

4.3 Case study 3 (CS3 Greece)

Concept focus	Fuels – examples and criteria for identifying the “best” fuels The meaning of “best” can change depending on context
Activities implemented	Activities A-D
Inquiry skills	Developing hypotheses Planning investigations Forming coherent arguments Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (making comparison) Scientific literacy (understanding that the meaning of “best” can change depending on context; making informed choices)
Assessment methods	Classroom dialogue Teacher observation Peer-assessment Self-assessment Worksheets Presentations
Student group	Grade: lower second level Age: 14-15 years Group composition: mixed ability and gender; 21 students Prior experience with inquiry: No prior experience with inquiry. The teacher had experience in IBSE through SAILS TEP Cohort 3 and about 10 years experience in teaching.

In this *guided inquiry* the teacher adapted the tasks to fit with the state curriculum, with a focus on appreciating the use of different types of fuel for different purposes. All SAILS inquiry skills and competencies were assessed, with several assessment opportunities identified by the teacher. The teacher observed the students during the activities and gave feedback. The suggested rubrics were used to evaluate worksheets and the teacher developed a rubric for self-assessment of the *working collaboratively* skill.

(i) How was the learning sequence adapted?

For this implementation of the **Which is the best fuel?** SAILS unit, the teacher made some adaptations to the suggested activities in order to fit with the state curriculum and the background of the students at this level (lower second level). The case study as adapted and implemented by the teacher is related to the following objectives:

- Appreciating the different uses of different kinds of fuels in practice
- The meaning of “best” can change depending on the context, and that different factors can be considered in determining the best fuel
- Carrying out an experiment using simple measurements (temperature and time) in order to investigate the “best” fuel in the context of cooking.

The teacher started the lesson by showing a video in order to warm-up the class:


- Types of fuel: https://www.youtube.com/watch?v=ndc_JZpJeK0 (in English).

After a short discussion the teacher asked students to fill in the first worksheet, in order to help them recall previous knowledge (Figure 1). Then, the teacher announced to the students the problem of the investigation. Students were divided by the teacher into groups of 3-4 members of mixed skills level and mixed gender and the teacher described the steps of the research process. The research question, “Which fuel is best?” motivated students. There were a lot of discussions

between groups. The teacher gave each group different meanings of the "best" and encouraged students to discuss all the meanings. At the end he gave a second worksheet and asked all groups to fill in all the activities (Figure 2).

Worksheet 1: Which is the best fuel?

Remembering...



Activity 1

Video: https://www.youtube.com/watch?v=ndc_JZpJek0

You have just watched a video that presents various types of fuel. Try to write them down. Next to each fuel try to write its possible use.

Fuel	Use

Activity 2

Taking under consideration the previous activity, try to find other fossil fuels. With the help of your classmates, rank fuels based on their physical condition.

Solid	Liquid	Gas

Figure 1: Worksheet 1

[illegible]

Figure 3: Worksheet for experiment.

The groups carried out the experiments at home and they wrote their conclusions into the corresponding worksheet. The teacher asked all groups to present and discuss their findings in class during the next lesson. Most of the groups didn't change their initial hypothesis in their conclusions, however small enhancements were observed in their justifications.

Finally, the teacher proceeded to a conclusions phase, where students had to make connections to other real life situations. He gave two worksheets to students and asked them to work in groups. The first worksheet included three activities where the students were asked to observe five kinds of fuels and their characteristics (without knowing their names) and then they had to select the most suitable fuel for a city car, in a list in order of priority (worksheet 3, Figure 4). The students had to justify their answers. In the last activity, students were provided with the names of the fuels and asked again if they want to change the list of priority.

Worksheet 4: Which is the best fuel?

Comparing...



