GAIA - Green Awareness In Action

GAIA

D1.2 – Final Pedagogical and Education Design

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Abbreviations

Abbreviation	Expression
BMS	Building Management System
DoW	Description of Work
EC	European Commission
EPB	Ethics and Privacy Board
GA	General Assembly
IoT	Internet of Things
IPR	Intellectual Properties Rights
KPI	Key Performance Indicator
PhC	Phone Conference
PIR	Passive InfraRed (sensor)
PM	Person Months
RoI	Return of Investment
SC	Steering Committee
TC	Technical Committee
TCB	Trials Coordination Board

Table of contents

Executive summary

The present document constitutes deliverable D1.2 'Final Pedagogical and Education Design' of the GAIA project (http://gaia-project.eu), a European research and innovation action aiming to improve energy efficiency in school buildings. This deliverable presents the outcome of the effort invested by the GAIA consortium of the GAIA since the very early stages of the work and up to the end of the second project year for the development of the pedagogical approach and educational design, i.e. the major methodological element of the project that complements its technological outputs.

The pedagogical approach and educational design in GAIA is the place where the technologies developed meet with their users in the school communities. The aim is to provide an educational vision and concrete methodology that will allow the use of the GAIA tools for the realization of interventions in schools which will: a) raise awareness of the need to save energy and of ways in which this can be achieved in everyday life, primarily among the users of school buildings (students, educators, other staff), and through them, indirectly, their wider communities (families, local communities); and, b) encourage the development of behaviors in users' everyday life, which can contribute to increased energy efficiency in the school building.

The pedagogical work presented in this deliverable has been systematically informed by the design and development of the overall GAIA solution and its technological components (WP1, WP2, WP3). In parallel, it has been carried out in synergy with the work conducted in WP4 for the development of a community of schools and educators around the project, and the design, preparation and realization of pilot activities involving the participating school communities.

Thus, the content of this deliverable is the result of a strongly collaborative and co-creative process of continuous design, development and refinement of educational activities and materials within the consortium and together with the school communities participating in the pilot activities of the project. This process remains open up to the end of the project, i.e. beyond the time of delivering the present text. An updated picture of more specific educational designs and materials emerging in the course of the ongoing field work and synergies with school communities will be available in the Resources/Educational material section of the project website.

1. Introduction - Deliverable context and structure

This deliverable presents the outcome of the effort invested by the consortium of the GAIA project (http://gaia-project.eu) since the very early stages of the work and up to the end of the second project year for the development of the pedagogical approach and educational design, i.e. the major methodological element of the project that complements its technological outputs.

The pedagogical approach and educational design in GAIA is the place where the technologies developed meet with their users in the school communities. The aim is to provide an educational vision and concrete methodology that will allow the use of the GAIA tools for the realization of interventions in schools which will: a) raise awareness of the need to save energy and of ways in which this can be achieved in everyday life, primarily among the users of school buildings (students, educators, other staff), and through them, indirectly, their wider communities (families, local communities); and, b) encourage the development of behaviors in users' everyday life, which can contribute to increased energy efficiency in the school building.

The pedagogical work presented in this deliverable has been systematically informed by the design and development of the overall GAIA solution and its technological components, as these are presented in deliverables D1.1 'GAIA Design', D2.1 'Initial Infrastructure Software', D2.2 'Final Infrastructure Software', D3.1 'Applications Prototypes', D3.2 "Applications Initial Release"; and D3.3 'Applications Final Release'. In parallel, it has been carried out in synergy with the work conducted in WP4 for the development of a community of schools and educators around the project, and the design, preparation and realization of pilot activities involving the participating school communities (cf. deliverables D4.1 'Initial Trial Documentation', D4.2 'Final Trial Documentation', as well as the final picture and synthesis that will become available by the end of the project in deliverable D4.3 'Trial & Educational Evaluation'.

Thus, the content of this deliverable is the result of a strongly collaborative and co-creative process of continuous design, development and refinement of educational activities and materials within the consortium and together with the school communities participating in the pilot activities of the project. This process remains open up to the end of the project, i.e. beyond the time of delivering the present text. An updated picture of more specific educational designs and materials emerging in the course of the ongoing field work and synergies with school communities will be available in the Resources/Educational material section of the project website.

The document consists of the following parts:

- Section 1 (the present section) provides the general introduction to the deliverable and its structure
- Section 2 describes in detail the pedagogical approach and educational design underlying school community activities in GAIA. This includes information on the aims and approach, the educational scenarios, and the processes of co-design together with the school communities.
- Section 3 takes the next step after the previous section towards practice, proposing ways of applying the core educational scenario of GAIA in the course of a school year, with details of an overall schedule and the distribution of the relevant activities in cycles
- Section 4 then focuses in particular on the rationale behind the activities involving the use the GAIA Educational Lab Kit, and ideas and guidance for the implementation of such activities in schools.
- Section 5, finally, puts the parts together into an overarching unified picture of GAIA activities in schools and how they match with the technological components of the GAIA solution.

The document also includes the following Annexes:

- Annex I – Templates for monitoring the educational settings and circumstances in the pilot sites
- Annex II – Gamified learning content for the GAIA challenge
- Annex III – Examples of adapted context-specific educational scenarios
- Annex IV – Sample material for GAIA educational activities.

2. Pedagogical design of educational activities in GAIA

2.1 The learning aims and educational approach

The overall learning aim of the GAIA project (http://gaia-project.eu) is to utilize the solution produced by the project[1] in order to:

● Raise awareness of the need to save energy and of ways in which this can be achieved in everyday life, primarily among the users of school buildings (students, educators, other staff), and through them, indirectly, their wider communities (families, local communities); and,
● Encourage the development of behaviors in users' everyday life, which can contribute to increased energy efficiency in the school building.

To achieve this aim, the project designs and implements educational activities in the pilot sites[2] which go far beyond merely informing the target audiences about energy efficiency. Indeed, the educational activities utilize the technological and methodological outputs of the GAIA project to turn students, their teachers, and those acting as the building managers of the schools into active agents collaborating with each other to monitor and shape energy use in the school. In this way, the project hopes to:

● Cognitively, emotionally and socially engage users of the school building deeply with the goal of energy efficiency, and
● Encourage them to experiment with, and adopt, behaviors that they have themselves experienced as proven effective ways to achieve the goal of saving energy without compromising school life quality – and that, following their decision and will rather than being instructed to do so by an external authority.

2.1.1 The core of the activities: within the school community

The core of the educational intervention takes place within the school, engaging the whole school community, and aspires to improve energy- related behavior in the school building. To this end, students and school staff in the pilot sites are motivated and facilitated to:

● Closely monitor and understand various aspects of their own and others' habits and behaviors that affect the use of energy in their school building
● Based on this, make informed decisions to take action in order to increase energy efficiency, by changing their habits and behaviors, and
● Observe and analyze the impact of their action in terms of saving energy as well as in terms of comfort, functionality, and avoidance of disruption of school life.

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[1] Detailed information on the GAIA solution can be found in the design deliverable (D1.1), in the deliverables on the infrastructure (D2.1, D2.2) and in the deliverables on the applications (D3.1, D3.2, and D3.3). All project deliverables are available at http://gaia-project.eu/index.php/en/resources/deliverables.

[2] Details on the pilot activities of the project can be found in deliverables D4.1 and D4.2, available at http://gaia-project.eu/index.php/en/resources/deliverables.

While the educational activities address and involve school staff too, including building managers, the focus lies heavily on the students' own personal engagement with the goal and process of the efforts for energy efficiency, with rich guidance and help from the teacher, so as to maximize the chances for true long-lasting impact.
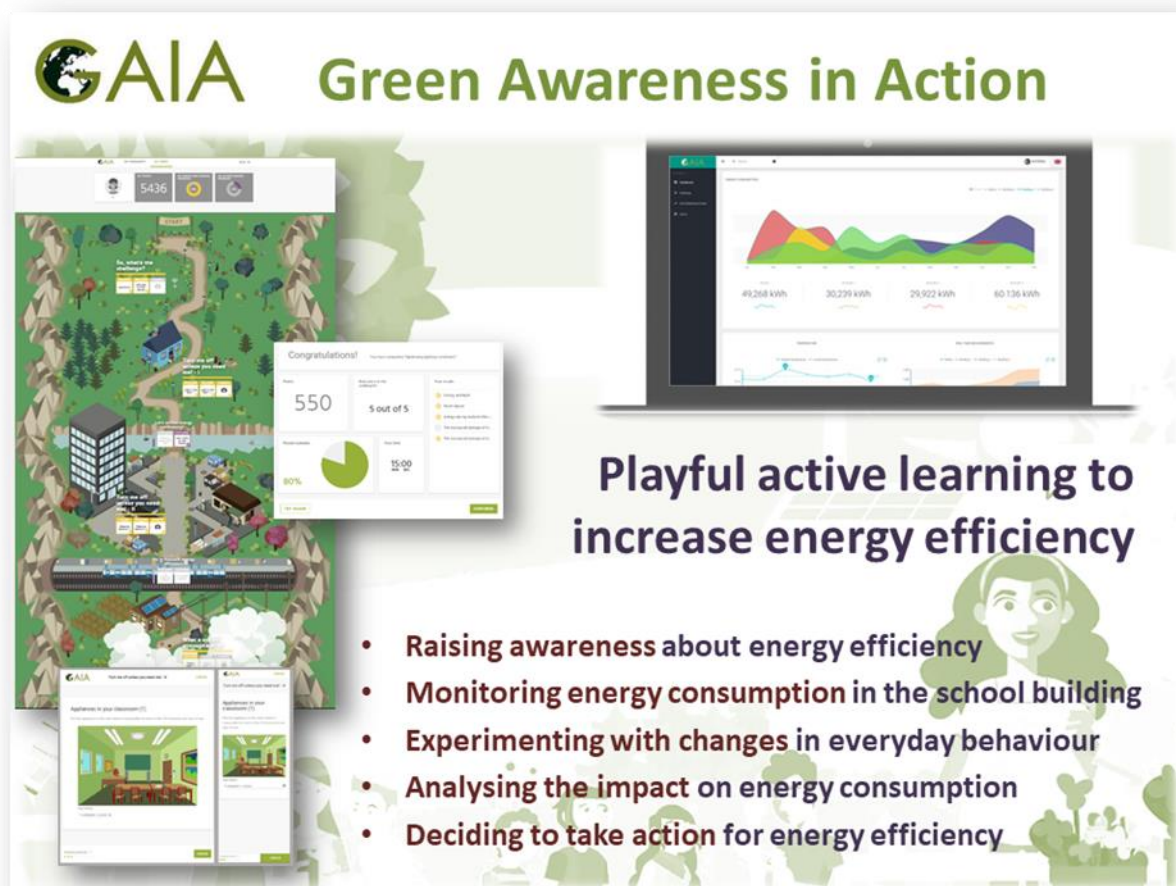
Figure 1: GAIA educational activities in a snapshot

2.1.2 Outward-looking activities: informing and engaging the community

The above core educational activities are complemented by outward-looking initiatives, aiming to spread the word for energy efficiency in the local community, involving students' families and local communities in awareness raising activities and encouraging the emergence of local initiatives informed and inspired by the mobilization of the school community for energy efficiency and its relevant experiences and achievements.

2.2 Educational scenarios in GAIA

In order to define the envisioned educational activities in detail and introduce them to the school communities, the project produces educational scenarios. The scenarios constitute activity plans and guidance describing educationally meaningful ways to use the technologies offered by GAIA in the context of the different educational realities addressed by the project.

2.2.1 The need for flexibility and adaptability

It is important to note that these educational realities are not homogeneous, nor unchangeable in the course of the three-year project. The pedagogical and educational design presented in this document is founded on a meticulous and continuous monitoring of the various and variable educational settings and circumstances that the project is addressing in its pilot sites. Templates developed and used for the collection and organization of this information are presented in Annex I. A good insight into the variety of the educational field of GAIA can be gained through the Activity Plans of the participating schools included in deliverable D4.2, and more generally in the documentation of the project trials (deliverables D4.1 and D4.2).

Thus, the educational contexts in GAIA include very diverse primary, secondary and tertiary education settings in three different countries: Greece, Italy, and Sweden. They also comprise different student age groups, school communities of different sizes and from diverse socioeconomic, cultural and geographical settings, and, in some cases, schools in which members of teaching staff are likely to change in the duration of the three-year project.

At the same time, the solution offered by GAIA consists of a number of technological possibilities, which are available for users to select and match with their own needs and circumstances, depending on the characteristics of the school building, its geographical location, and the patterns of its use.

What is more, the GAIA project sets ambitious educational aims going far beyond raising awareness among users of the school buildings. To hope to contribute towards behavior change fostering energy efficiency, the project needs to find ways to truly motivate and deeply engage students and teachers in 'energy efficiency missions' that will be relevant to them and their everyday life, and that will be 'owned' by them rather than externally imposed to them.

For these reasons, the educational scenarios offered by GAIA to the school communities are indicative of possibilities and options rather than prescriptive, constituting an open flexible framework enabling an array of educational activities. They constitute a starting point for school communities to design and enact concrete activities that are relevant to their own circumstances and meaningful to their members, as well as applicable and realizable in their own everyday educational realities. By entrusting the 'ownership' of the educational interventions with the school community, the project puts the goal of improved energy efficiency in the school building on the desks and in the hands of students and school staff, as part of their own everyday life in the school.

2.2.2 The generic core educational scenario

The generic core educational scenario is the basic description of all those necessary elements that each educational intervention in GAIA should include, and of all those open options for teachers to consider and decide how to handle based on the interests, priorities and realities in their own teaching context.

Using the generic core educational scenario as their framework and guidance, teachers can generate their own context-specific scenarios of practice. The elements of the generic core educational scenario are summarized in Table 1 below and described in the subsequent sections.

Table 1: Required, desired and optional elements of the generic core educational scenario

Required	Strongly desired	Options available
Use of GAIA technologies	● Cycles of collaborative active learning	● Steps in the learning path ● Time frame

	Educational work with data from the school buildings A playful spirit in the educational activities	Levels of social engagement Adjustment to local educational characteristics Thematic coverage Educational projects and wider-frame narratives

Table 2: Educational uses of GAIA applications

The GAIA Building Manager Application:	● Provides users with access to data which is collected through various meters and sensors monitoring energy consumption and environmental conditions in the school building: ➔ Electricity consumption in the whole building and/or parts of it ➔ Temperature, humidity, luminosity, noise levels, presence/movement, in each space where relevant equipment has been installed ➔ Weather conditions in the area of the school. ● Allows users to insert their own measurements of energy consumption and/or environmental conditions, e.g.: ➔ Fuel purchased for heating ➔ Readings from the power meter ➔ Conditions and levels of comfort in a certain part of the building, etc.
The GAIA Challenge:	● Raises awareness and playfully sustains students' interest in, and engagement with, longer-term educational activities, through: ➔ Knowledge missions, i.e. knowledge quizzes related to energy efficiency ➔ Action missions, i.e. playful sparking of student action in the school building aiming to increase energy efficiency ➔ School-safe, energy-efficiency-centered social networking among students, and competition among student groups.
The GAIA Community Engagement Game:	● Raise awareness and playfully sustain students' as well as the wider community's interest in, and engagement with, project activities, through weekly GAIA Scavenger Hunt hashtag games implemented in popular social media.

