available on the ThinkiFic LMS and due to be transferred to CANVAS for use in the academic year 2023/24 at UBHAM.



Table 2: List of modules established for the TeachHy programme including availability in different languages. Status: F2 - Finished, run and peer reviewed, F1 - Finished (for first run), P2 - In progress slides ready, P1 - In progress, slides in draft, N - Module defined, not started.

Section	No.	Title	Lead	Status	Language
Core / Mandatory	C1	Fuel Cell Electrochemistry	UoB	F1	EN
	C2	Fuel Cell Technology	UoB	F2	EN, FR / part DE
	C3	Hydrogen and hydrogen-based fuels	UPB - UCPT - INP	F2	EN, RO
	C4	Fuel cell modelling tools and control	POLITO, INP, TUD	F2	EN
	C5	Techniques of Fuel Cell Characterisation	UoB	F1	EN
	C6	Fuel Cell and Hydrogen Lab	POLITO / UoB	F2	EN
	C7a	Principles of Hydrogen safety	UU	F2	EN
	C7b	Hydrogen Safety	UoB / BAM	F2	EN / part DE
Optional / Elected	O1	Environmental analysis, life cycle analysis	UoB	N	n/a
	O2	Low temperature fuel cells	DTU, UCPT, INP	F2	EN
	O3	High temperature fuel cells	KPI TUD	F2	EN, UA
	O4	Fuel Cell Systems	UoB	F2	EN
	O5	Advanced Electrochemical Applications	UoB	F2	EN
	O6	Advanced electrochemical characterisation	n/a	N	n/a
	O7	High temperature electrochemistry for SOFCs/SOEs	n/a	N	n/a
	O8	Fuel cell electric vehicles	UoB	F2	EN / part DE
	O9	Politics, markets, regulation, codes and standards	UoB - ULB	F1	EN / part DE / part FR
	O10	Energy systems & storage	UPB / UoB	F1	EN
	O11	Advanced modelling	POLITO - INP	F1	EN
	O12	Fuel Cell Design	TUD/RUG	N	n/a
	O13	Electrolysis	UoB, ULB	P1	EN, FR
	O14	Hydrogen Infrastructure	UoB, UPB	P1	EN
	O15	Innovation Mgmt.	UoB	F1	EN
Additional	A1	Electrocatalysis	Grenoble INP	F1	EN
	A2	Power to X	UoB	F1	EN

## 1.4 Lessons learnt from trial run

Deliverable D3.3 described the circumstances and outcomes of the 1<sup>st</sup> trial of the TeachHy MSc programme at UBHAM. A number of issues have now been addressed.

### 1.4.1 Programme modification to avoid visa issues

As all teaching had to go online during the Covid lockdowns, there was a common understanding between UK universities that students would not attend teaching in person and therefore could attend classes from wherever they were located on the globe. Normally, though, in-person attendance is required and monitored, especially for the international students. Students receive a specific (Tier 4) visa for this. Students following online-only courses and programmes ('distance learning', DL) are not issued student visas. If they need to enter the country (e.g. for exam purposes or the degree ceremony) they can do so on a tourist visa.

The UK Home Office, though, has refused to issue visas to 'blended learning' registered students. As a consequence of this situation, the programme was in 2022/23 set up in two different versions, 'on campus' and 'distance learning' (DL), which are essentially identical from the point of view of programme content. The only impact is the type of visa the students will receive for their studies.

### 1.4.2 Teaching delivery

With respect to teaching delivery, student feedback resulted in two main points to be improved:

- timing of class tests: performing a class test during the Support Week was deemed difficult by the students, as no time remained to revise or prepare; tests are now run the week following the Support Week
- more practical exercises: tutorials will be used to offer more exercises, especially those that will prepare for the coursework.

A further point noted was that lecture recordings that appeared to be two to three years old were considered 'outdated' although the material was still relevant. We have therefore refrained from mentioning any dates in lectures or on lecture slides.

### 1.4.3 Compatibility with CPD courses

Delivering TeachHy modules in CPD mode has shown that professionals will hardly ever follow a module (course) full time, but in practically all cases alongside daytime work obligations. Although the blended learning approach allows for free time management (apart from the fixed times for tutorials), outside participants find it difficult to follow the respective amount of learning material in the time of a week.

We have therefore chosen to separate university from CPD delivery, stretching the one-week university modules to three to four weeks in CPD mode. Apart from this, the teaching material is identical. Participants can obtain ECTS/UK credits on completion of the same assessment as university students, but will mostly choose not to.