Activity

Suppose you want to install a heating system in your home. You have to choose between using three fuels: heating oil, natural gas and coal. In the table below you can see each one's characteristics.

	natural gas	heating oil	coal
calorific value	11.1 kWh/L	11,1 kWh/L	4.2 kWh/kg
cost	0.80 €/L	0.86 €/L	120 €/tonne
pollutants (mg/kwh)	particles: 9 NOx: 118 SO ₂ : 0,9 CO: 60	particles: 40 NOx: 286 SO ₂ : 786 CO: 57	particles: 1268 NOx: 116 SO ₂ : 17 CO: 500
flammability	Extremely flammable Risk of explosion	flammable	flammable
Storage/supply	Network of permanent supply	Qualified tank of several tonnes	Required storage space

1. Compare the above features and write what are, in your opinion, the advantages and disadvantages of each fuel.

	natural gas	heating oil	coal
advantages			
disadvantages			

2. Based on your previous answers what fuel will you choose? Are there any differences in your selection criteria in relation to the car? If yes, which ones?

.....

.....

.....

Figure 5: Worksheet 4

(ii) Which skills were to be assessed?

The skills assessed in this case study were *developing hypotheses*, *planning investigations* (to test a hypothesis), *forming coherent arguments*, *working collaboratively*, *scientific reasoning* (making comparisons), and *scientific literacy* (understanding that the meaning of “best” can change depending on context; making informed choices).

The teacher observed the students during the activities and gave feedback. The suggested rubrics were used on the written artefacts. The teacher used the suggested rubric of the unit with some adaptations to comply with the underlying scenario (Table 1). The teacher also developed a separate rubric for the self-assessment of the *working collaboratively* skill (Table 2). The teacher built all assessment instruments before the lessons.

Table 1: Assessment of skills developed in CS3 Greece

Skill	2 Acceptable	1 Needs improvement	0 Poor/NA
Developing hypotheses	Yes (no gaps)	Needs improvement (some gaps exist)	No
Testing a hypothesis	I was right	I edited it	I rejected it
Forming coherent arguments <i>Drawing appropriate conclusions</i>	Yes (no gaps)	Needs improvement (some gaps exist)	No
Forming coherent arguments <i>Support conclusions, using reasoned arguments & evidence</i>	Yes (no gaps)	Needs improvement (some gaps exist)	No
Making comparisons	The answer is correct (no gaps)	The answer needs improvement (some gaps exist)	The answer is irrelevant or incorrect
Understanding	The answer is correct (no gaps)	The answer needs improvement (some gaps exist)	The answer is irrelevant or incorrect

Table 2: Self-assessment of working collaboratively

Behaviour	3-always	2-sometimes	1-rarely
1. I actively participated in all discussions of the group			
2. In all discussions I took into consideration the views of all team members			
3. I helped in resolving disputes between team members			
4. I used convincing arguments to support my views			
5. I provided assistance in the team whenever needed			
6. I looked for information on the subject in all phases			
7. I completed without delay all the work undertaken to do in the team			

(iii) Criteria for judging assessment data

The teacher identified specific opportunities throughout the lessons, for evaluation of the chosen skills. Table 3 outlines the skills assessed, along with the underlying assessment context.

Table 3: Assessment opportunities identified for each skill

Skills	Assessment context
Developing hypotheses	Worksheet Let's Experiment! Activity 1: In your opinion which of the two fuels is more suitable for cooking? For what reason?
Testing a hypothesis (part of planning investigations)	Worksheet Let's Experiment! Activity 3: Based on your measurements – observations and experiences from step 2 – would you change the choice that you made in activity 1? What factors influence your decision?
Forming coherent arguments	Worksheet 3 Below we detail five kinds of fuel and their characteristics. Question 3: If you now know that A fuel is gasoline, B Diesel, the C Lignite, D natural gas and E LPG, how do you judge your previous choices based on your experience of everyday life? Worksheet 4 Suppose you want to install a heating system in your home .You have to choose between using three fuels: heating oil, natural gas and coal. In the table below you can see each one's characteristics. Question 2:Based on your previous answers what fuel will you choose? Are there any differences in your selection criteria in relation to the car? If yes, which ones?
Making comparisons (scientific reasoning)	Worksheet 3 Below we give you five kinds of fuel and their characteristics. Question 1: Based on the above characteristics select the most suitable fuel for a city car, in a list in order of priority. Justify your choice Worksheet 4 Suppose you want to install a heating system in your home .You have to choose between using three fuels: heating oil, natural gas and coal. In the table below you can see each one's characteristics. Question 1: Compare the above features and write what is, in your opinion, the advantages and disadvantages of each fuel.
Understanding (scientific literacy)	Worksheet Let's Experiment! Activity 1: In your opinion which of the two fuels is more suitable for cooking? For what reason?