Required: use of GAIA technologies

A compulsory element of educational activity in GAIA is to include the use of an appropriate set of the technologies comprising the GAIA solution, in educationally meaningful ways to achieve the educational aims of the project. The generic core scenario, as well as all context-specific scenarios of practice derived

from it, guides students, teachers and/or building managers to use all, or a selection of, the digital applications[3] offered by GAIA, as summarized in Table 2 above.

Strongly desired: cycles of collaborative active learning

Preferably, learning in GAIA activities is predominantly collaborative, realized through student teamwork, students' guidance and facilitation by their teachers, and students' and/or teachers' collaboration and interaction with the building manager and/or other school staff of community members, where and as applicable.

While there is flexibility with respect to the length and timing of the various activities (discussed further below), the 'big picture' of learning in GAIA incudes consecutive cycles. These cycles start from getting information about the facts of energy efficiency, moving to engaging in practical activities in order to gather energy-efficiency related data and experiences, and, eventually, to reflecting on the experiences, discussing the results, drawing conclusions, making decisions. Going through the stages of this process, learners gradually go deeper into understanding energy efficiency and draw closer to adopting the desired change in their everyday habits and behaviors.

Figure 2: Cycles of collaborative active learning

Strongly desired: educational work with data from the school buildings

The educational approach of GAIA prioritizes educational activities, which utilize the data collected with the installed and/or other portable IoT equipment, i.e. the various meters and sensors monitoring energy consumption and environmental conditions in the school buildings[4]. Using the GAIA Building Manager Application, users access and use this data in order to monitor and observe their school environment,

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[3] Detailed information on the digital applications offered by GAIA can be found in deliverables D3.1, D3.2, and D3.3, which are available at http://gaia-project.eu/index.php/en/resources/deliverables.

[4]   Detailed information on the GAIA infrastructure can be found in deliverables D2.1, D2.2, which are available at http://gaia-project.eu/index.php/en/resources/deliverables.

engage in data-driven decision-making, implement their informed decisions, and see the impact of their action.

Strongly desired: a playful spirit in the educational activities

An overall playful approach to learning and action taking for improved energy efficiency is strongly promoted in GAIA educational activities. The aim is to motivate and sustain long-term user –and especially student– interest in, and engagement with, the activities, and nurture the emergence of deeper understanding of energy efficiency issues, so that long-term impact on user behavior and energy consumption can be achieved.

In the gamified online environment of GAIA Challenge, students are engaged in series of knowledge and action missions. In the knowledge missions, they are challenged to solve knowledge quizzes on various aspects of energy efficiency. Through the action missions, teachers playfully spark student action aiming to increase energy efficiency in the school building. In addition, GAIA Challenge offers a school-safe digital social networking environment for students and student groups to interact with each other on energy-efficiency related matters by sharing their experiences and achievements and competing for better scores for their group.

In the context of the GAIA Community Engagement Game, students as well as members of the various wider communities of the schools are engaged in weekly GAIA Scavenger Hunt hashtag games implemented through popular social media such as Facebook, Twitter, and Instagram. Teachers, or others, initiate a web-based scavenger hunt each week, whereby players are asked to get active in order, for example, to look for something, find an answer to a question, complete a certain task, or create relevant digital content such as an image or a video. By including the appropriate hashtags in their responses, players indicate the link of the response to a particular activity and their own country. On this basis, scores for activities and countries can be calculated in the context of various competitions.

Options available: how far down the learning path

Depending on their educational objectives, the time available and the other local conditions and circumstances, teachers are free to decide how far down they wish to take their students on the learning path of GAIA. While they are expected to take at least the first step, they will also potentially make further steps with their students in the progression explained in Table 3 below.

Table 3: The four steps in the learning path of GAIA

1st Step: Awareness Raising	Students get informed about the need to save energy and realize that there are things they can do in everyday life, in school and beyond, to improve energy efficiency.
2nd Step: Observation	Students monitor and analyze energy consumption in the school building and its change over time, in order to understand it.

3rd Step: **Investigation**	Based on their findings from observation, students experiment with short-term changes in their everyday habits and behaviours that affect energy consumption in the school building. They analyze the impact of these short-term changes on energy consumption in the school building and their potential for improved energy efficiency.
4th Step: **Action**	Based on their findings from short-term investigation, students decide to take longer-term action in order to achieve greater energy-efficiency results. They observe and analyze the impact of these longer-term changes on energy consumption in the school building and their potential for improved energy efficiency, monitoring the course towards achieving their goals.

At the most superficial, yet important, level of raising awareness, GAIA supports members of the school community to get informed about energy efficiency. This is done attractively by providing appropriate knowledge content through the Knowledge Missions of GAIA Challenge.

Building on this foundation of awareness and at a deeper level of engagement and understanding, GAIA encourages users of the school building to engage in practical hands-on learning activities, in which they gather data and experiences relating to their current behavior and how this can be changed to improve energy efficiency. Users may realize this at various levels of involvement, taking one or more of the 2nd to 4th steps above (Observation, Investigation, and Action). This process is enabled and enhanced through the combined use of GAIA Challenge and the GAIA Building Manager Application.

Options available: timeframe

Time availability, appropriate timing and balance of the various activities in the schedule of school life are some of the most demanding aspects of teaching practice. For this reason, and in order to increase the chances for the realization of GAIA activities in the various educational contexts addressed, the educational scenarios foresee a very flexible time frame allowing for an array of interventions lasting from a few minutes to months or a whole school year. GAIA activities can be introduced into educational settings at various degrees of integration with the everyday work of schools, ranging from one-off exceptional events to larger projects integrated with aspects of the curriculum.

Of course, increased energy efficiency and corresponding behavioural change can only be achieved and sustained in larger periods: one-off initiatives stand little chance of success other than at the level of informing and raising awareness. Therefore, the project strongly encourages school communities to seek the most appropriate ways in their own circumstances to be engaged in GAIA activities for longer periods. In such a longer time span, they can flexibly pick and match any of the shorter or longer-term activities proposed, in any meaningful combination serving the larger goal of improving energy efficiency in their school buildings by developing appropriate everyday behaviours.

Table 4 below offers an indicative distribution of the various levels of engagement into three timeframes.

Table 4: Distribution of different levels of engagement in different timeframes

	Raising awareness	Engaging with energy efficiency	
Short term *Minutes to hours*	Knowledge Missions	Observation	Investigation
Medium term *Day to weeks*	Knowledge Missions	Observation	Investigation
Long term *Month to years*	-	Action	

The teacher may more easily introduce short-term activities at any point as either they consider appropriate, according to their previous planning or even spontaneously when an opportunity arises. On the contrary, medium and long-term activities require more precise structuring and planning. The scenarios developed by the project offer an indicative time plan as guidance and support to teachers, who will of course adjust this to the realities of their classrooms.

Options available: levels of social engagement

The educational intervention proposed by GAIA is strongly characterized by collaboration in the classroom and within the school community, as well as with engagement with the local society. The extent to which each school and teacher will decide to take GAIA activities out of the boundaries of the school and engage the local society depends on the local circumstances.

Within the school, learning in GAIA activities is predominantly collaborative, realized through student teamwork, students' guidance and facilitation by their teachers, and students' and/or teachers' collaboration and interaction with the building manager and/or other school staff of community members, where and as applicable. GAIA Challenge offers a school-safe digital social networking environment, which can enhance this sense of school community action for energy efficiency. Students, student groups, teachers and school staff can use this online environment to interact with each other, share their experiences and achievements, and compete for better scores for their group.

Engagement with the local community can take various forms, ranging from awareness raising initiatives of the school to more active engagement of students' families and more generally of the local population in GAIA-inspired action for energy efficiency, e.g. in homes and in the town. This aspect is can be supported effectively through the deployment of GAIA Community Engagement Games, in which students and the school community, together with members of the various wider communities, will be engaged in weekly GAIA Scavenger Hunt hashtag games implemented through popular social media such as Facebook, Twitter, and Instagram.
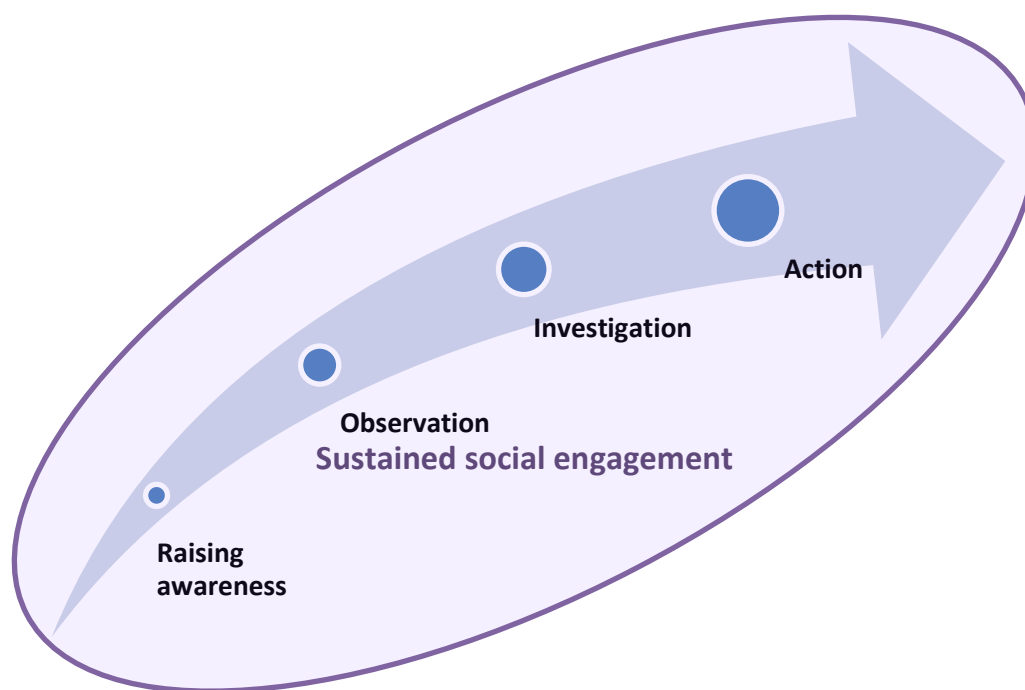
Options available: adjustment to local educational characteristics

As already pointed out, the educational scenarios of GAIA offer guidance to teachers without being strictly prescriptive, on the premise that each school and teacher will adjust GAIA activity to the characteristics and circumstances of their local educational settings. In addition to the options described above, other parameters to be taken into account when defining the practicalities of introducing GAIA activities in a school include the following:

- Technological circumstances:
  o Availability of installed or portable IoT equipment (meters, sensors), and its kind
  o Availability of user devices (smartphones, tablets, computers) and internet connection for use in the activities, any restrictions in their use
- Educational circumstances:
  o Age of students involved
  o Number of students involved
  o School staff involved (how many and which teachers, person acting as building manager)
  o Preference or not for the connection of the activities with specific curriculum subject areas (e.g. environmental education, science and more generally STEM – cf. mathematical and scientific thinking, problem solving –, cross-curricular approaches with links to social, ethical, other humanities-related aspects)
  o Possibilities and preferences for the place of GAIA activities in the school schedule (e.g. as part of the usual teaching activities during lessons, and/or as additional activities beyond lessons such as in afternoon clubs or projects)
  o Stability of educational circumstances, e.g. whether significant changes can be expected in the course of longer-term activities.

These different aspects of the local educational characteristics and settings of school environments addressed by GAIA provide the framework for the description of the Activity Plans of the different pilot sites which are included in deliverable D4.2 'Final Trial Documentation'. From those Activity Plans, it is interesting for the purposes of presenting the educational approach of GAIA to focus here on the variety of learners'

age groups and position of GAIA activities in relation to the curriculum and school schedule. This is summarized in Table 5 below.

Table 5: Student age groups and relation to curriculum and school schedule in GAIA

School	Student age group	Subject area(s) and/or cross-curricular activities	Place of GAIA activities in the school schedule
GREECE			
GR01: 1st Junior High School of N. Philadelphia	13-15	Environmental education programme, Informatics, Technology, Physics	Extra hours In the computer lab during the lesson of informatics
GR02: 1st Junior High School of Rafina	13	IT, Technology, Home Economics	During lessons
GR03: 8th Junior High School of Patras	15	Chemistry, Technology	During lessons and outside lesson hours
GR04: Primary School of Lygia	8, 11, 12	Environmental education programme	During lessons and outside lesson hours
GR05: Primary School of Megisti		Not defined	Not defined
GR06: Junior High School of Pentavrissos	12-15	Maths, Physics, Literature, Technology, Informatics	During lessons
GR07: Model Experimental Junior High School of Patras	13-15	2 environmental education programmes	During lessons and after the end of the lessons
GR08: 1st Technical High School of Patras	16	Not defined	After school hours
GR09: 1st Laboratory Centre of Patras	15-16	Environmental education programme	Outside lesson hours
GR10: 46th Primary School of Patras	11-12	Environmental education programme, Greek language, Physics, Geography	During lessons
GR11: 2nd Primary School of Paralia	11	Physics	During lessons
GR12: 6th Primary School of Kaisariani	10-11	Science, Geography, IT	During lessons
GR13: 5th Primary School of N. Smirni	10-12	Physics, Informatics	During lessons
GR14: Ellinogermaniki Agogi	11-17	Science, Geography, Mathematics, IT, interdisciplinary projects	During lessons
GR15: 1st Primary School Psychico	11	Physics Sciences, Informatics, Environmental education programme	During school lessons, in several school activities during school schedule
GR16: High School of Pompia	17	Environmental education programme	After school hours
GR17: Ekpedeftiria Panou	14-15	Informatics, Physics, Environmental education programme	During lessons
GR21: 3rd High School of N. Philadelphia	17	Students' research project, linked to a current eTwinning programme	Mostly during school hours
GR22: 2nd Junior High School of N. Ionia	13-15	Physics, Chemistry, Geography, Maths	During lessons

ITALY			
IT18: Gramsci Keynes School in Prato	16-18	Physics and Maths, Building, Land evaluation, Geopedology, English, Science	During lessons
IT19: Sapienza University	Adults, various ages	Seminar in Software and Services, Development projects	During seminars
SWEDEN			
SE20: Technical High School of Söderhamn	16-20	Physics or general science, and student workshops, linked to the Natural Science Programme and the Technology Programme. Students assembled devices installed inside SK building.	Introduction during lessons and then in class and in students' own time

Options available: thematic coverage

Educational activities may cover one or more of the following aspects of improving energy efficiency in the school building, depending on the local circumstances and educational focus:

● Use of lighting
● Use of electrical and electronic devices
● Use of heating or cooling
● Building and local characteristics (e.g. orientation, insulation, local climate)

The project strongly favors the coverage of all four of these thematic areas in the wider timeframe of a long-term action of the school community spanning over several months.