## 2 Full implementation of TeachHy MSc programme

### 2.1 Student recruitment

After starting to actively advertise the MSc programme from May 2022, we received about 40 applications. Unfortunately we had to put them on hold until the UK Home Office issue around the on campus/DL delivery had been circumvented by creating the DL twin programme. This took until aug./Sept. 2022, so that we have to presume that a large number of students had moved on, as we only then were able to issue offer letters.

Out of the 40+ applications, 8 students accepted the offer, with one student of the 2021/22 cohort studying part-time, also joining. The academic year 2022/23 therefore started with 9 students, of which all remained on the programme up to taking their final research project.

In 2023 the number of applications has risen to 70+, though it is still too early to establish how many of these will in fact attend studies. This will only be clear on the first day of studies, 25 Sept 2023, unfortunately.

With application and admission numbers considerably on the rise for the third run in 2023/24, we are targeting a number of 15 to 25 students, which will then be the maximum capacity, seeing that all these students have to be equipped with a final research project. These projects are supervised by academics, PostDocs and PhD students and require considerable staff time, whilst due to the brevity of student engagement (10 to 12 weeks) not much output for publications can be expected. This is a decisive flaw in the UK system.

### 2.2 Implementation details

Flipped Classroom means that students receive the lecture material upfront of the interactions with the lecturers in order to prepare, read, and formulate any questions they might have. In-person lectures and tutorials are then located towards the end of the course and do not serve the purpose of transferring knowledge, but rather as Q&A sessions, exercises, and additional information events. In the context of the arrangements found at UBHAM for the Covid Years 2020 & 2021 this meant that students were given access to the online material one week ahead of the timetabled module ('Release Week'). The following week ('Support Week') opened with an Induction Tutorial on the Monday morning (in hybrid mode, i.e. in-person attendance with the option to participate online), followed by two online-only tutorials on Thursday and Friday morning, and two mainly in-person (hybrid if feasible) tutorials on the Thursday and Friday afternoons. This format has now been adopted for all TeachHy MSc modules at UBHAM.

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- visited all lecture pages, and
- completed all quizzes.

Originally, we also required a participation in the Discussion Board exchange (posting remarks, feedback, questions etc.) but as many students did not want to participate or had nothing to contribute, we dropped this requirement.

All module elements had to be in place by Release Week Monday. Where partner input was lacking at this point (or reasonably before), UBHAM existing material was inserted instead, thus allowing the students to complete their studies as planned. This concerned modules C1, C5, O2, and O3. Partners were of the opinion (though informed many times this was not so) that lectures would need to be delivered by the timetabled date, not noting the needs of online teaching which require considerable preparation well before due dates.

The programme is now fully implemented and tested. Any changes based on renewed student feedback will be implemented prior to the next delivery of the programme.

Table 1 shows the modules offered to the students in the academic year 2022/23. This in contrast to the 2021/22 delivery included a number of modules larger than 12, so that options were available for students to select specialisation modules.

The UBHAM implementation of the TeachHy programme is a 12-month degree programme, equivalent to 120 (UK) credits plus a final research project with thesis submission valued at 60 credits. This corresponds to a 90 ECTS programme in the EU. In contrast to most Continental universities who tend to spread the MSc programme over 18 to 24 months, the research project is included in the 12 months, running from June to August. Universities with 18 or more months programmes will have the research project run after the first year of studies, sometimes adding another semester of taught modules to expand to 24 months, which is considered beneficial for the student experience and the scientific depth of training at some universities.

Several modules are also open to other MSc programmes (most notably the Global Energy Technology and Systems, GETS) and Year 4 students (targetting an MEng degree). We therefore regularly have up to 100 students on the C2 module.

### 2.3 Transfer to other LMS

Within the reporting period 4, all material was transferred to UCTP/VSCHT and onto their Moodle LMS. The transfer is complete and the programme has been accredited. The time remaining in Autumn 2022, though, was insufficient to advertise for students, so that the programme will be initiated in Sept. 2023.

Further details are reported in Deliverable D6.1.

### 3 Summary Conclusions

The MSc programme has now been offered twice at UBHAM. The start was a bit rough, as the permission to go ahead came late (as reported in D3.3) so that advertising was very limited.

The 2<sup>nd</sup> run of the TeachHy MSc programme at UBHAM successfully started on 26 Sept 2022.

A number of updates were completed following the 1<sup>st</sup> (trial) run in the academic year 2021/22.

Ongoing module development work with project KICstartH2 and the JESS summer school is resulting in a large body of teaching material that is available to the partnering network. Elements will be expanded and added with every new academic year.