(iv) Evidence collected

Teacher's opinion

The teacher reported that it was a successful experience and the students really enjoyed the inquiry lesson.

Sample student artefacts

The followings are samples of students' work that have been characterised by the teacher as good (Figure 6 to Figure 11).

Βίντεο
https://www.youtube.com/watch?v=ndc_JZpJcK0
Δραστηριότητα 1^η:
Μόλις παρακολούθησατε ένα βίντεο στο οποίο παρουσιάζονται διάφορα είδη καυσίμων. Προσπαθήστε να τα καταγράψετε. Δώστε από κάθε καύσιμο προσπαθήστε να γράψετε που μπορούμε να το χρησιμοποιήσουμε.

Καύσιμο	Χρήσιμότητα
Πετρέλαιο	Θέρμανση, κίνηση
Βενζίνη	αυτοκίνητα
βουτάνιο	γαστρο
μαζούτ	ναυτιλία
κηροζίνη	αεροπλάνα

Δραστηριότητα 2^η:
Λαμβάνοντας υπόψη την προηγούμενη δραστηριότητα, προσπαθήστε να βρείτε και άλλα ορυκτά καύσιμα. Στη συνέχεια με τη βοήθεια των συμμαθητών σας κατατάξτε τα καύσιμα με βάση τη φυσική τους κατάσταση.

Στερεά	Υγρά	Αέρια
λίγνιτς	βουτάνιο	φωσφο αέριο
άνθρακας	πετρέλαιο	προπάνιο
	μαζούτ	

Activity 1:

You have just watched a video that presents various types of fuel. Try to write them down. Next to each fuel try to write its possible use.

Fuel	Use
<i>Petroleum</i>	<i>Heating/transportation</i>
<i>Gasoline</i>	<i>Vehicles</i>
<i>Butane</i>	<i>Camping gas stove/cooking</i>
<i>Crude oil</i>	<i>Shipping</i>
<i>Kerosene</i>	<i>Aircrafts</i>

Activity 2:

Taking under consideration the previous activity, try to find other fossil fuels. With the help of your classmates, rank fuels based on their physical condition

Solid	Liquid	Gas
<i>Lignite</i>	<i>Petroleum</i>	<i>Natural gas</i>
<i>Coal</i>	<i>Crude oil</i>	<i>Propane</i>
<i>Butane</i>	<i>Butane</i>	

Figure 6: Example of worksheet 1, assessed as “good”.

Ας μελετήσουμε.....

Δραστηριότητα 1^η:

- 1) Γράψτε την αντίδραση της καύσης του μεθανίου
 $CH_4 + O_2 \rightarrow CO_2 + 2H_2O + \text{θερμότητα}$
- 2) Πότε η καύση χαρακτηρίζεται ως τέλεια και πότε ατελής;
τέλεια... με αρκετό O_2 ατελής... με λίγο O_2
- 3) Τι μορφή ενέργειας παράγεται κατά την καύση;
θερμότητα (αυτή είναι η αιτία που χρησιμοποιούμε την ενέργεια που προκύπτει από την καύση υδρογονανθράκων)
- 4) Ποιες εφαρμογές από την καθημερινή ζωή γνωρίζετε, στις οποίες χρησιμοποιούμε την ενέργεια που προκύπτει από την καύση υδρογονανθράκων;
παραγωγή ηλεκτρικού ρεύματος, κίνηση αυτοκινήτων, μαγειρεύοντας

Δραστηριότητα 2^η:

Η καύση των υδρογονανθράκων σε πραγματικές συνθήκες, είναι ατελής. Η παρακάτω εξίσωση περιγράφει ποιοτικά τα παράγωγα της ατελούς καύσης:

καύσιμο + αέρας $\xrightarrow{\text{πραγματικές συνθήκες}}$ $CO_2, N_2, H_2O, SO_2, NO, NO_2, CO, HC, O_2$ + καυματοί (αθάλη) + θερμότητα