Options available: educational projects and wider-frame narratives

The implementation of educational projects and the use of wider-frame educational narratives addressing students as agents in purposeful missions are useful for teachers wishing to engage students in longer-term action. GAIA has developed some examples of educational projects that can engage students for longer periods in missions and action linked to the use in energy at school. These examples, complemented by teacher guidance and student worksheets, can be found in the 'Educational Material' section of the project website[5]. They can be described in summary as follows:

Guardians of the Lights: Students become the guards of the lights in their class. For two weeks, they try to limit the use of lighting when it is not necessary. They record the time during which the lights in their class are on and the daily weather conditions affecting natural lighting, they calculate energy consumption for lighting, and decide on relevant ways to save energy. They are careful to maintain luminosity above the limit of 220 lux. At the end of the two weeks, students calculate how much electricity they have used and how much they have managed to save, comparing the results of their calculations with the data they get from the IoT equipment installed in their classroom, through the GAIA building manager application. They calculate the amount of coal required to cover the energy needs of their class in order to secure proper lighting.

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[5] http://gaia-project.eu/index.php/en/educational-material

Energy Labels Investigators: Students locate electrical and electronic devices in their classroom; they study their energy labels and record their characteristics. They look in the internet for information about the meaning of the various features described in the energy labels. They observe and record power consumption during the operation of devices such as computers, the interactive whiteboard, etc., in various modes (e.g. standby, full operation, charging) and over various periods of time (minutes, in a day, in a month, in a school year).

A Paradise for Learning - at the right temperature and levels of humidity! Students study diagrams of relative humidity and temperature, they define the satisfactory and ideal conditions for their classroom, and record their conclusions. They then record their measurements of humidity and temperature in the classroom, determine the appropriate conditions, and decide how to intervene in order to save energy.

A Paradise for Learning - with help from the windows! How is temperature in the classroom affected by opening or closing the windows? How can students measure and handle noise from the outside environment and attend their lessons with the least disruption from it? What will change in the conditions of the classroom if they use the curtains of their classroom differently? They record temperature and levels of noise in the classroom with open and closed windows, and with open or closed curtains. They decide what the ideal conditions are for the lesson so that we can save energy used for the heating or cooling of the classroom.

Choosing Orientation and Insulation! Students build the mock-up model of a building with 2 windows in the middle of its long side. They first take the model to the schoolyard and with the help of a compass. Then, they orient the model to a different point on the horizon each time. They record the temperature inside the model and interpret the results of their experiment. Using the compass, they then find classrooms with different orientations in their school. They use the temperature data collected through the IoT equipment installed in the different classrooms, and verify the results of their experiment, suggesting possible solutions for saving energy used for heating or cooling. Respectively, they can also test the effect of the use of various heat insulating materials on the model and the school.

2.3 Co-design together with the school communities: teacher-generated context-specific scenarios of practice

The generic core educational scenario described in the previous sections outlines the characteristics, which each educational intervention in GAIA should have.

Using this generic core educational scenario as their framework and guidance, and by making decisions on the open options offered based on the interests, priorities and realities in their context, teachers can generate their own context-specific scenarios of practice.

GAIA encourages and facilitates teachers to document and share their experiences and practices with the teacher community in the website and social media of the project, thus enriching GAIA practice with teacher-generated scenarios.

The teacher-generated context-specific scenarios of GAIA practice are the final products of an overall co-design approach which drives the pedagogical and educational design process in the project. In synergy with activities under WP4 'Trials and Evaluation' and as documented in detail in the deliverables providing the documentation of the trials (D4.1 and D4.2), the GAIA consortium systematically involves teachers in the design of the educational intervention of the project, both through continuous collaboration between the research team and educators within the consortium, and through regular interaction of the research team with teachers from the pilot sites and more generally the educational community.

Characteristic examples of products of co-design with educators within the GAIA consortium are the educational projects and wider-frame narratives described in the previous section, which, together with their learning and teaching materials, have been developed in close collaboration with teachers in Ellinogermaniki Agogi (EA). I addition, a further case of such co-design with educators within the consortium is the development of the gamified learning content of GAIA Challenge on the basis of educational content developed for this purpose by teachers in EA. This educational content was turned into game content, and structured into gaming tasks, based on game design and educational design considerations in the context of cycles of intensive co-design involving educators and game designers and developers. The result of this process is the rich structure and content (5 Knowledge Missions and 2 Action Missions, including 14 tasks and approximately 140 sub-tasks) of GAIA Challenge. An example of this content is included in Annex II of the present document for illustration purposes.

In parallel, through a series of workshops, training sessions and meetings documented in the deliverables on the trials (D4.1 and D4.2), the research team has been in continuous collaboration with the teachers from the pilot sites with the aim to enable and support them to develop their own context-specific scenarios of GAIA practice to implement in their educational settings during the trials. The Activity Plans of the schools included in deliverable D4.2 reflect this process and the characteristics shaping each context-specific scenario. These scenarios of practice are open-ended and flexible, continually adapted by the participating teachers to the realities of the trials in the pilot schools. In their final shape and form they will be documented in deliverable D4.3 "Trial and Educational Evaluation" at the end of the project.

As examples of the adaptation of the generic core scenario of GAIA to the local educational circumstances, Annex III of the present document includes the scenarios developed for the pilot activities in the Technical High School of Söderhamn (pilot site SE20, Sweden) and in Sapienza University (pilot site IT19, Italy).

3. The GAIA generic core educational scenario in the course of a school year

3.1 Overall schedule

Based on the approach presented in the previous section, the project proposes an organisation of the GAIA activities in an overall schedule in the course of a school year with the following characteristics:

- Four cycles of activity spanning the whole school year
- Approximately 6-7 weeks each cycle
- Each cycle dedicated mainly to one for the four thematic areas:
  - o Use of lighting
  - o Use of electrical and electronic devices
  - o Use of heating or cooling
  - o Building and local characteristics (e.g. orientation, insulation, local climate)
- After a theme is introduced and worked in depth during a certain cycle, it will remain active and will be revisited during subsequent cycles.

An example of realizing the above proposed distribution of GAIA activities in a school year is presented in the tables below for 2017-2018 (Table 6).

Table 6: Indicative schedule of GAIA activities in the course of school year 2017-2018

1st cycle		2nd cycle		3rd cycle		4th cycle	
Week no	Starting on	Week no	Starting on	Week no	Starting on	Week no	Starting on
1	30/10/2017	8	18/12/2017	15	19/2/2018	22	23/4/2018
2	6/11/2017	9	8/1/2018	16	26/2/2018	23	30/4/2018
3	13/11/2017	10	15/1/2018	17	5/3/2018	24	7/5/2018
4	20/11/2017	11	22/1/2018	18	12/3/2018	25	14/5/2018
5	27/11/2017	12	29/1/2018	19	19/3/2018	26	21/5/2018
6	4/12/2017	13	5/2/2018	20	26/3/2018	27	28/5/2018
7	11/12/2017	14	12/2/2018	21	16/4/2018	28	4/6/2018

	1st cycle	2nd cycle	3rd cycle	4th cycle
1st theme	Focus on the theme	Long-term action on the theme		
2nd theme		Focus on the theme	Long-term action on the theme	
3rd theme			Focus on the theme	Long-term action
4th theme				Focus on the theme

	1st cycle 30/10-15/12/2017	2nd cycle 18/12/17-12/2/2018	3rd cycle 19/2-16/4/2018	4th cycle 23/4-8/6/2018
Use of Lighting	Focus on the theme of lighting	Long-term action on the theme lighting		
Use of Heating		Focus on the theme of heating	Long-term action on the theme of heating	
Use of Devices			Focus on the theme of devices	Long-term action on the theme of devices
Building/local characteristics				Focus on the theme of building characteristics

3.2 Example distribution of activities in a cycle

A proposed distribution of the various activities in a cycle is presented in Table 7 below, based on an assumed average availability of 100 minutes (~two teaching hours) of teaching time for GAIA per week.

Table 7: Indicative distribution of GAIA activities in a cycle

	Focus on the theme	Long-term action on the theme
Weeks 1-2	● Introduction to the theme: conventional teaching ● Play on the theme: further learning on the theme using GAIA Challenge	
Weeks 3-4	● Action Mission on the theme: using the GAIA Application in practical observation and investigation activities in the school building ● *Optional addition: use of the GAIA Educational Lab Kit to implement further activities on the theme*	
Week 5	● Portfolio - Draft 1: reporting on experiences and achievements in the Action Mission, uploaded in GAIA Challenge ● *Optional addition: use of the GAIA Educational Lab Kit to implement further activities on the theme*	● Decision on long-term action for energy efficiency ● Continuation of use of the GAIA Application to monitor the impact
Week 6-7	● Community involvement: informing other members of the school community and/or the local community ● Playful social engagement: implementing GAIA Community Engagement Games ● Portfolio - Final: reporting on experiences and achievements in the cycle, uploaded in GAIA Challenge and social media ● *Optional addition: use of the GAIA Educational Lab Kit to implement further activities on the theme*	● Continuation of long-term action for energy efficiency, using the GAIA Application to monitor the impact
After the end of the cycle	*Optional: use of the GAIA Educational Lab Kit to implement further activities on the theme*	● Continuation of long-term action for energy efficiency, using the GAIA Application to monitor the impact

3.3 Detailed description of the activities in a cycle

3.3.1 (Before) Week 1: Preparations

Before the start of the 1st cycle, the following preparatory activities need to take place.

Registration with GAIA Challenge

GAIA Challenge can be accessed at http://gaia-challenge.com. Students access GAIA Challenge for the first time, to create their own user accounts. Each of them will define a username and password of their choice for themselves. If they wish, that can also provide their email address, so that it is used by the system to help them if they should forget their password. They can always go to the 'My profile' area and edit their user information, and upload an image to represent themselves in the community of GAIA Challenge (their "avatar"), if they wish. The teacher uses this opportunity to discuss matters of online safety and security with students.

The teacher accesses the Challenge through this 'hidden' address, for teachers only: http://gaia-challenge.com/el/user/register/teacher. There they create their own user account with advanced rights allowing them to create and manage Mission Teams for their students. In addition, with their account the teacher will be able to access the Mission Team Management area in GAIA Challenge to get an overview of Mission Teams and each student's individual progress.

Setting up the Mission Teams in GAIA Challenge

Students participate in the GAIA Challenge both individually, as well as members of Mission Teams. These are groups of students who work together to accomplish various energy efficiency Missions. The size of a Mission Team may vary greatly: it can be a team within a class, a whole class, an across-school team, etc. The teacher decides how to define and use the concept of the 'Mission Team' so that it best suits their teaching purposes and local circumstances.

Using their advanced user rights in GAIA Challenge, the teacher accesses the Mission Team Management area to create the group, i.e. the Mission Team, which the students will belong to. When the Mission Team is created in the system, the teacher receives an invitation code, which he/she gives to the students so that they can use it to join the team. The students go to the 'Join Mission Team' area in GAIA Challenge and enter the invitation code they have been given by their teacher. This automatically links them to the Mission Team the teacher has created for them and their peers.

Access to the GAIA Application

The GAIA Application Building Energy Management Application, or simply the 'GAIA Application', is the central tool for the realization of the learning activities during Action Missions and the subsequent long-term action phases. The GAIA Application can be used by teachers and students on both computers and mobile devices (tablets, smartphones).

The teacher will decide if they will use the GAIA Application themselves 'centrally', projecting their screen to show the content to their students, or if they will allow their students to become users of the Application directly. There are different levels of access rights to the Application, matched with the roles of 'student' and 'teacher' in the system. Before the start of the first Action Mission (in week 3 of the first cycle), respective accounts need to be created.

3.3.2 Weeks 1-2: Raising awareness

The teacher introduces the theme focused upon in the activities cycle, through any means they consider appropriate. The project can offer teaching materials and ideas. The aim is to acquaint the students with the basic and important concepts linked to the topic.

Setting out on a Knowledge Mission

Students are introduced to the relevant Knowledge Mission in GAIA Challenge. By playing this knowledge game, they will further explore the theme and go deeper into its various aspects. The thematic coverage of the available Knowledge Missions and the time required on average for the completion of each quest are presented in Table 8 below.

Table 8: Indicative distribution of GAIA activities in a cycle

Theme	Knowledge Mission	Quests in the Knowledge Mission	Quest topic	Average time required
Introduction to energy efficiency and GAIA (to be covered at the beginning of the 1st cycle)	So, what's the challenge?	Let's stay on this planet!	The need for energy efficiency	20-30 minutes
		Let's GAIA!	Let's play GAIA to learn energy efficiency	5-10 minutes
Use of lighting	Turn me off unless you need me! – I	Light in the dark – I	More energy efficiency through wiser use of the lights – First Part	20-30 minutes
		Light in the dark – II	More energy efficiency through wiser use of the lights – Second Part	20-30 minutes
Use of heating or cooling	What a school atmosphere! - I	Hot or cold? – I	More energy efficiency through wiser use of heating and/or cooling – First Part	20-30 minutes
		Hot or cold? – II	More energy efficiency through wiser use of heating and/or cooling – Second Part	20-30 minutes
Use of electrical and electronic devices	Turn me off unless you need me!- II	Sleeping demons – I	More energy efficiency through wiser use of devices – First Part	20-30 minutes
		Sleeping demons – II	More energy efficiency through wiser use of devices – Second Part	20-30 minutes
Building and local characteristics (e.g. orientation, insulation, local climate)	What a school atmosphere! - II	Building smartness – I	More energy efficiency through appropriate building and adjustment to the local climate – First Part	20-30 minutes
		Building smartness – II	More energy efficiency through appropriate building and adjustment to the local climate – Second Part	20-30 minutes

Students can play the Challenge using a computer, a tablet, or even a smartphone with a large enough screen. The same Mission and Quest can be played by the same player several times, and can be interrupted at any time and repeated at a later point. Students can also play the game from anywhere, not just their classroom, if there is not enough classroom time. The teacher advises them that in case they face any problems, they can always try the 'Help' area, which provides useful information on how to use the GAIA Challenge. Thus, the game has been designed so that it can be used very flexibly by the teacher, who will decide how often and for how long each time the students will play it (cf. Table 9):

Table 9: Knowledge Mission in short-term or medium-term activities

	Raising awareness through a Knowledge Mission
Short term	For some time (e.g. 20-30 minutes) during a single teaching session
Medium term	For some time (e.g. 10-15 minutes) over a number of teaching sessions

In cases where economizing classroom time is of priority, the teacher can also ask the students to play with some or all content of the Quests in their own time, or even in their own place and time (e.g. at home).

Playing the Quests

In GAIA Challenge, students will land in the 'My Quest' area. There they see the Quest Map, which gives them an overview of the five Knowledge Missions and the Quests belonging to them. The Quest Map also offers a visual representation of the student's progress in the challenge: in the beginning it is completely covered by clouds, but the more quests a student plays, the more the clouds clear and the map is revealed. Nevertheless, all Knowledge Missions are available for the students to play whenever they want.

