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MUSTANG

A Multiple Space and Time scale Approach for the quantification of deep saline formations for CO₂ storage

Project Number: 227286

Work-Package: WP10

**WP Title
Impact**

**Deliverable D105
Proceedings of the first annual workshop**

20th September 2010



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Status	(DRAFT,)
Version	1.00
Review level	(WP, PSC, EU, SIRAB, ALL)
Planned delivery date	Month 15
Actual delivery date	Month 16
Leading participant	AMPHOS 21
Contributing participants	CSIC UPPSALA UNIVERSITY

Dissemination Level

PU	Public	X
RE	Restricted to the consortium members, the SIRAB, the end-users and the EU officers	
CO	Confidential (only the consortium and the EU officers)	

Deliverable number	105
Deliverable name	Proceedings of the first annual workshop
Work-package	10
Lead participant	AMPHOS21

Version	Submitted by	Review level	Submitted	Reviewed
1.00	AMPHOS	WP, PSC, SIRAB, EU, ALL	1 ST September 2010	16 Sept. 2010
1.01	AMPHOS		20 Sept 2010	
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..				

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Executive summary	
<p>Within the framework of the MUSTANG project, the Institute of Environmental Assessment and Water Research (IDAEA-CSIC) and the Department of Geotechnical Engineering and Geosciences of the Technical University of Catalonia (UPC) organised a short training course on CODE_BRIGHT for CO₂ Sequestration Modelling. The course was held on 17th to 19th June 2010 at the Technical University of Catalonia, Barcelona.</p> <p>CODE_BRIGHT is a general-purpose finite element program developed by the UPC Department of Geotechnical Engineering and Geosciences for the analysis of coupled thermo-hydro-mechanical (THM) phenomena in geological media.</p> <p>The course provided contextual training on the use of CODE_BRIGHT to model and to simulate some phenomena related to CO₂ geological storage. It targeted both the partners currently involved in the research areas of MUSTANG and new members of the CCS community.</p>	
Keywords	Training course, CODE_BRIGHT, Modelling



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Table of contents

1. COURSE DESCRIPTION	7
1.1. TEACHING STAFF	7
1.2. ORGANISERS	8
1.3. PROGRAMME	8
2. PARTICIPANTS	9
3. EVALUATION.....	10



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List of Figures

FIGURE 1. PARTICIPANT'S TYPE OF ORGANISATION	10
FIGURE 2 PARTICIPANT'S FIELD OF EXPERIENCE	10
FIGURE 3 COMMUNICATION CHANNELS OF THE COURSE	12



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List of tables

TABLE 1. TEACHING STAFF	7
TABLE 2 COURSE PROGRAMME	8
TABLE 3. PARTICIPANT LIST	9



1. Course description

The first MUSTANG training course on The Use of CODE_BRIGHT for CO₂ Sequestration Modelling was held in Barcelona from 17th to 19th June 2010. This 3 day course was organised by the Institute of Environmental Assessment and Water Research (IDAEA-CSIC) and the Department of Geotechnical Engineering and Geosciences of the Technical University of Catalonia (UPC), in collaboration with Amphos 21

CODE_BRIGHT is a general-purpose finite element program developed by the UPC Department of Geotechnical Engineering and Geosciences for the analysis of coupled thermo-hydro-mechanical (THM) phenomena in geological media. Application fields cover geoenvironmental engineering (multi-barrier protection systems, radioactive waste disposal schemes, clay liners, two-phase liquid/gas flow, soil-atmosphere interaction) and geotechnical engineering (embankments, earthdams, expansive and collapsible soils, pavements, tunnels). CODE_BRIGHT has been extensively verified and validated in international benchmark exercises (EVEGAS, CATSIUS CLAY, C2S2).

The course aimed at providing contextual training on the use of CODE_BRIGHT to model and simulate some phenomena related to CO₂ geological storage (multiphase flow and transport with hydromechanical coupling) for the partners currently involved in the research areas of MUSTANG. In addition the course trained new members of the CCS community. The course illustrated the theoretical background, the numerical aspects, the details of problem solving and some examples of application.

The objectives of this short course were:

- Showing the capabilities and the numerical approach of CODE_BRIGHT.
- Developing simple tutorial examples in the context of CO₂ geological storage.
- Discussing the feasibility of extending some functionalities of CODE_BRIGHT to describe supercritical CO₂ storage.