- 1) Ποιους ρύπους αναγνωρίζετε στα προϊόντα της καύσης και ποια είναι η επίδρασή τους στη ρύπανση της ατμόσφαιρας;
 $CO_2 \rightarrow$ Αιτία για το φαινόμενο του θερμοκηπίου
 $NO, NO_2 \rightarrow$ αιτία οξέων βροχής, φωτοχημικά βρώμικα
 $SO_2 \rightarrow$ αιτία βροχής οξέος
 $CO \rightarrow$ πολύ δηλητηριώδες

Activity 1

1) Write the reaction of combustion of methane
 $CH_4 + O_2 \Rightarrow CO_2 + 2H_2O + \text{heat}$

2) When is combustion characterised as complete, and when as incomplete?
Complete: reaction with sufficient amount of oxygen - **Incomplete:** reaction with inadequate quantity of oxygen

3) What form of energy is produced during combustion?
Heat

4) Which applications from everyday life do you know, where we use the energy derived from burning hydrocarbons?
Transportation (cars, airplanes, ships, trains) Energy-electricity production, heating, cooking

Activity 2

Q1: Which pollutants do you recognise among the products of combustion and what is their effect on air pollution?
 $CO_2 \Rightarrow$ pollute the atmosphere, green house effect; $NO, NO_2 \Rightarrow$ acid rain, photochemical smog; $CO_2 \Rightarrow$ acid rain; $CO \Rightarrow$ very poisonous

Δραστηριότητα 3^η:

«Σημείο ανάφλεξης ονομάζεται η θερμοκρασία στην οποία ένα καύσιμο υγρό πρέπει να θερμανθεί για να παραχθεί ατμό, ο οποίος αναφλέγεται όταν έλθει σε επαφή με γυμνή φλόγα ή σπινθήρα. Το σημείο ανάφλεξης αποτελεί την ένδειξη για τη θερμοκρασία κάτω από την οποία ένα προϊόν μπορεί να διακινηθεί χωρίς κίνδυνο να αναφλεγεί.» (πηγή Βικιπαίδεια).

- 1) Ποιοι κίνδυνοι γνωρίζετε ότι υπάρχουν κατά τη μεταφορά και τη φύλαξη των υγρών και αέριων καυσίμων;
 Ρίσκο πυρκαγιάς
 Ρίσκο έκρηξης
 Κίνδυνος αερίων που είναι πολύ τοξικά
- 2) Αναφέρετε με ποιους τρόπους θα μπορούσαμε να περιορίσουμε τους κινδύνους αυτούς.
 Η μεταφορά των καυσίμων πρέπει να γίνεται μόνο με ειδικά μέσα και μόνο σε ειδικά κατασκευασμένα δοχεία.
 Η αποθήκευση μόνο σε κατάλληλες θέσεις με σωστά θερμοκρασία και πίεση

Activity 2:

2) Which ways do you know, or can you propose, to reduce air pollution from fuel emissions?
Changes and improvement of car engine operation, Improvements of used fuels, Use of renewable energy sources, electric cars, stop using cars without a serious reason

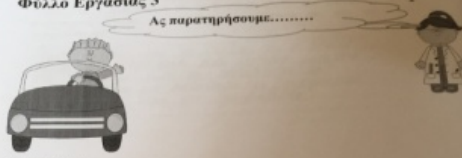
Activity 3:

1) What kind of risks may occur during transport and storage of liquid and gas fuels?
Risk of fire, Risk of explosion, Risk of respiratory problems

2) Indicate in what ways we could reduce these risks.
Transportation of fuels should be done only by specialized vehicles or ships and only in suitable containers. Storage only in appropriate tanks with temperature and pressure safety equipment.

Figure 7: Example of worksheet 2, assessed as “good”.

Φύλλο Εργασίας 3
Ας παρατηρήσουμε.....



Δραστηριότητα:
Στην παραπάνω εικόνα βλέπουμε ένα αυτοκίνητο πόλης. Τα αυτοκίνητα χρησιμοποιούν καύσιμα για τη μετακίνησή τους. Παρακάτω σας δίνουμε 5 είδη καυσίμων με τα χαρακτηριστικά τους.