By clicking on the box corresponding to a Quest, students start playing it. This involves responding to a series of short tasks, one after the other. In each Quest, there is a variety of tasks for students to interact with, such as single and multiple-choice questions with text and images, image-based drag and drop tasks, selection and search tasks, texts with gaps to fill in, or value estimation tasks. After each response, they receive feedback from the system, in the form of a short explanation.

By playing, students score points for their Mission Team. As they can replay tasks as often as they wish, in this way may increase the score of their team, but only up to the maximum score per task and not beyond that. Additionally, for each player there are time-restricted bonus points rewarded only for the first play-through of each task. This ensures that those players who perform well in the first play-through are able to score more points than players who repeatedly play the task but did not perform well in their first attempt. Once a student has completed all tasks in a Quest, they can play the same quest again, or exit it and be brought back to the Quest Map.

When the student has completed all Quests of a Knowledge Mission, they can submit a Snapshot for this mission and in this way share their achievement with the community. To do this, they click on the Snapshot box under the respective Knowledge Mission, and they edit their submission, adding texts, images, and/or videos from YouTube or Vimeo. They can shape their Snapshot as they wish, dragging and moving around the different blocks of their con tent. They then submit the Snapshot, which will now appear in the public gallery in the 'My Community' area.

At the top of the 'My Quest' area, the student can also see their scored points, and their overall progress through the Knowledge Missions and Action Missions. At the bottom of the page, they can find the activity log, which shows their recent activities and achievements in the GAIA Challenge.

The 'My Community' area of the Challenge is devoted to showing the achievements of the different Mission Teams. There is a Mission Team leader board, where students can click to reveal more information about each Mission Team and its achievements, including its members' personal scores. There is also a gallery of all Snapshots and Portfolios submitted by the Mission Team. Students can click on them and get access to the complete submissions with all their texts, images and videos.

3.3.3 Weeks 3-4: Observation and investigation in an Action Mission

After the introduction to the theme in the previous weeks, the focus of the learning activities now shifts to practical observation and investigation in the school building, which the teacher orchestrates in the form of an Action Mission. During the Action Mission, students apply in practice the knowledge they have gained on the theme focused upon. They work with data from the school buildings in order to observe how energy is used in them; they experiment with changes in everyday habits and behaviours, and monitor their impact on energy consumption.

In the observation phase: Guided and facilitated by the teacher, students monitor and analyze the energy consumed for a particular purpose (lighting, heating, cooling, the use of certain devices, etc.) in the school building, as well as the conditions within the school building and the weather conditions outside. Their aims is to start understanding how energy can be used more efficiently for this particular purpose, without disrupting functional and pleasant living in the school building.

In the investigation phase: Investigation builds on, and extends the observation activities above. Based on their findings from observation, students experiment with short-term changes in their everyday habits and behaviours that affect the energy consumed for that particular purpose. They analyze the impact of these short-term changes on energy consumption and their potential for improved energy efficiency in the school building.

Timeframe

The timeframe is again very flexible. The teacher will decide how long and how often students will be engaged in the observation and investigation activities, depending on the teaching settings and local circumstances. Generally, investigation requires more time than observation (cf. Table 10 below).

Table 10: Action Mission in short-term or medium-term activities

	Inquiry: Engaging with energy efficiency through an Action Mission	
	Observation	**Investigation**
Short term *Minutes to hours*	As part of a teaching session (e.g. a 15-30 minute activity)	A whole teaching session or a few hours within a day
Medium term *Day to weeks*	Distributed instances in a time frame of several hours or days	Distributed instances in a time frame of several days or weeks

Week 3	**Week 4**
Observation	Investigation

It is recommended to use the whole or part of Week 3 largely for observation activities, and at least Week 4 for investigation activities. Starting investigation activities during the first week will create a slightly wider timeframe that will allow for deeper investigation activities. However, this loose indicative division needs to be adjusted to the time availability and the characteristics of each educational setting.

Working with data from the school buildings: from illustration to inquiry

The availability of data from the school buildings allows the teacher to realize a wide range of practical learning activities. The minimum possibility is to demonstrate data to the students, as a form of illustration, so that pupils gain first-hand experience of energy consumption and the various aspects of the energy efficiency problem. This can be useful if the purpose is to provide a basis for introducing concepts, discussing, and thinking about energy efficiency. This is a useful starting point, which can be used in teaching even before the start of the Action Mission.

However, GAIA offers unique opportunities for students' more active and open-ended involvement in inquiry-based learning moving far beyond the illustration paradigm. In such activities, the teacher takes students to observation and investigation voyages in which they make decisions about why and how to observe or investigate. Table 11 below presents what students ask and do in the three phases: a) Illustration, b) Observation, c) Investigation.

Table 11: Inquiry-based learning in an Action Mission

Inquiry: Engaging with energy efficiency using data from school buildings		
Weeks 1-2	**Week 3**	**Week 4**
Illustration	**Observation**	**Investigation**
What do we need to know about energy efficiency?	How is energy used in the school building? Is it wasted? How can it be used more efficiently?	What effect do certain changes in everyday habits and behaviours have on energy consumption in the school building? How effective can these changes be in our efforts for energy efficiency?
Students develop basic knowledge and understanding of energy efficiency.	Students explore, describe, sort and classify, note similarities and differences in the data, in order to identify and explain important features of the energy efficiency problem.	Students make a hypothesis, plan the collection of evidence, collect evidence, analyze and interpret it, draw conclusions, communicate their conclusions and reflect on them and the inquiry process.

The schematic representation of a proposed inquiry-based learning process in Figure 3 below can be of use for teachers developing relevant lesson plans for the Action Mission phase:
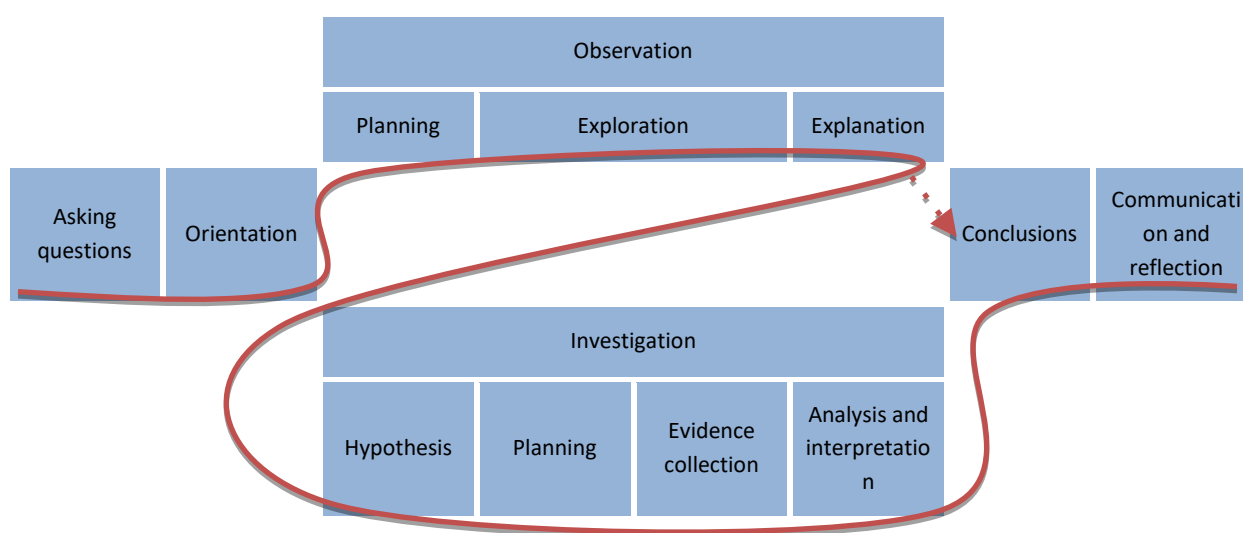

Figure 3: Proposed inquiry-based learning process in an Action Mission

Data to observe and investigate per thematic area

The data that students may observe and investigate per thematic area are summarized in Table 12 below.

Table 12: Data to observe and investigate per thematic area

Theme:	Use of lighting	Use of heating or cooling	Use of electrical & electronic devices	Building and local characteristics
Data from installed equipment				
Electricity consumption	X	(X)	X	X
Luminosity	X			X
Presence/movement	X			
Temperature		X		X
Relative humidity		X		X
Noise levels		(X)		X
CO, CO2		(X)		X
Weather conditions	X	X		X
Measurements from other equipment (participatory sensing)				
Electricity consumption: readings from power meter	X	(X)	X	X
Fuel consumption: readings from fuel meter		X		X
Fuel consumption: quantity purchased		X		X
User comfort level: light	X			X
User comfort level: sense of heat or cold		X		X
Luminosity	X			X
Temperature		X		X

Steps to follow in the data-based observation and investigation activities

Step 1: Defining the physical space observed and establishing the availability of data

The teacher adjusts the teaching approach to the availability of equipment and data.

Teacher and students define the space observed: a classroom, a group of classrooms, or the whole building? Their own school building, other that of another school (too)?

Teacher and students discuss the installed equipment and what it records, and/or what other measurements they can also make to understand how energy is used in the school.

Even if there are no installed meters and sensors in their own school, the teacher and students can still do data-based activities. They can:

- Work with the data from other schools
- Collect and record data themselves.

In the former case, another school can be chosen as a case study. In the latter case, students are guided by the teacher to use portable equipment to make relevant measurements and submit them to the system of GAIA. Even in cases in which automatic metering and measurements are available, it may be considered pedagogically useful to engage students in participatory sensing practices such as, for example, submitting readings from the power meter, in order to foster students' awareness and personal involvement.

Such user-inserted measurements can be of different kinds, such as:

- metrics of energy consumption (e.g. electricity used in a given period, oil bought, or gas used for heating in a given period),
- temperature,
- level of user comfort, e.g. by defining and using a scale of integers from 1 to 5 (e.g. how comfortable we feel with the available right in a given room, or how comfortable we feel in terms of our sense of heat or cold in a given room),
- other values that are interesting in the local context (e.g. how much paper is used for photocopies in a given period).

Step 2: Observing and comparing values

Students can observe:

- Current values and their fluctuations during the observation window
- Change of the values over longer periods of time (day, months, seasons, years) (using historical data for the school building)
- 'Building condition now':
    - Overall building consumption
    - Building summary (Floor Plan)

They can make comparisons within the same building (their own building or other building observed):

- Values from the same sensor/meter in different timeframes (cf. differences between times of the day, day and night, winter and summer, workdays and weekends/holidays, etc.)
- Values from different sensors/meters in the same timeframe (cf. differences between parts of the building with different needs, different uses, different characteristics, etc.)

Alternatively, they can make comparisons between different buildings (their own building with another, two other buildings):

- Total building measurements
- Specific sensor values (same kind of measurement in the two different environments of the two schools)

In all observations and comparisons, they choose the appropriate granularity: "Per 5 minutes", "Per Hour", "Per Day", "Per Month".

Step 3: Observing behaviours and habits affecting energy use

Students observe and record everyday habits and behaviours that have an impact on energy consumption:

- Turning on/off the lights
- Turning on/off the heating/air-conditioner
- Opening/closing the windows
- Opening/closing the curtains/shades
- Turning on/off the fans
- Turning on/off other devices (e.g. computers, projector)

Students match the observed behaviours with patterns in the data.

Step 4: Investigating the impact of behavioural changes on energy consumption

Based on their findings from observation, students experiment with short-term changes in their everyday habits and behaviours that affect the energy consumed for a certain purpose.

They observe and analyze the impact of these short-term changes on energy consumption for that purpose. They also consider the impact of the investigated changes on the level of comfort and convenience of the users of the school building: if habits and behaviours change, is that likely to disrupt functional and pleasant living in the school building? What are the chances of them being accepted and adopted? How can people be helped to adopt them?

They calculate the potential for improved energy efficiency in the school building, if the investigated changes in everyday behaviours and habits are adopted in the long term.

Things to investigate include:

- Changes in the use of lighting in the course of a day, linked to the variation in natural light or the needs for lighting during different activities
- Use of different kinds of lighting technologies
- Changes in the timing and duration of the use of heating and/or cooling
- Changes in the timing and duration of ventilation of the room (opening the windows, use of fans)
- Changes in the timing and duration of the use of window curtains, blinds, etc.

In short-term investigational activities (e.g. a teaching session or a few hours within a day) will involve aspects of energy consumption that can be observed and investigated in such a short time span, such as:

- the consumption of energy by an electrical heater or cooler,
- the consumption of energy by certain lighting devices,
- the effect on room conditions of certain ventilation or sun-blocking practices, etc.

In medium-term investigation activities, observations and experiments may be distributed over a number of days or weeks, so that they can take account of patterns emerging only over longer periods. E.g. referring to energy consumption in different times of the day over a week, or in periods of normal operation compared to weekends, or allow comparisons linked to the weather, etc. The use of historical data further widens the time window for the investigation, e.g. allowing for comparisons linked to seasonal variation of natural light, temperature, etc.

Part of the investigation can be 'what if' scenarios and calculations, such as of the equivalent of certain energy uses in CO_2 emissions, e.g.:

- What would be the saving in energy used for heating if we reduced inside temperature by 2oC on a cold winter day, and on a warmer winter day?
- What would be the saving in energy used for lighting if we reduced the time of use of the lights by x minutes, or if we changed the lighting technology?

Using the GAIA Challenge for the 'Action Mission'

The teacher can create a 'footprint' of the Action Mission in the game environment of GAIA Challenge, with which students are already familiar.

Apart from the five Knowledge Missions, GAIA Challenge also includes Action Missions. Action Missions are by default hidden on the Quest Map, and can be activated by the teacher for a particular Mission Team. Then, the Action Mission shows up on the Quest Map for the next 14 days for the students of the Mission Team. During that time, Mission Team members can play with the Action Mission in GAIA Challenge. After this 14-day period is over, the Action Mission is automatically closed and cannot be reopened for this team.

Using their advanced user rights in GAIA Challenge, the teacher accesses the Mission Team Management area to start the Action Mission. They carefully select the time for this, as the Action Mission can only be started once for every Mission Team. After the activation by the teacher, the Action Mission appears on the quest map of the students participating in this particular Mission Team, for the next 14 days.

Working with the GAIA Application during the Action Mission

To conduct the data-based learning activities, teacher and students use the GAIA Application Building Energy Management Application, or, in short, the 'GAIA Application'.

Visiting the Sensors page in the Application, they can view the current values of all sensors and meters of their building. By clicking on a sensor, they view its history in a chart presenting the last recorded values.

The GAIA Application can be used by teachers and students on both computers and mobile devices (tablets, smartphones). In addition, it has been designed for access by both students and teachers, at a different level of access rights for each group. The teacher will decide if they will use the GAIA Application themselves 'centrally' and project their screen (or even use printouts) to show the content to their students, or if they will allow their students to become users of the Application directly.

Participatory sensing

Teacher and students can use the relevant area of the GAIA Application to upload measurements they wish to keep track of. User-inserted values appear in the Application as 'virtual sensors'. With their teacher account, in the Sensors page the teacher can to add a virtual sensor for their school, name it appropriately, and link it to a corresponding category. After this virtual sensor has been added, the teacher, as well the students through their own accounts, can upload values to the system for this virtual sensor.