1.1. Teaching Staff

Most of the course consisted of lectures and discussions in an informal classroom atmosphere at the technical University of Catalonia. The tutors of the course are directly or indirectly involved in MUSTANG and have an excellent scientific and technical knowledge of the subject. The list of tutors and organisations involved in the training course is shown in the table below.

Table 1. Teaching staff

Organisation	Country	Tutor/s
Technical University of Catalonia	Spain	Sebastià Olivella (SO)
IDAEA-CSIC	Spain	Víctor Vilarrasa (VV)
Technical University of Catalonia	Spain	Maarten W. Saaltink (MS)
IDAEA-CSIC	Spain	Orlando Silva (OS)
Technical University of Catalonia	Spain	Nuria González

1.2. Course organisation

The organisers of the course were the following organisations:

- Consejo Superior de Investigaciones Científicas (CSIC) (Partner nr. 4).
- Institute of Environmental Assessment and Water Research (IDAEA-CSIC).
- Technical University of Catalonia (UPC).
- Amphos 21 (Partner nr. 14).

The course was free of additional charges for Mustang members. For other people it was requested a fee of 500€ per person.

1.3. Programme

The three-day course combined theoretical presentations and practical exercises with the delivered tutorials. The contents of the course, the presentations, information on MUSTANG and related bibliography were distributed to the attendants in electronic and paper version. Annex 1 reports the presentations and the contents of the course.

The programme is shown below.

Table 2 Course programme

First day (17 th June 2010)			
9:30-10:00 h	Presentation		
10:00-10.45 h	Fundamentals, basic laws and state equations in CB	MS	
10.45-11:15 h	Coffee break		
11.15-12.15 h	Basic laws and state equations for CO ₂	OS	
12:15-13:00 h	Advective and non-advective fluxes. Multiphase flow and deformation. Two phase flow of water and CO ₂	VV	
13:00-13:30 h	General structure of CODE_BRIGTH and capabilities. Numerical approach	SO	
13:30-15:00 h	Lunch		
15:00-16:00 H	Tutorials. Processing. Tutorial example. User interface. Pre-processing and Post-processing (GiD)	All	
16:00-17:00 h	Tutorials. Linear problems. Heat and mass flow	All	
17:00-18:00 h	Tutorials. CO ₂ injection in a small sample	All	
Second day (18 th June 2010)			
9:30-10:15 h	Mechanical constitutive laws. Stress-strain relationships. Behaviour of unsaturated soils and rocks	NG	
10:15-10.45 h	Coffee break		
10.45-11:30	Stress-strain relationships	SO	

11:30-12:00 h	Boundary conditions. Constant flow and constant pressure	SO
12:00-12:30 h	Implementation of density and viscosity functions for CO ₂ . Verification	VV
12:30-13:00 h	CO ₂ injection in a deep saline aquifer including mechanical interactions	VV
13:00-15:00 h	Lunch	
15:00-16:00 h	Tutorial example for CO ₂ injection in situ	All
16:00-18:00 h	Other tutorial examples with CODE_BRIGHT	All
Third day (19th June 2010)		
9:30-11:00 h	Discussion of future developments	All
12:00 h	Closure	

2. Participants

The course was attended by 15 participants from different countries and types of organisations. The list of the participants is showed below.

Participant	Organisation	Country
Tobias Roetting	CSIC	Spain
Julia Riera	CSIC	Spain
Gaby Davila	CSIC	Spain
Jorge Jodar	CSIC	Spain
Jordi Escorcia	CSIC	Spain
Miguel Luna	Amphos	Spain
Joaquin Sala	Amphos	Spain
Anthony Credoza	Amphos	Spain
Paolo Trincherio	Amphos	Spain
Charlotte Garing	Montpellier	France
Linda Luquot	Montpellier	France
Liang Tiang	Uppsala University	Sweden
Dimittri Laurent	Geosciences Montpellier	
Kristina Rasmusson	Uppsala University	Sweden
Maria Rasmusson	Uppsala University	Sweden
Mohamed Kassab	Geosciences Montpellier	France
Manfred W. Wuttke	Leibniz Institute for Applied Geophysics (LIAG)	Germany
Albert Folch	UAB	Spain

Table 3. Participant list

The participants were members of universities (75%), consultancies (19%), and research institutes (6%), as shown in Figure 1.