Καύσιμο	Φυσική κατάσταση	Θερμότητα ανά λίτρο	Ρύποι (mg/Kwh)					Κόστος
			ΣΟΜΑΤΩΔΙΑ	NOx	SO2	CO	CO2	
A	Υγρό	9,4 KWh/l	1,5	107	214	57	247.500	1,3 €/l
B	Υγρό	11,1 KWh/l	40	286	786	57	264.643	1,11 €/l
Γ	Στερεό	4,71 KWh/Kg	3446	1196	2309	43	361429	0,013 €/Kg
Δ	αέριο	10 KWh/m ³	9	118	0,9	60	200357	0,8 €/m ³
Ε	Υγρό	6,9 KWh/l	10	116	0,9	60	201789	0,715 €/l

1) Με βάση τα παραπάνω χαρακτηριστικά επιλέξτε το κατάλληλότερο καύσιμο για το αυτοκίνητο πόλης σε λίστα με σειρά προτεραιότητας.

1. A
2. B
3. E
4. D
5. C

2) Δικαιολογήστε την επιλογή σας:

1) A => μικρό όγκο καυσίμου, μέση ρύπων, μέση τιμή
2) B => μικρό όγκο καυσίμου, μέση ρύπων, μέση τιμή
3) E => μικρό όγκο καυσίμου, μέση ρύπων, μέση τιμή
4) D => αέριο καύσιμο, μέση ρύπων, μέση τιμή
5) C => στερεό καύσιμο, μέση ρύπων, μέση τιμή

Worksheet 3

Activity 1: In the picture above, we see a city car. The cars use fuel for their movement. Below we give you five kinds of fuel and their characteristics...

1. Based on the above characteristics select the most suitable fuel for a city car, in a list in order of priority

- 1) **A**
- 2) **B**
- 3) **E**
- 4) **D**
- 5) **C**

2. Justify your choice

A=>high calorific value, average pollutants, high cost, B=>higher calorific value and lower cost but much more pollutants, E=>low cost, low pollutants but lower calorific value than A and B, D=>gas fuel, not appropriate for car, E=>solid fuel, impossible use for car

Ποιο είναι το καλύτερο καύσιμο

3) Αν τώρα γνωρίζατε ότι το καύσιμο A είναι Βενζίνη, το B Diesel κίνησης, το Γ Λιγνίτης, το Δ φυσικό αέριο και το Ε Υγραέριο/LPG, πως κρίνετε τις προηγούμενες επιλογές σας με βάση την εμπειρία σας από την καθημερινότητα;

2

Προτιμάω... το A... γιατί είναι... το πιο κοινό καύσιμο... το B... γιατί είναι... το πιο κοινό καύσιμο... το C... γιατί είναι... το πιο κοινό καύσιμο... το D... γιατί είναι... το πιο κοινό καύσιμο... το E... γιατί είναι... το πιο κοινό καύσιμο...

Figure 8: Example of worksheet 3, assessed as “good”.