They can add these values using a computer, or mobile devices (smartphones, tablets) with the Participatory Sensing app offered by GAIA. They simply select one of the virtual sensors that have been created for their school, they type in their measurement, and they save it. In addition, they can also use the Auto Gathering function of the app to add values that are automatically provided by their device, such as luminosity measurements.

Working with diagrams

By default, the Application presents the available data of the buildings through diagrams. Teacher and students view the recorded data in the form of charts, where the x-axis represents time and the y-axis the chosen measurement.

Teacher and students can choose to view the data in a bar chart or a linear chart. Placing the mouse on the chart, they can view the exact value for a specific time. Next to the chart, the system also presents the daily and monthly average values.

The chart presents the last 48 recorded values. Using the relevant features of the Application, teacher and students can set a specific timeframe for which they want to view the values, and thus alter granularity: "Per 5 minutes", "Per Hour", "Per Day", "Per Month". They can also zoom in an area of the chart.

Teacher and students can save the diagram locally on their computer in the form of an image. In this way, they can print it, or use it as content for their Portfolios and other reports.

Working with numerical data

In addition to presenting the data in charts, the Application also offers the possibility to download the data in the form of lists of numerical values. This offers additional possibilities for mathematics, science, or even IT learning activities.

Making comparisons

Making comparisons between data from different contexts is central to the data-based learning activities. Teacher and students can use the Application to draw comparisons of one or more of the following types:

- Within the same building (typically, their school building)
    - Values from the same sensor/meter in different time frames
    - Values from different sensors/meters in a given time frame
- Between different buildings
    - Total building measurements

In the Application, students and teachers are facilitated to draw such comparisons through combinational charts of the chosen measurements.

Working with the floor plan

The Application includes the Floor Plan feature, which can offer additional teaching opportunities. The Floor Plan page depicts the top view of all areas of the building that are being monitored. Clicking on it, teacher and students can see the sensors located in the chosen area and their measurements, and thus have a summary view of the status of the building on a "realistic" depiction of its floor plan. Note, though, that the Floor Plan represents an abstraction rather than an accurate map of the building.

In addition, using the feature available for editing the Floor Plan, teacher and students can experiment with different arrangements that may serve them better in their projects. Note that the arranged view of the Floor Plan is saved locally, and therefore different computers may have different depictions of the plan.

3.3.4 Week 5: Reporting on Action Mission and deciding on long-term action

In this phase, having just completed the Action Mission, students report on it and tis the results in a Portfolio, and. Based on their experiences and findings, decide on relevant long-term action for energy efficiency.

Reporting through a Portfolio

Students share their experiences and achievements in the Action Mission by developing a report and having a Portfolio uploaded by the teacher in GAIA Challenge. During the Action Mission, students of the Mission Team have worked collaboratively to collect and generate content for this Portfolio. When the Action Mission is completed, students author the Portfolio in a first version, in which they report on their experiences, achievements and findings in the preceding two weeks of the Action Mission. They can use texts, images, and videos from YouTube or Vimeo, in different combinations. When it is finished, the teacher uses the content prepared by the students to submit the portfolio for the Mission Team. The teacher can do this using their GAIA Challenge teacher account with advanced user rights allowing them to access the Mission Team Management area to submit.

Deciding on long-term action

Based on their experiences from the Action Mission, students decide to take long-term action to improve energy efficiency in a wider timeframe, i.e. during several weeks or months.

Through discussion, students realize that to achieve noticeable results on the energy consumption of the school building their action requires longer-term engagement over several months. The timeframe of a school year, or of a substantial part of it, is useful for setting an ambitious target and motivating the school community to work towards achieving it under various weather conditions during the different seasons.

Long-term action builds on and extends the observation and investigation activities conducted during the Action Mission. While preparing towards their decision for certain action, and then as they start implementing it, students continue doing data-based activities expanding on what they have already done during the Action Mission. During the action phase, they continue observing and analyzing the impact of the longer-term changes in everyday school behaviours and habits on energy consumption, monitoring their course towards achieving their goals.

Students' reporting to the school (e.g. the building manager, or the head teacher) on energy use for a certain purpose and action required to improve energy efficiency can also be an engaging practice. Just indicative examples include students asking the manager, based on the analyzed data, to change the threshold value of the thermostat for heating or cooling, to change the kind of bulbs used, to use timers, to make changes in the use of the building to exploit better its orientation and other characteristics, etc.

Regular monitoring through alerts and notifications

Long-term engagement in action can be further fueled by automatic notifications sent to teachers and students by the GAIA platform based on the data gathered through the monitoring infrastructure, e.g. when:

- temperatures recorded in the building indicate excessive use of heating or cooling
- lights are on in rooms where no motion is detected
- data gathered indicate that all lights are on while just half of them, maybe natural light alone, would suffice to provide proper lighting conditions, etc.

The Application offers the possibility of defining rules that generate automatic notifications when certain values are observed in the data from the school building. This offers a very useful element for the long-term action projects of the students.

The students can ask a user with managerial rights (e.g. the building manager) to define an alert rule on the measurements of particular sensors. This rule will generate notifications, which the building manager will be

able to see in the corresponding page in the Application. In addition, students can also have a rule defined, which will send notifications to the email of the teacher, or any other email address.

Students name, describe the rule, and define the message to appear when the rule is activated. They choose the relevant sensor and they use operators (<, >, or =) to formulate a rule involving a threshold value. E.g., when the humidity in the room is higher than 35, the message "Open windows" will appear.

3.3.5 Weeks 6-7 and beyond: Community involvement and playful social engagement

Throughout the education path of GAIA, in the context of social networking and mild competition among classes and schools in the GAIA Challenge, students share their experiences and achievements in the activities, and teachers share news on the progress and completion of the activities and its results. In this final phase of the activity cycle, community involvement and social engagement become the focus, in parallel to the long-term action that has started.

Informing the school community

Students collaborate to produce materials and organize events within the school to inform the other members of the school community.

Informing the wider local community

Students collaborate to produce materials and organize an event addressing the local community. For example, they propose and organize synergies with their families and the rest of the local community, taking action not only in the school building, but also at home and in their local area.

GAIA Community Engagement Games

Teacher and students design and set up a GAIA Community Engagement Game, aiming to raise awareness and playfully sustain the wider community's interest in, and engagement with, energy saving activities, through weekly GAIA Scavenger Hunt hashtag games implemented in popular social media.

Final version of the Portfolio

Students prepare and submit their final report on their experiences and achievements overall in the cycle, in the form of the final updated version of the Portfolio, which the teacher eventually uploads in GAIA Challenge and social media.

After the end of the cycle: continuing long-term action

The long-term action for energy efficiency taken by the students is continued after the end of the cycle of activities, using the GAIA Application to monitor the impact.

3.3.6 Using the GAIA Educational Lab Kit

Throughout the cycle of activities focused on a given theme, and ideally following the first introduction to the theme (i.e. from week 3 onwards) the GAIA Educational Lab Kit can be used to implement further activities. The design of educational activities involving the use of the Lab Kit are presented in the following section.

4. Educational Lab Kit activities

4.1 Overall Description

An integral part of the educational aspects of the project is the Educational Lab Kit, initially described in Deliverable 1.1, "GAIA Design". In short, the kit aims to teach students using a "hands-on" approach, in which they get to use IoT components and electronics based on guides provided by the project, they examine data from their school building and go through the peculiarities of consuming energy, how the building behaves in the various classrooms in terms of environmental parameters, and more. It includes already assembled devices and commercial IoT parts to enable students to complete classes and lab tutorials regarding energy and sustainability, as well as provides guidelines for implementing crowdsensing quests (also related to the gamification component of GAIA). In such quests, students using suitable devices "map" their respective school building over specific parameters, e.g., energy, insulation, etc. It also serves as an additional means of interacting with the project and further increasing the end-user engagement, alongside the other feedback options produced by GAIA, such as the gamification platform and the BMA.

We base this approach on the assumption that, by using this hands-on approach, it will allow for a more personalized and engaging experience to the students. In the majority of the available educational lab kit activities the focus is on mapping what is actually happening inside a school building in real time. This is done in two ways:

- Students use a "floor map" of their school as a surface to place all electronic components and devices, essentially assembling a small-scale interactive installation in most educational lab kit activities.
- They also conduct small quests inside the different parts of their buildings, indoors and outdoors depending on the activity, detecting and pinpointing specific rooms/devices/ways where there is energy-efficiency-related activity.

The educational lab kit has been used during the mini-trials in spring 2016, as documented in Deliverable D4.2, "Final Trial Documentation", and has been in use during the main trials phase of the project. Related documentation will be soon made public on the website of the project, in the "Educational Material" section.

4.2 Implementation of the Lab Kit

Regarding the actual implementation of the kit, it includes IoT devices, commercial or GAIA-designed, together with other IoT hardware components that can be used to assemble custom IoT systems, which can enable:

- *Monitoring of real-world parameters*, in a way similar to the stable IoT infrastructure installed inside GAIA school buildings, but which will be done in a more "personalized" and direct manner through the educational kit devices.
- *Communication with GAIA ecosystem software services*, in similar ways to the ones used by the infrastructure, also providing a clearer picture of how the overall GAIA system works.
- *Familiarization with electronics*, using common components, such as LEDs, resistors, switches, etc.

We have avoided the use of aspects such as extensive wiring between the different components, or complicated interconnections by using:

- *Conductive ink*, in order for students to "draw" the interconnections required between the various electronic components. In this manner, we avoid the extensive use of cables and breadboards, simplifying the overall activity and saving time.
- *Raspberry GrovePi hats,* that have standardized connectors for input/output interfaces, i.e., students and teachers do not have to worry about how to connect the components, or where, since all interconnections are carefully labeled to prevent confusion.
- *Magnet-carrying electronic components*, which enable easy placement on top of a metal surface. The use of magnets prevents the components from slipping and moving around during the lab kit activity.
- *Printed paper school building floor maps,* which illustrate both the parts of the building and the placement of electronic components for the lab activity. The paper maps are placed on top of a metal surface, which means that components that carry magnets are placed firmly during the lab activity.

In addition, in order to carry out certain activities for the lab kit, we utilize additional thermal cameras integrated into smartphones. For these specific activities, students are engaged in an energy inspection-like tour of their building, in which they are asked to spot issues related to energy consumption, and identify probable causes/solutions.

Regarding the composition of the hardware part of the Lab Kit, we utilize the following components:
- *Raspberry Pi*, as the device handling the main computing and networking duties for the lab activities.
- *Conductive ink markers*, for sketching out wire paths onto paper. At this point, we are using the Circuitscribe[6] markers.
- *Electronic components*, such as LCD screens, resistors, switches, potentiometers, etc. At this point, we are using Circuitscribe components, mainly due to their magnetic clip attachments, ease of use and overall safety.
- *Sensors with standardized interfaces for connecting to the Raspberry Pi*. At this point, we are using the GrovePi[7], an open-source family of sensors available from various distributors, which use standardized interfaces and are suitable for educational activities due to their design.
- *Custom electronic boards*, which ease interfacing with GAIA and visualization of real-time data used during the lab activities.
- We plan to enhance the available options and use additional components and technologies in the coming months, in order to provide more options for interfacing as well as cover cases where schools may already have similar equipment and would like to utilize it.

Regarding the software part of the Lab Kit, the Raspberry Pi devices use the Raspbian Linux distribution, while the Lab Kit activities are based on a number of Python scripts provided by the consortium. The lab kit activities use the default options for Python provided by Raspbian, while we use the standardized Web interfaces of GAIA for communicating to the system for real-time data, thus no additional changes are required to the vanilla Raspbian distribution for Raspberry Pi.

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[6] https://www.circuitscribe.com/

[7] https://github.com/DexterInd/GrovePi

4.3 Organization of the Lab Kit activities

Regarding the overall organization of the activities and the provided material, the consortium has prepared a series of lab activities, covering aspects of energy consumption and efficiency inside school buildings. The thematic list covered is the following:

- Energy consumption in our school.
- Lighting inside school buildings.
- Heating inside school buildings.
- Temperature, Humidity and Thermal Comfort.
- Devices and Energy efficiency.
- Energy Inspectors - The energy footprint of our building.

An additional activity can be implemented in case a certain school would like to implement a "stable" interactive installation, in the form of a class project by the students, in order to depict some kind of energy efficiency metric in its own school building. We include some examples of activities in Annex IV of this document.

Regarding the provided material, there are available guides for each activity. In the description of each activity, we include the title of the subject, the necessary cognitive background for the teams to be implemented (theoretical and practical) and a short description of the tasks to be completed (goal). One set of material concerns the educators, identifying the educational target for each activity, the methods used, as well as a schedule for the proposed lab activity. Another set of material addresses the students' part, giving specific instructions on how to perform the envisioned activities, explaining how to interconnect sensors and electronic components, and how to execute the Python scripts provided by the consortium.
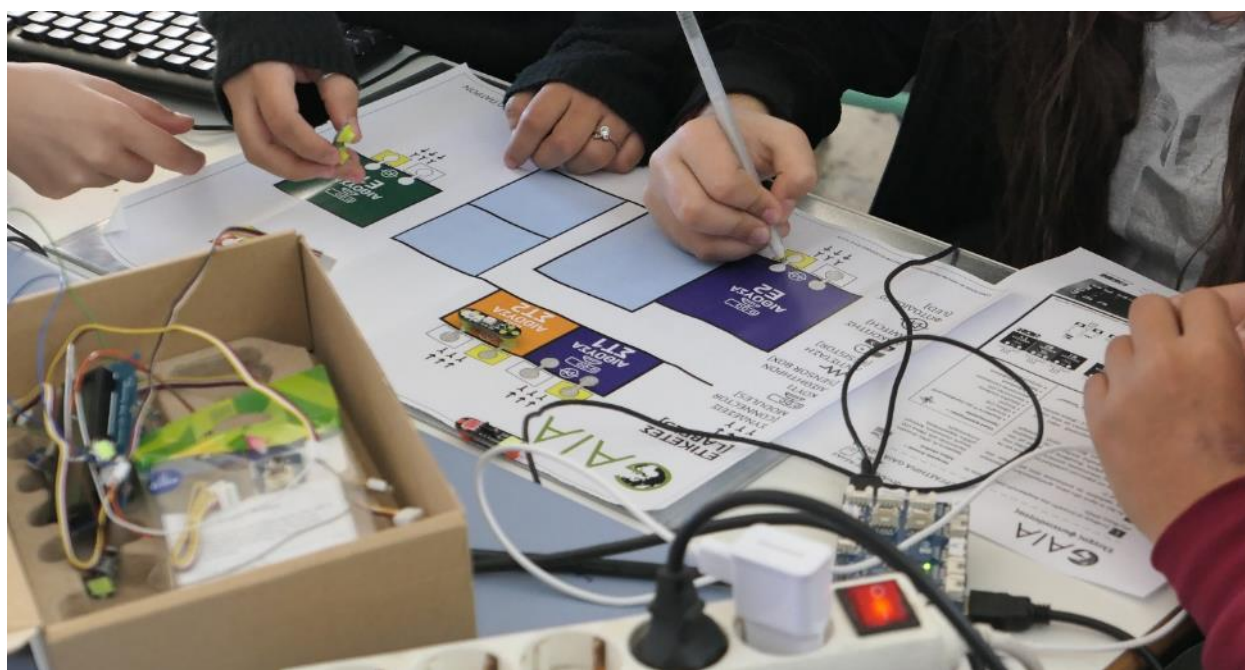