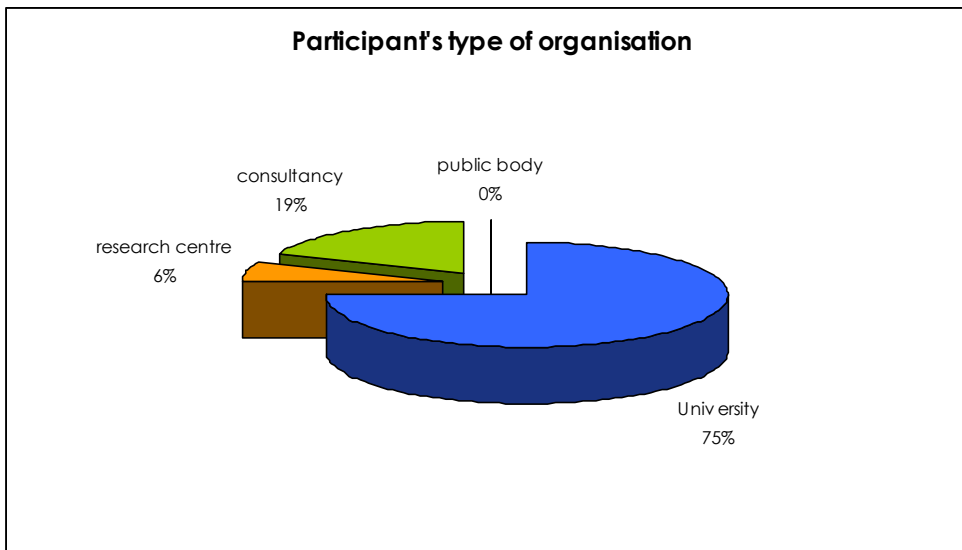


Figure 1. Participant's type of organisation

Most participants had an expertise domain in Hydrogeology (50%), but also in Numerical modelling (29%) and geochemistry (21%), as shown in Figure 2.

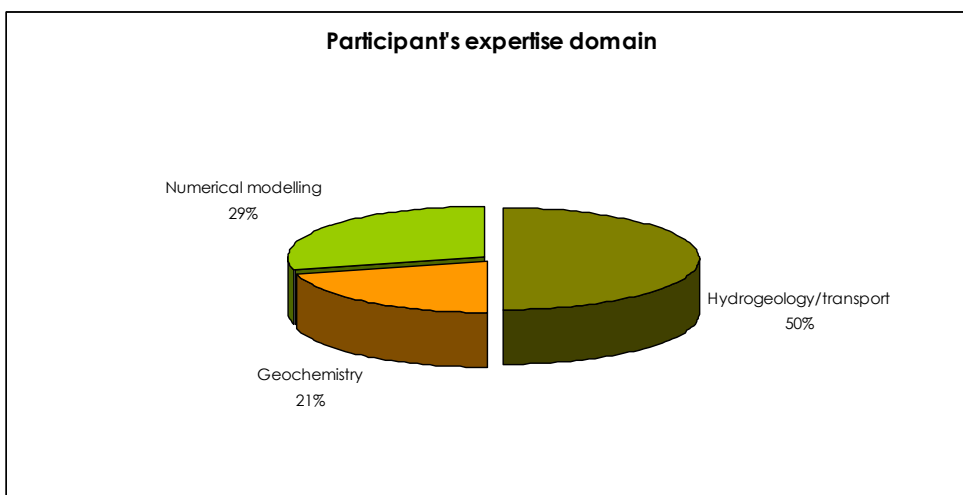


Figure 2 Participant's field of experience

3. Evaluation

At the end of the course the participants were required to fill in a feedback sheet (Annex 2) to evaluate all aspects of the course. In general, the structure of the course was considered of high quality and the topics chosen for the course were also evaluated to be of interest and relevant for the course. In general, the technical level of the course was positively evaluated and lecturers showed great expertise and competency.

A general opinion concerning the organization of the 1st MUSTANG training course (Figure 1) shows that **87 % of the participants** confirmed having received enough and adequate information concerning the arrival and the stay in Barcelona for the participation in the course, and that the course structure and practicalities were well organized.