<p>Ας πειραματιστούμε!</p> <p>Θα συγκρίνουμε στη πράξη την απόδοση του βουτανίου και του κάρβουνου στο μαγείρεμα. Πρώτα, θα μετρήσουμε το χρόνο βρασμού συγκεκριμένης ποσότητας νερού χρησιμοποιώντας τα δύο καύσιμα και ύστερα θα ψήσουμε την ίδια ποσότητα κρέατος.</p> <p><u>Δραστηριότητα 1η</u></p> <p>Κατά τη γνώμη σας ποιο από τα δύο καύσιμα είναι πιο ιδανικό για μαγείρεμα; Για ποιο λόγο;</p> <p><i>Κατά τη γνώμη μου, καλύτερο καύσιμο είναι το βούτανο επειδή έχει μεγαλύτερη θερμότητα ανά μονάδα και είναι σχετικά οικονομικό. Επίσης είναι αρκετά πιο εύκολο από το κάρβουνο να ξεχειμασθεί τσάνες παξιμάδων αναμειγμένο.</i></p>	<p>We will compare in practice the performance of butane and charcoal for cooking applications...</p> <p><u>Activity 1</u> In your opinion which of the two fuels is more suitable for cooking? For what reason?</p> <p><i>In our opinion the best fuel is butane because it has higher calorific value than charcoal. Also, butane hasn't high cost and we think it is more usable than charcoal. Charcoal causes many fumes.</i></p>
<p><u>Δραστηριότητα 3η – Συμπεράσματα</u></p> <p>Σύμφωνα με τις μετρήσεις, τις παρατηρήσεις και τις εμπειρίες σας από τη 2η δραστηριότητα, θα αλλάζατε την επιλογή που κάνατε στην πρώτη δραστηριότητα; Ποια γεγονότα επηρέασαν την επιλογή σας;</p> <p><i>Αν θα άλλαζα την αρχική μου πρόταση για το βούτανο βέβαια στη πράξη παρατηρήσαμε ότι το φούσκι στο κάρβουνο κάνει το γυρίδι πιο εύκολο, γεγονός που θα μπορούσε να επηρεάσει την απόφαση και γυρίσις, αν οι συνθήκες επιβάλουν το αντίθετο.</i></p>	<p>Testing hypothesis</p> <p>In your opinion which of the two fuels is more suitable for cooking? For what reason?</p> <p><i>We wouldn't change our initial opinion about butane. In practice we observe that cooking when we use charcoal gives better taste but the critical factor for our decision is the conditions under which we can use it.</i></p>

Figure 10: Example of experiment worksheet, assessed as “good”.

<p>Ας πειραματιστούμε!</p> <p>Θα συγκρίνουμε στη πράξη την απόδοση του βουτανίου και του κάρβουνου στο μαγείρεμα. Πρώτα, θα μετρήσουμε το χρόνο βρασμού συγκεκριμένης ποσότητας νερού χρησιμοποιώντας τα δύο καύσιμα και ύστερα θα ψήσουμε την ίδια ποσότητα κρέατος.</p> <p><u>Δραστηριότητα 1η</u></p> <p>Κατά τη γνώμη σας ποιο από τα δύο καύσιμα είναι πιο ιδανικό για μαγείρεμα; Για ποιο λόγο;</p> <p><i>Διότι το κάρβουνο γιατί είναι το καλύτερο καύσιμο και το βούτανο μπορεί να εκραγεί.</i></p>	<p>We will compare in practice the performance of butane and charcoal for cooking applications...</p> <p><u>Activity 1</u> In your opinion which of the two fuels is more suitable for cooking? For what reason?</p> <p><i>We choose the charcoal because we know that gives food a better taste while the butane can be exploded</i></p>
<p><u>Δραστηριότητα 3η – Συμπεράσματα</u></p> <p>Σύμφωνα με τις μετρήσεις, τις παρατηρήσεις και τις εμπειρίες σας από τη 2η δραστηριότητα, θα αλλάζατε την επιλογή που κάνατε στην πρώτη δραστηριότητα; Ποια γεγονότα επηρέασαν την επιλογή σας;</p> <p><i>Το βούτανο βράζει ταχύτερα πιο γρήγορα και δεν έχει τόσο καπνό, αλλά το κάρβουνο είναι καλύτερο.</i></p>	<p>Testing hypothesis</p> <p>In your opinion which of the two fuels is more suitable for cooking? For what reason?</p> <p><i>The butane boils the water faster and there are not so much fumes, however we believe the charcoal is better fuel for cooking.</i></p>

Figure 11: Example of experiment worksheet, assessed as “good”.

(v) Use of assessment data

The teacher was completely satisfied with the inquiry lesson. After completion of the lesson, he discussed it with the students and they had very positive comments. The students responded that they feel they had deeper understanding on the specific subject; they appreciated the real life experience in order to understand that the meaning of “best” depends on the context; they also understood the difficulties in doing real life experiments. Finally, they learned how to formulate reasoned arguments and they appreciated the collaborative work. The teacher will try more inquiry lessons in the future, but he believes inquiry lessons need more time to complete and there is a need for changes to the time schedule of the underlying curricula in order to give more time for inquiry lessons.

(vi) Advice for teachers implementing this unit

A new teacher must have practice in IBSE before any implementation in class. Especially, teachers need to be well prepared to achieve the assessment of inquiry skills. The existence of units such as SAILS units is very useful.