Figure 4: Example of in-class activity with the Lab Kit. Primary school students use conductive ink to draw circuits on top of a printed floor map of their school.
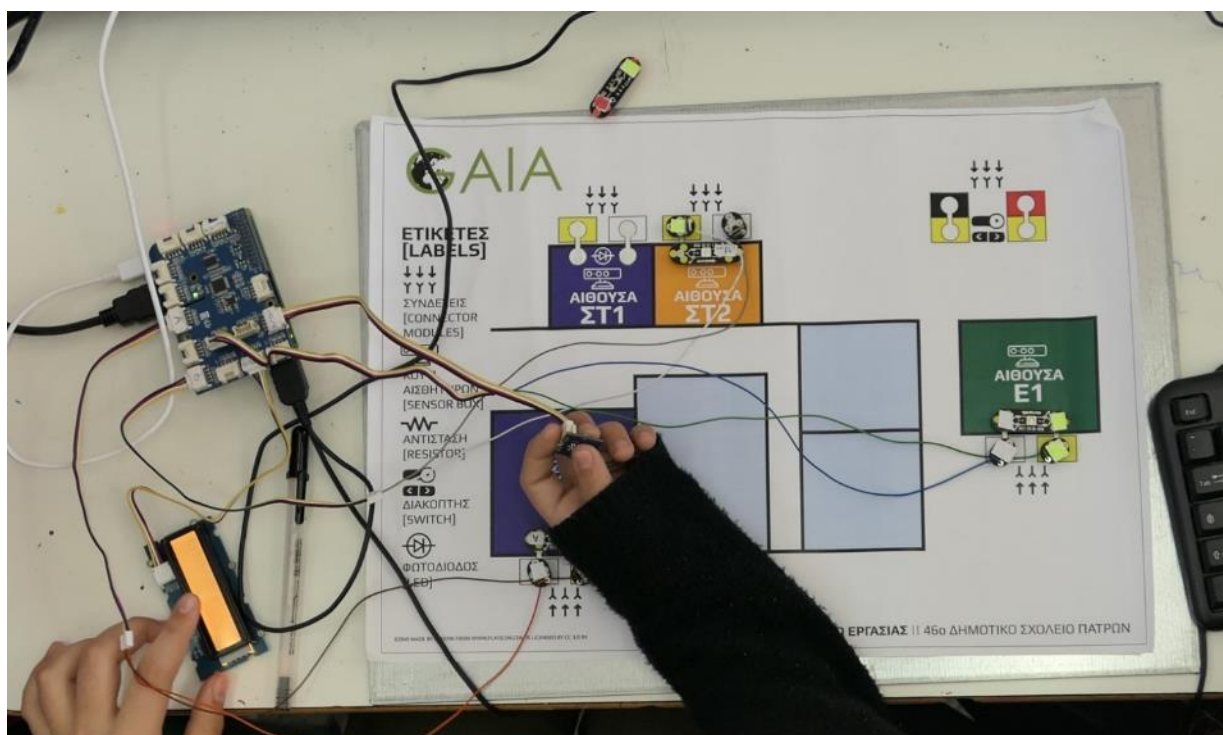
Figure 5: Example of in-class activity with the Lab Kit. A student uses the kit to visualize temperature readings in different classrooms of her school building (purple, orange and green rooms).
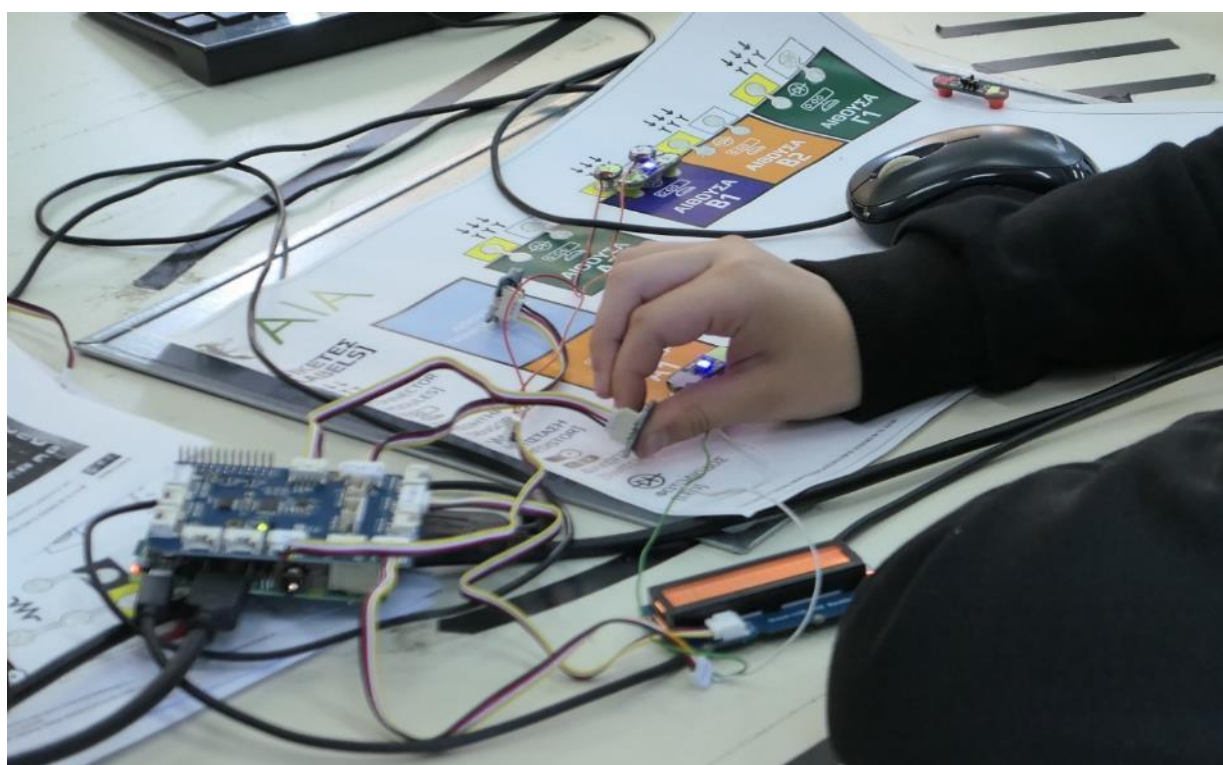

Figure 6: Example of in-class activity with the Lab kit. A student uses a button to visualize different modes of readings inside his school on LEDs and an LCD screen.

4.4 Integration within GAIA Challenge and other GAIA tools

The lab kit activities have also been integrated into the GAIA Challenge, in the form of additional quests unlocked for the schools that are planning or are participating in such activities. Essentially these quests are

a visual aid for students to prepare for the lab or understand a bit better aspects such as e.g., the wiring between electronic components. Educators can choose to "unlock' these Lab Kit-specific quests before or after the first Lab Kit activity, in order to familiarize students with the Lab, or repeat some of the activities in order for students to get a better understanding of the tools and methodology used.

We also provide sample additional activities to the educators, suggesting ways to integrate the rest of the GAIA toolkit with the lab activities, e.g., in the period between two successive lab activities students can use the Building Manager Application to monitor environmental parameters that they checked during a lab activity. They can then discuss their findings with their teachers when they have their next lab activity at school. They are also encouraged to share their findings/progress on the GAIA Challenge or Facebook page of the project. GAIA Challenge can also be used as homework, so that students do not lose contact with the workshops for a long time. The content of the questions may refer to the completed or the next workshop as a means of assessing or preparing the children respectively.
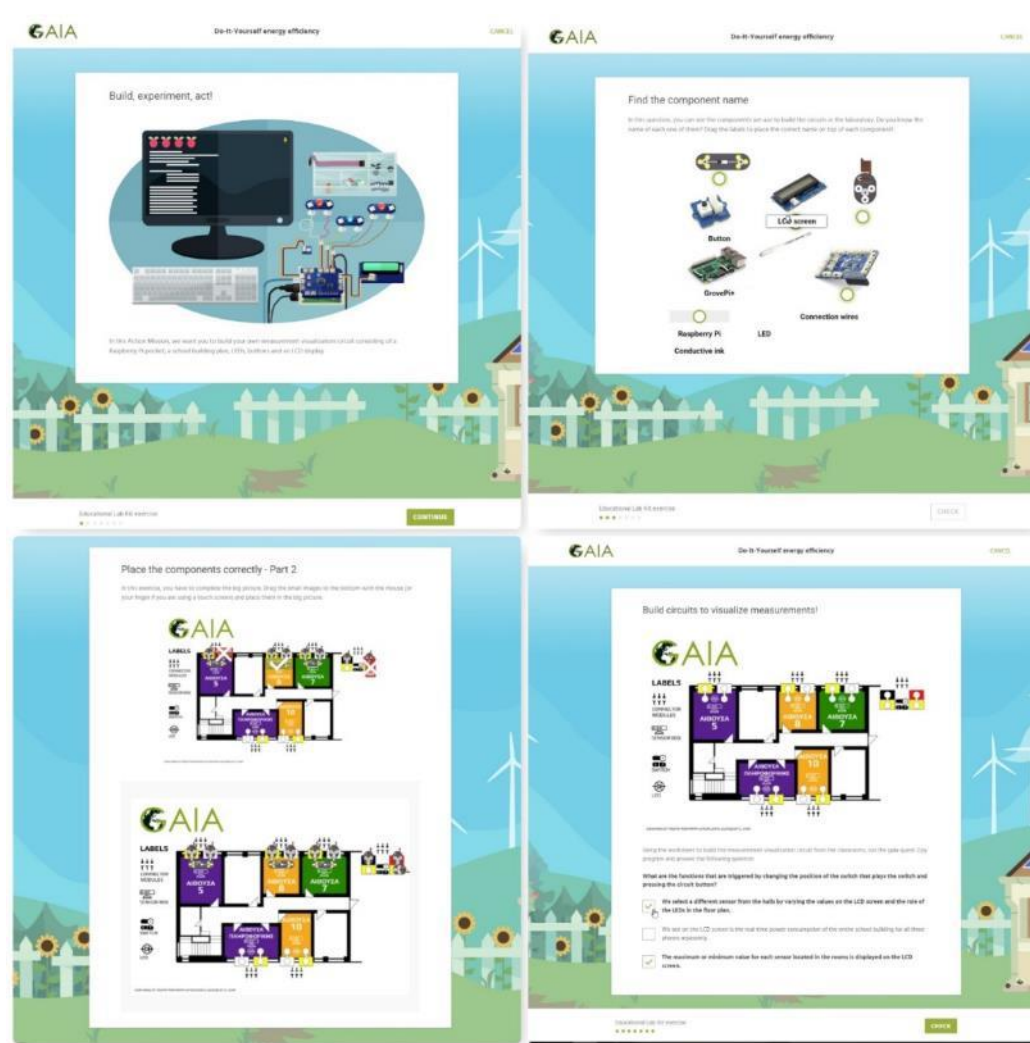

Figure 7: Screenshots for the Lab Kit mission included in the GAIA Challenge
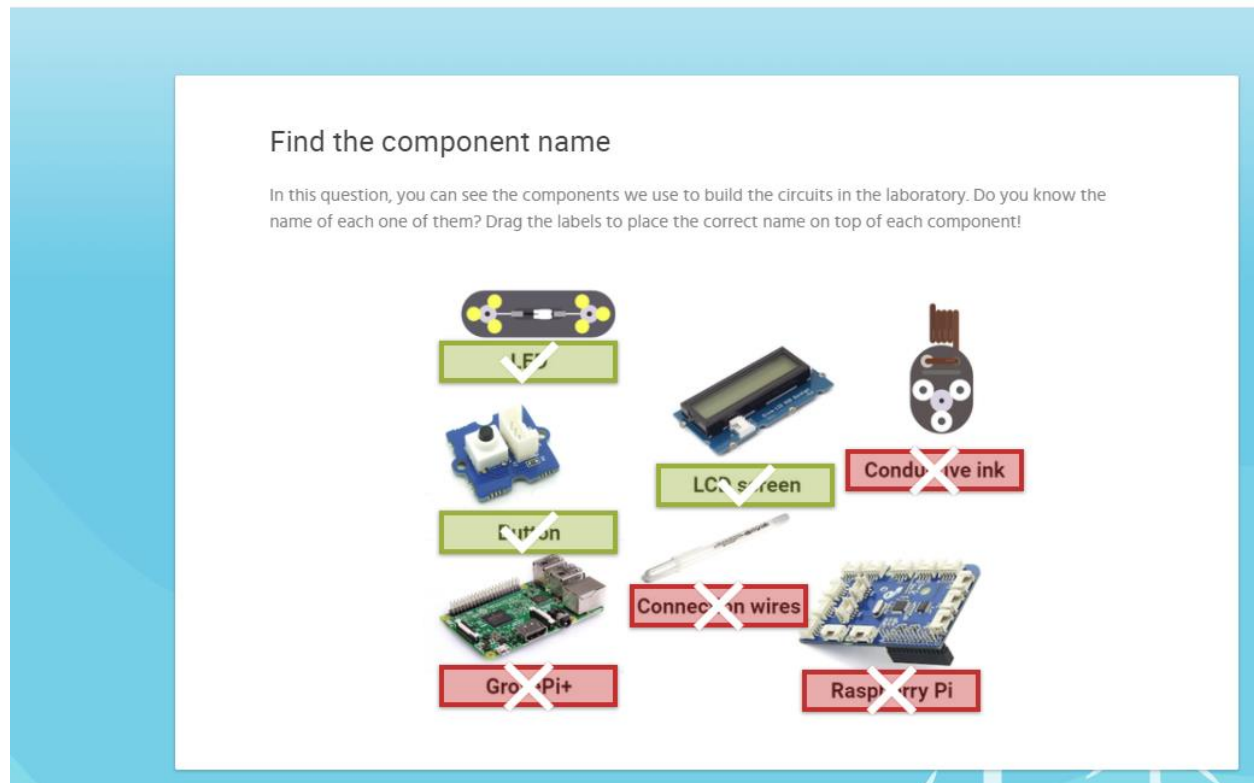
Figure 8: Example of activity within GAIA Challenge asking students to identify the names of the components used with the Lab Kit

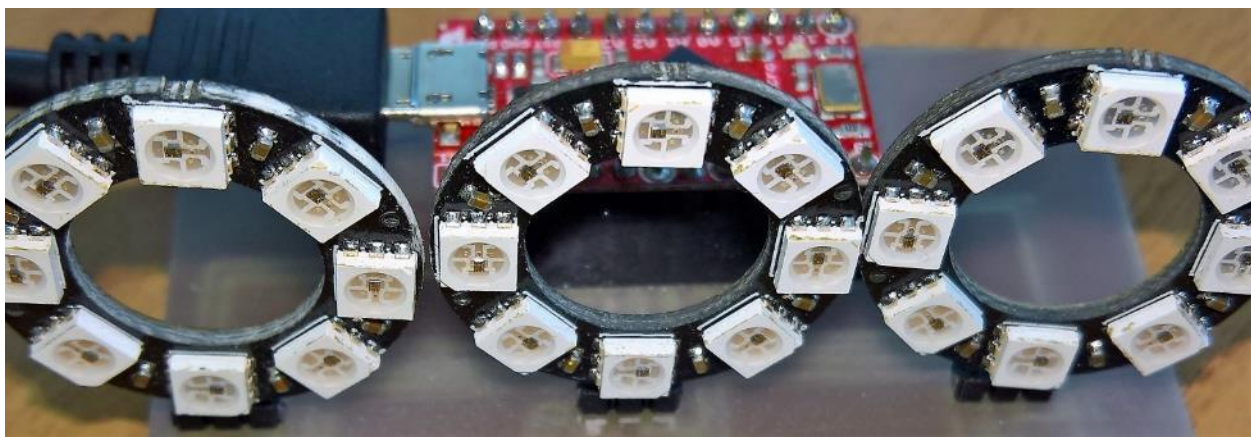Figure 9: Example of a custom component used in some of the Lab Kit activities. The 3 LED rings are used as "dials" to display levels of power consumption, temperature, humidity.