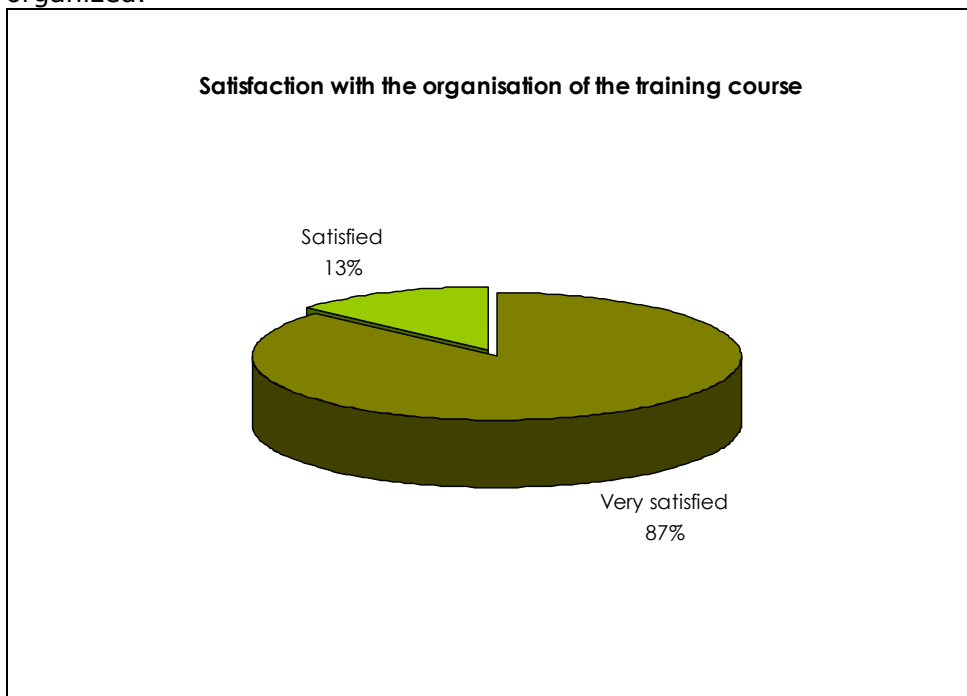


Figure 3 General opinion concerning the organisation

The participants were primarily informed about the existence of the course through the MUSTANG and UPC mailing lists, and also through the MUSTANG public website.

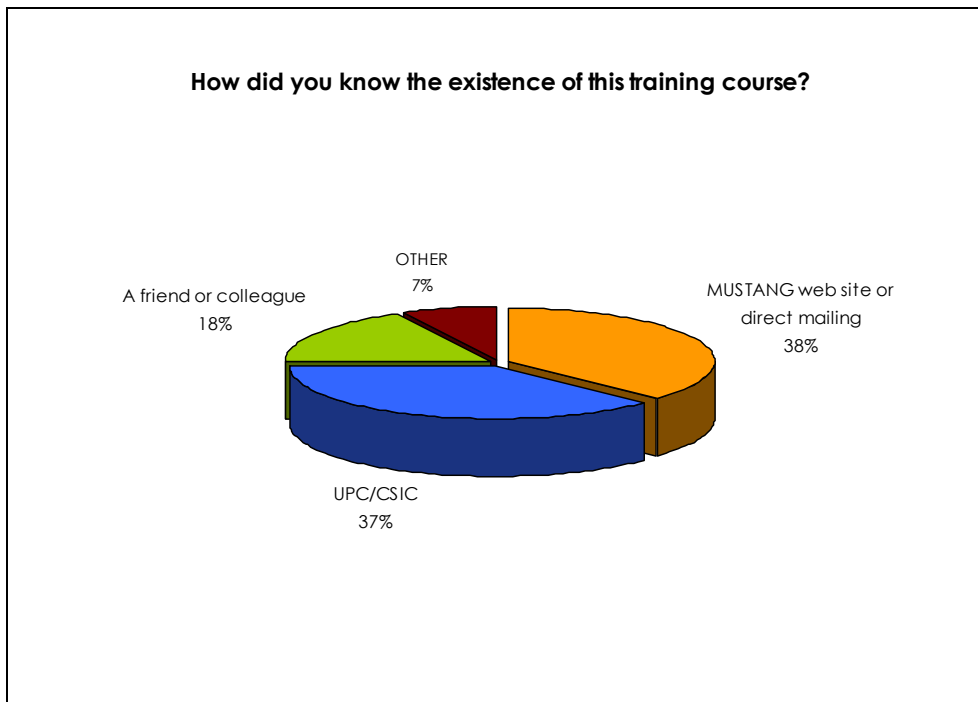


Figure 4 Communication channels of the course

The figure below shows the opinion of the attendants with relation to the scientific and technical knowledge of the course. It can be observed that 60% of the participants were very satisfied and 40% were satisfied with the course.

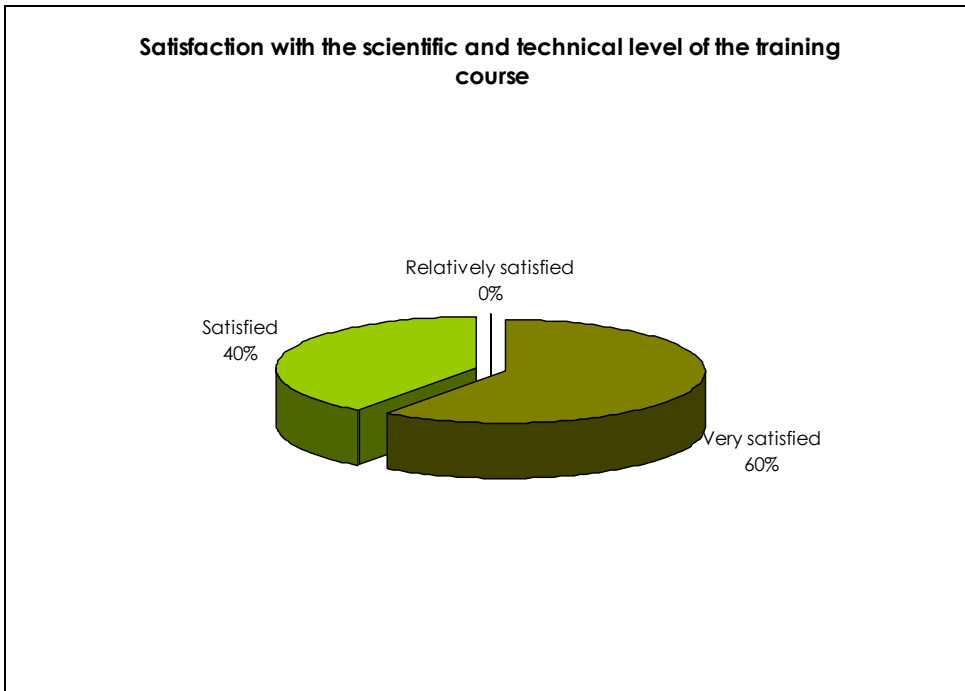


Figure 5 Evaluation by participants of the course’s scientific and technical level.

The participants were very satisfied (60%) and satisfied (40%) with the theoretical contents of the course. As regards the exercises, 79% of the participants declared to be very satisfied, 14% satisfied and 7% relatively satisfied. Some comments and suggestions of the attendants in order to improve further CODE_BRIGHT courses are reported in Annex 3.