4.5 Educational Lab Kit Guidelines for the Educators

In this section, we include some of the guidelines laid out for educators in order to form their student groups during the lab kit activities, and proposed methods for implementation.

4.5.1 Suggested methodology and educational scenario requirements

The first and most important step for the success of the lab exercises is the establishment of a "Learning contract". For this reason, at the beginning of the workshops, a series of rules are presented with respect to communication in groups. Then, assignment of roles to groups and set the person who directs and communicate with the teacher signals. When students share their work to gain the knowledge you need to have multiple roles, which will rotate and will "play". The aim is to operate independently within the Group and the roles they can play. Other helpful tools to understand the concepts that the members of teams have to conquer or to control the smooth flow of workshops can be:

- Short (about two to three) questions in each worksheet.
- Sudden question – e.g., what is the goal of the group? The question is provided by the leader and answered on paper by the team.
- The worksheet will refer to the workshop's central concepts (keywords).

We must always bear in mind that students learn better, when they are more actively involved in the educational process. Regardless of the theme of the workshop, students working in small and collaborative groups conquer more knowledge.

4.5.2 Design and organization of work groups

All of the tasks the teams need to complete, during the lab activities, require interdependence on how members work. The members who form a group are responsible and depend on all the others who are involved in it. In general, we suggest having teams of four or five members. Large groups reduce the chances of active membership of each member. In addition, the fewer cognitive abilities of members who are invited to participate in a workshop, the smaller they must be in groups. Finally, the shorter the duration of a workshop, the smaller the size of the groups. For the above reasons, the optimal number of people proposed to participate in each group of the lab is three (3) to five (5).

4.5.3 Interdependence within groups

To instill/foster a feeling of interdependence within groups, all members should:

- Keep notes that help complete the work.
- They hear each other.
- They learn that they can each other.
- They want to make sure they are on the "right track" to solve problems or to understand the work to be done.
- They contribute to the work of their team members.
- They share their knowledge in every way.

4.5.4 Motives for engagement and reinforcement of self-esteem

In order to encourage teams to provide incentives during the workshops, the following strategies are proposed:

- We interact as often as possible with the teams, reminding them that they are doing very well and have many possibilities.

- The work of the teams must correspond to the level of knowledge of its members. This means that they should not be too easy to complete, but also not too difficult to discourage students.
- We call the members of the teams with their small name and discuss with them both *before* and *after* the workshops (e.g., during the break). We talk to them about possible queries and we make your team your own team by talking to the first plural person (e.g., I think our team is going horribly. Is there any question that we would like to discuss?)
- We always stress that the error is not a failure, but an attempt to achieve the goal to be rewarded. We must constantly point this out emphasizing that "error is an essential ingredient to success".
- We give value to the efforts of the children participating in the workshops, highlighting the benefits they derive from their engagement with them and their prospects through the knowledge they gain.
- Under no circumstances should performance of teams be compared. Competition, in most cases, has a negative effect on cooperation (Morton Deutsch, 2003).

The way teams are created is a matter decided by the educators themselves, as it depends on many and complex factors related to the composition of classes and interpersonal relationships between students. Maintaining the consistency of groups is also a very important aspect, and we suggest not change the team even if it is not working properly.

4.5.5 Suggested methodology for problem solving

We suggest using group control mechanisms, which in turn help to deal with non-cooperating members:

- After each workshop, all team members answer a series of questions or complete a task that they will have to deliver to the next workshop.
- If possible, keep the number of members in each group low. In this way, we can avoid as much as possible the occurrence of people with the role of "observer".
- We must constantly emphasize to the groups that one of their tasks is to find the way through which they will face the non-productive behaviors that may arise.

A certain way of eliminating these problems is to prepare activities with a clear division of the work that each member of the group has to accomplish, defining in any case a clear goal. At this point, a reward system for teams that have successfully completed their work should be discussed as a model for cooperation and work effectively in each case.

4.5.6 Difficulty levels

Difficulty levels must be related to the cognitive background of the children participating in the lab activities, as well as to their age group. We have the following categorization of the activities:

- *Introductory/starter*, intended for all student groups to familiarize with the project's technologies and the monitored parameters. Such activities are the minimum set of activities that all participating schools (ideally) should have completed.
- *Normal*, after having completed the introductory activities these are the core activities of the lab kit.
- *Advanced*, intended for older students or students familiar with technologies used in Arduino and electronics.

For the sake of each scenario, the following list of documents - educational tools should exist:

- Teacher's Course Scheme

- Student worksheet
- Teacher's worksheet (with instructions)
- Student Assessment Work (Questions)
- Teacher evaluation work (Questions - Answers)

4.5.7 Setting educational lab goals

In education, the objectives of a unit of study are classified according to the dominant trends of international literature and practice in three levels:

- Level of knowledge: What knowledge will students acquire and/or what skills they will develop - related to the acquisition and exploitation of knowledge (understanding, analysis, synthesis, assessment).
- Level of competencies: What will students be able to accomplish after the end of the module.
- Levels of attitudes: What values will students develop or acquire, influencing their preferences and behavior towards certain persons, things or situations.

4.5.8 Introduction - Familiarization

Concluding a "Learning Contract" by agreeing on a set of communication rules in teams. Subsequently, roles are assigned to the groups and a person who directs and communicates with the teacher's signals. The use of the marks is also done by the teams. Finally, there is an introduction to the philosophy of the workshops to be implemented in the GAIA program. Children are divided into groups and respond to worksheet questions about the environment and how new technologies can be exploited to protect it. Discussion and submission of proposals are recorded.

4.5.9 Team formation

The working groups will be divided in different parts of the building by undertaking separate work. One part of the teams will build circuits that they plan to implement automation, and the other part of the teams will examine the state of the building and record the problems it detects using special instruments. The first part of the teams will implement the "internal workshop" and the second part of the teams the "external workshop".

5. Putting it together: GAIA applications in the educational activities

In this section, after having introduced the design and thinking behind the educational aspects of the project, we try to explain how these applications blend into the educational part of the project and the overall schedule of activities, through a series of examples. The GAIA application set includes applications for all the members of the school community: an educational serious game, a social networking application and a "monitoring-advice provisioning" application. These three applications aim to:

1. Educate the school community.
2. Engage them in the challenge of reducing energy consumption.
3. Support them with recommendations/suggestions.
4. Provide feedback and measure energy efficiency-related and educational achievements.

The application set of GAIA is described in more detail in Deliverables D3.2 "Applications Initial Release", D3.3 "Applications Final Release", and D4.2 "Final Trial Documentation". The reader should note that the application set is complemented by the Educational Lab Kit, i.e., educators can combine their scheduled activities with a lab kit activity to further add to the engagement of students, as well as augment the learning objectives of their curriculum. In the following table, we summarize the contributions of each component during the trials phase.

Table 13: The contribution of the various GAIA components in the context of school activities

GAIA component	Educate the school community	End-user engagement	Recommendations - suggestions	Feedback - Achievements
Social networking	√	√		
GAIA challenge	√	√		√
Building Monitoring		√	√	√
Lab Kit	√	√		√

It is important to note that the design and implementation of the application set and the lab kit was based on the following line of thought: GAIA wants to produce tools that help schools, teachers and students to perform their lectures and curricula by offering tools that can be adopted to the reality of each school, and not vice versa. The reality of each school cannot be easily adopted to the toolset of GAIA, while the project is ongoing. Educational programs and school schedules are already tight enough to prohibit long-term actions that disrupt such realities and time schedules.

In the following, we describe how our applications are used in the context of a generic educational scenario along the course of several weeks of lectures, following the guidelines mentioned earlier in this document. We assume that the teacher has already completed a first unit title "Introduction to energy efficiency and GAIA" and then the class proceeds to a second theme focusing on lighting inside buildings. The idea is to use a set of educational material to conduct the lecture part of the activity during 7 weeks, while relying on the

GAIA toolset to enhance these class activities. We provide an example with general guidelines e.g., on how the Building Manager Application could be used within this context and timeframe.
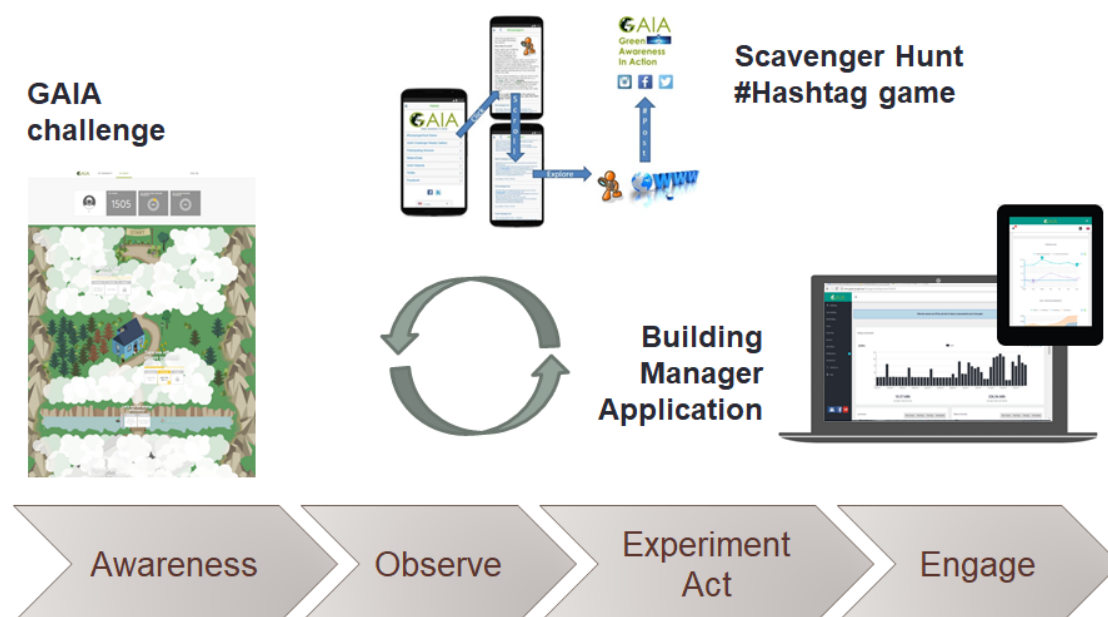

Figure 10: The interplay between different GAIA applications and the overall planning of activities

5.1 Setup before educational cycle begins

During this step, registration with GAIA Challenge and setting up of the mission teams in GAIA challenge occurs. Access to the GAIA BMS application is also granted by the consortium to all user groups that should have access during the trials. Accounts are created either by registering in the platform from scratch, or upon invitation from a high-level user.

5.2 Weeks 1-2: Raising awareness

Initially, the teacher introduces his students to the theme through conventional teaching. The aim is to acquaint the students with the basic and important concepts linked to the topic. Then we sets out the knowledge mission "*Turn me off unless you need me! - I*". Students are introduced to the relevant Knowledge Mission in GAIA Challenge. They play the quests "*Light in the dark – I*" at school and the teacher asks the students to play the "*Light in the dark – II*" at home.

Playing with the quest, students respond to a series of short tasks, one after the other. In each Quest, there is a variety of tasks for students to interact with, such as single and multiple-choice questions with text and images, image-based drag and drop tasks, selection and search tasks, texts with gaps to fill in, or value estimation tasks. After each response, they receive feedback from the system, in the form of a short explanation. By playing, students score points for their Mission Team. When a student has completed all Quests of a Knowledge Mission, she can submit a Snapshot for this mission and in this way share an achievement with the community. At the top of the 'My Quest' area, students can also see their scored points and overall progress in the Challenge. At the bottom of the page, they can find the activity log, which shows their recent activities and achievements in the GAIA Challenge. The 'My Community' area of the Challenge is devoted to showing the achievements of the different Mission Teams. There is a Mission Team leader board, where students can click to reveal more information about each Mission Team and its achievements, including its members' personal scores.

5.3 Weeks 3-4: Observation and investigation in an Action Mission

The observation and experimentation phases can be considered as action missions in the "GAIA challenge" terminology.