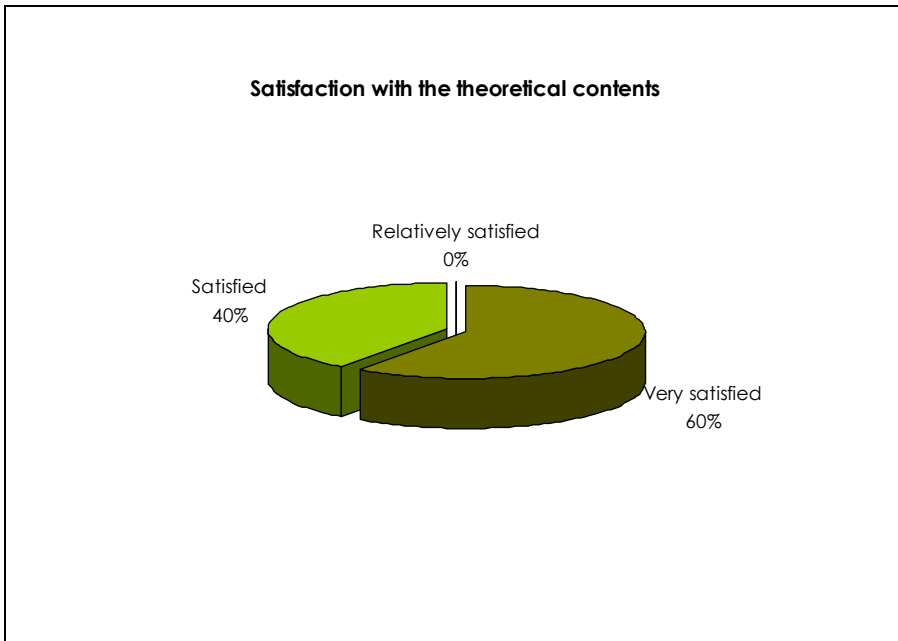


Figure 6 Level of satisfaction with the theoretical content

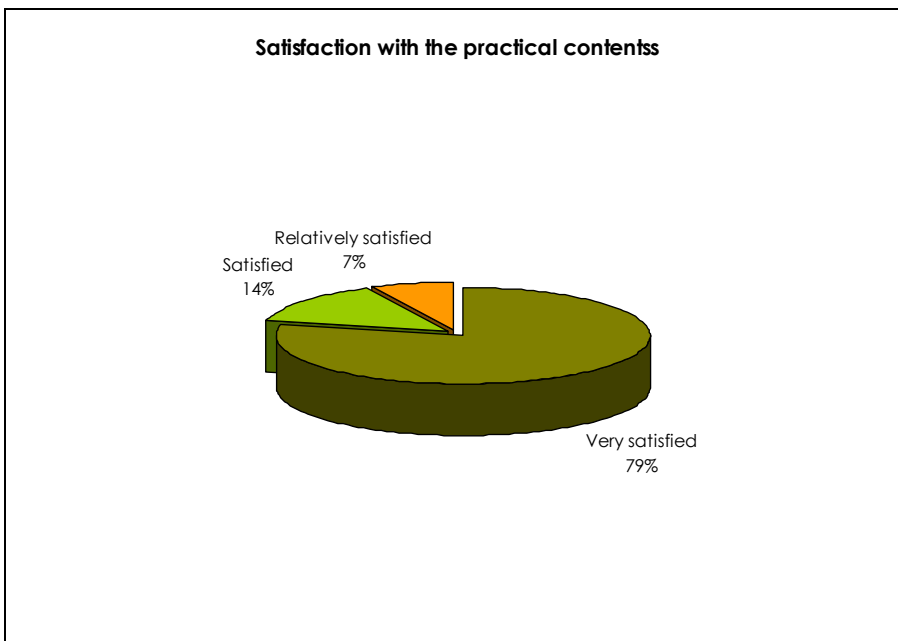


Figure 7 Level of satisfaction with the practical content

The course has facilitated interactions between participants and lecturers, as well as interactions among the participant (Figure 8 and Figure 9).

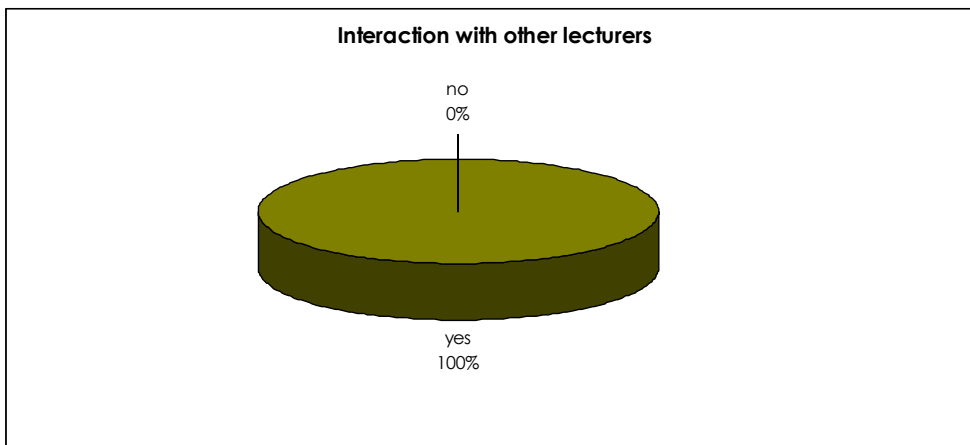


Figure 8. Percentage of assistants who think this course has facilitated interactions with lecturers

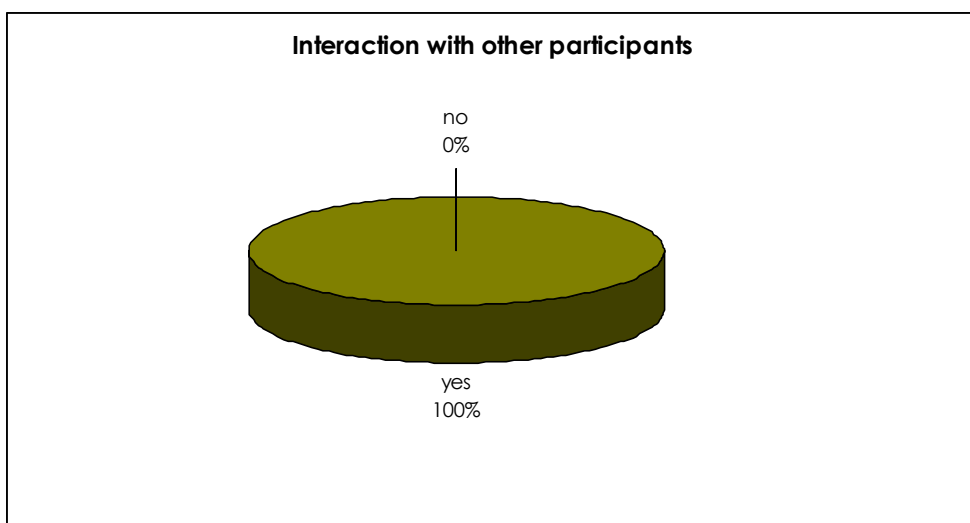


Figure 9 Percentage of assistants who think this course has facilitated interactions with other participants

Generally, the course was well balanced and highly informative. Overall, the training course was very positively evaluated and fulfilled the participant expectations. More than 80% of participants (14 out of 15) confirmed that they have achieved their expectations. The participant declaring that the course had not fulfilled his expectations explained that this was due to the fact that he was not working on CCS issues, so that he did not have precise expectations.

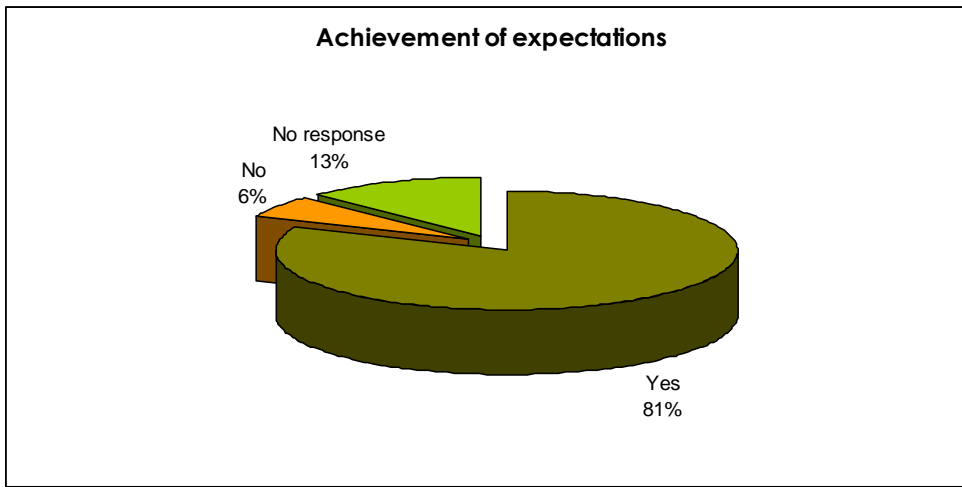


Figure 10. Achievements of expectations

Summarizing, the course has been addressed to the scientific community involved in modelling and simulation phenomena related to CO₂ geological storage. In general, the course was considered of good quality and has achieved the expectations of the attendants.

Most of the participants belong to organisations members of Mustang project. Although, the number of participants from different organisations was expected to be higher, however the final number of assistants was appropriate. Next editions of this course or other training workshops within Mustang project will enhance the impact of these events among the organisations involved in Mustang.