In the observation phase, the teacher guides the students monitor and analyze a) the energy consumed for lightning in the school building, and b) the light levels in their classroom. The BMA offers data visualization in chart format, which can be used by students under the guidance of their teachers.
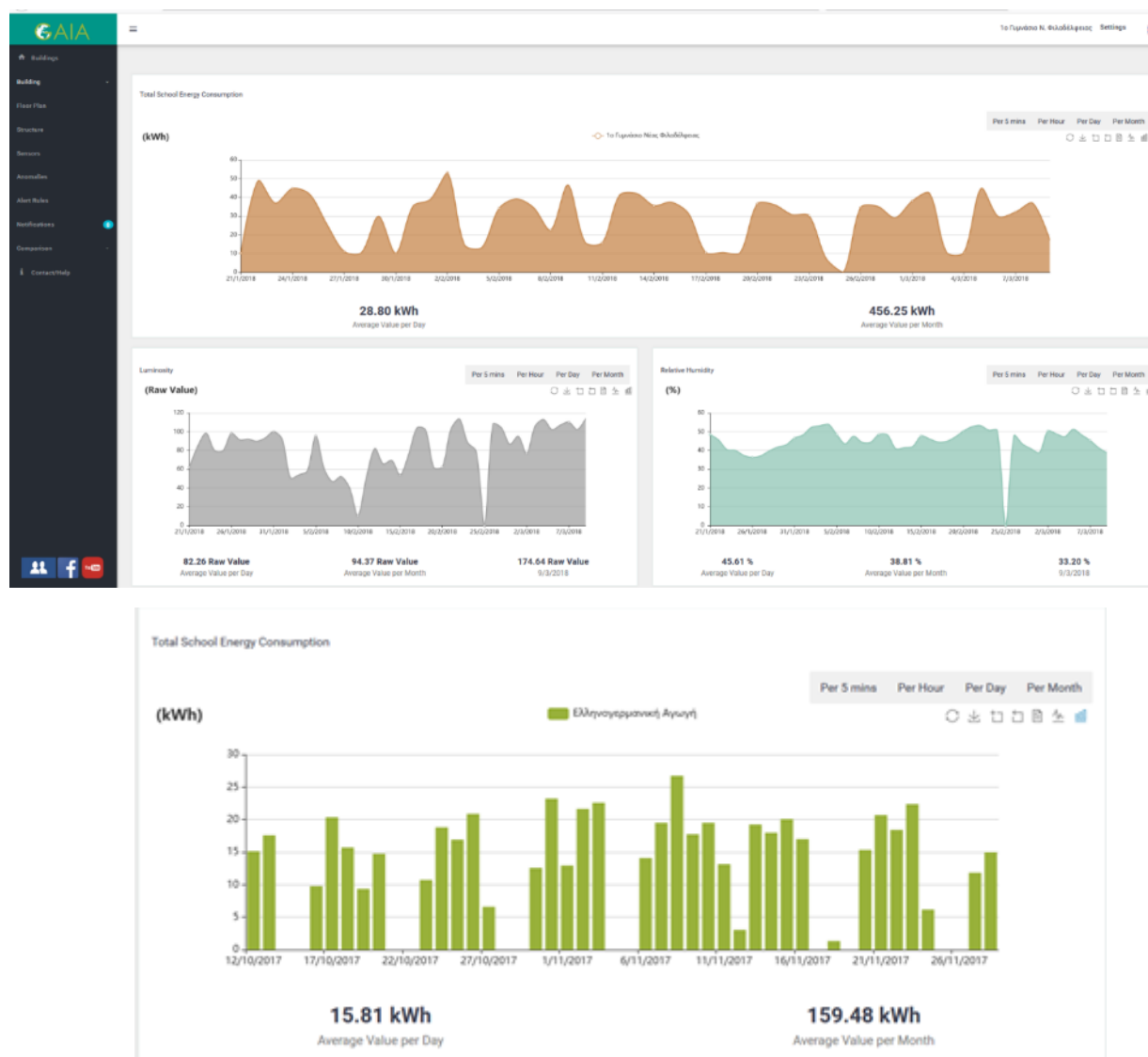

Figure 11: Data visualisation in the BMS

Depending on the age of the community and their background, they can be guided to explore the set of sensors installed in their school through the Sensors page.
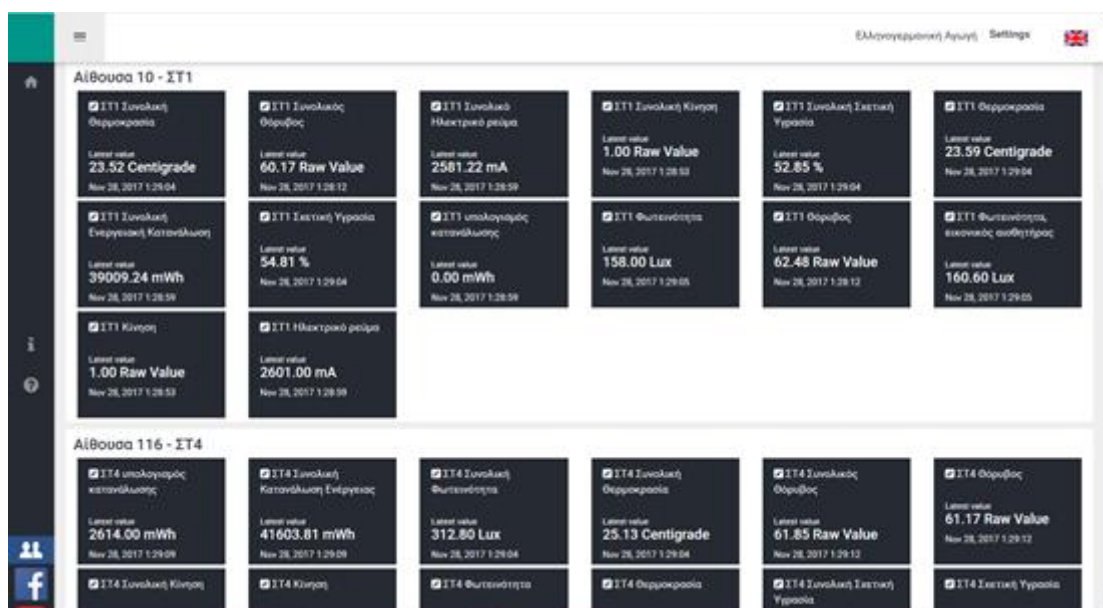
Figure 12: Sensor page on the BMS

By clicking on a sensor, they view its history in a chart presenting values in the chosen granularity. In our case, focusing on the use of lightning, the luminosity can also be measured by the GAIA mobile app automatically, exploiting the luminosity sensors that exist in any mobile device. The teacher and the students can check whether the luminosity is appropriate or not. In the **investigation phase**, students turn off the lights and check whether the luminosity remains within the thresholds defined by standards as appropriate to learning purposes. If so, they check the impact on the consumed energy. They can even compare between different periods, e.g. before and after turning off the lights as shown in the following figure. The teacher can also prompt the students calculate the energy saved in a school-day-time and the corresponding CO_2 emissions saved.
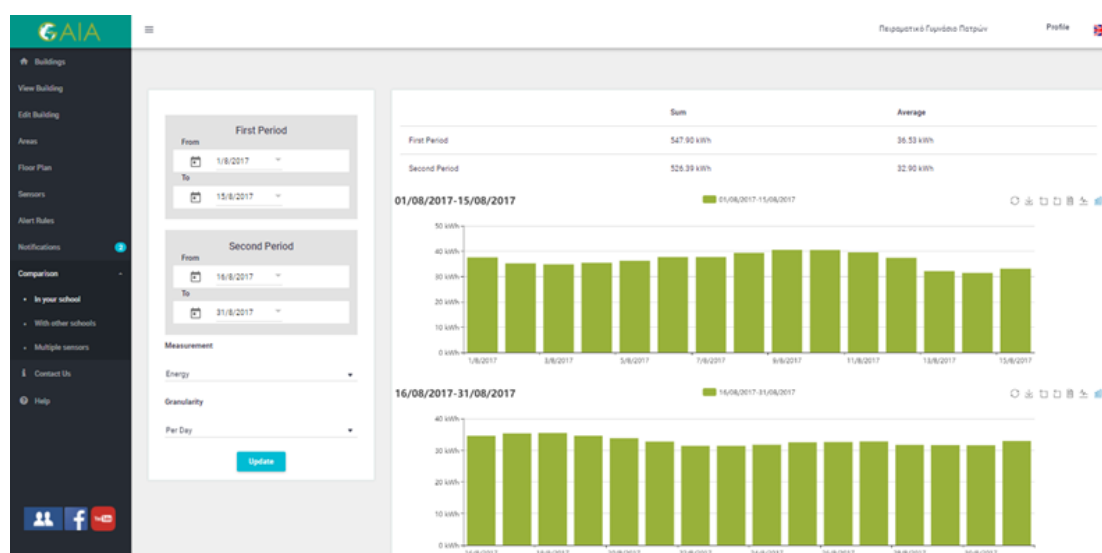
Figure 13: Visualization of readings for the same building for two different periods

Educators and students may define the space observed (e.g., a specific classroom). Even if there exist no installed GAIA meters and sensors in their own school, the teacher and students can still do activities by collecting and recording data themselves, e.g., by submitting readings from the power company's meter. Depending on the target school community, users can choose to view the data in a bar chart or work with numerical data, as the Application also offers the possibility to download the data in various formats.

Additionally, they can compare with other schools. To support this comparison, all users of the BMS application have access to the data of all the participating schools in GAIA. In the following figure, the energy consumption of two Greek schools over the same period is visualized.

Figure 14: Energy consumption comparison between two different schools in the BMS in a user-defined period

5.4 Week 5: Reporting on Action Mission and deciding on long-term action

In this phase, having just completed the Action Mission, students report on it through a Portfolio uploaded by the teacher in GAIA Challenge. Its content may include snapshots of the BMS showing the achieved energy savings, information pieces used to calculate the equivalent of savings in CO2 emissions and pieces of advice to other groups, or any other material.

Based on their experiences from the Action Mission, students decide to take **long-term action** to improve energy efficiency in a wider timeframe, i.e. during several weeks or months. Through discussion, students realize that to achieve noticeable results on the energy consumption of the school building their action requires longer-term engagement over several months. While preparing towards their decision for certain action, and then as they start implementing it, students continue activities based on data and expanding on what they have already done during Action Missions. During the action phase, they continue observing and analyzing the impact of the longer-term changes in everyday school behaviors and habits on energy consumption, monitoring their course towards achieving their goals.

The GAIA Challenge plays multiple roles in the GAIA ecosystem: the applications are interlinked among each other in many ways:

- Students and teachers pick up tasks from the Challenge and either work on these tasks directly in the Challenge and use the Social Networking Game and/or the Building Manager Application as tools.
- Knowledge Missions are played directly in the Challenge browser window, but may require additional research or actions from the other applications.
- Findings, results and ideas can be shared in the form of Snapshots with the local and the online community.

- For Action Missions, no direct interaction within the Challenge is required but instead students have to engage with their school community, the school building and the other applications.
- The results of these Action Missions can be documented in the form of written portfolios supplemented with photos and videos taken by the students.
- Data visualizations can be grabbed from the Building Manager Application and embedded into Snapshots and Portfolios as well.
- Portfolios and Snapshots can be shared easily with an even bigger community via the Social Networking game.

The long-term engagement in action can be further fueled by notifications sent to teachers and students by the GAIA platform, based on the data gathered through the monitoring infrastructure. In our example, the students may decide to set a rule that generates notifications when the luminosity is above a certain threshold so that they turn off the lights. This can be done through the BMS as shown in the following figure. This rule will generate notifications, which the building manager will be able to see in the corresponding page in the Application.
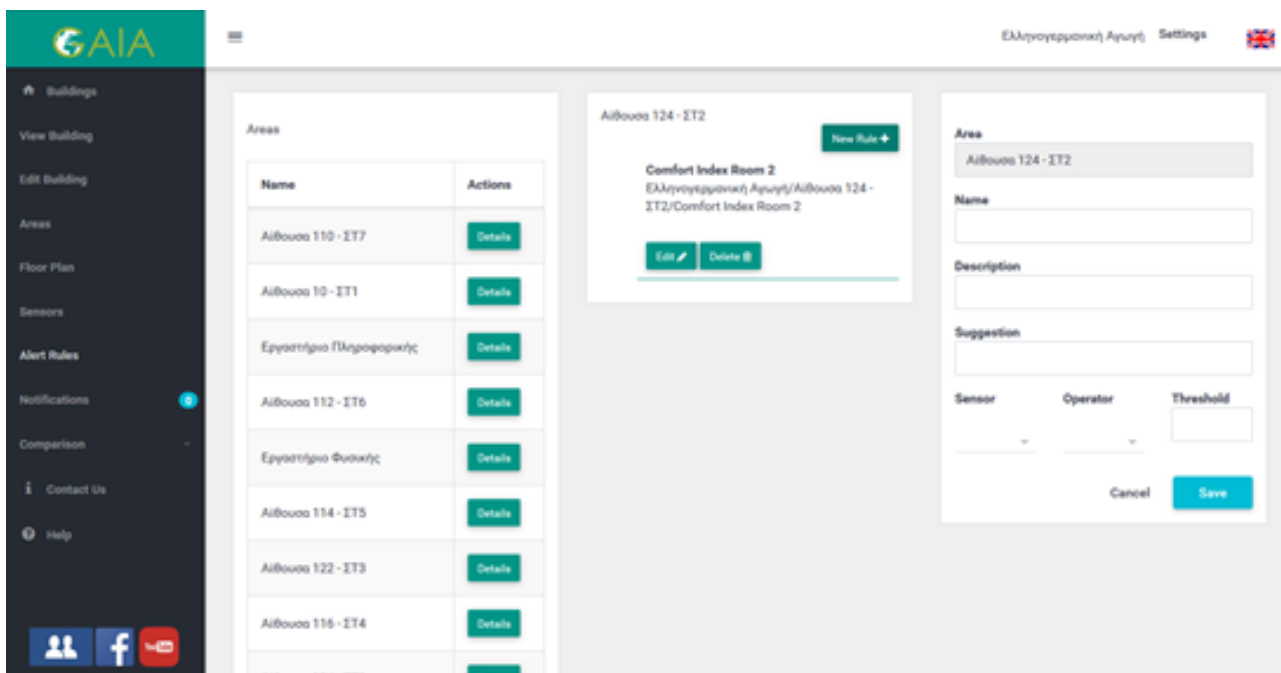

Figure 16: Rules and rule creation in the BMS

5.5 Weeks 6-7: Community involvement and playful social engagement

In this final stage, the students produce materials and disseminate them through the GAIA Community Engagement Games. Setting-up a GAIA Community Engagement and Social Networking Game, to raise awareness and playfully sustain students' as well as the wider community's interest in, and engagement with, project activities, through weekly GAIA Scavenger Hunt hashtag games implemented in popular social media.

A specific scenario of the usage of this within the trials is an action mission that is already a part of the *Educational Serious Game,* entitled **"Let's wake up the locals".** This task involves the students using their private Facebook, Twitter and/or Instagram to encourage their respective friends and followers to comment

on or share energy efficiency-related photos, images, drawings and memes created by the class to see how far they can spread. The posts will be tracked using a unique #hashtag or #hashtags the class or groups within the class have decided upon.

The *Community Engagement and Social Networking Game (Connectome game)* and *the Educational Serious Game* share ideas and goals that go hand in hand with each other. They share the concepts of raising awareness, sharing information, expressions of creativity and competition.

A specific scenario in of the usage of our *Community Engagement and Social Networking Game* within the trials is an action mission that is already a part of the *Educational Serious Game,* entitled **"Let's wake up the locals".** This task involves the students using their private Facebook, Twitter and/or Instagram to encourage their respective friends and followers to comment on or share energy efficiency-related photos, images, drawings and memes created by the class to see how far they can spread. The posts will be tracked using a unique #hashtag or #hashtags the class or groups within the class have decided upon.

For example, a student may have made a drawing as the one pictured to the left. She and her team can decide that they would like to use it to "Energize the Community" so they all post it on their social networks with a short explanation of what they are learning in school and what this experiment is about. Along with the explanation, they will use a specific #hashtag they have come up with using the word "GAIA" somewhere in it, like #GAIAclass2soderhamn or #PhysicsSoderhamnGAIA. Additionally, they request that their friends and followers share it. The #hashtag will be used to track how far the image has spread. The teacher may then search for the different groups of #Hashtags that were used to find out which image spread to the most people across the Facebook, Twitter and Instagram.

Their posts would contain the image above as well as some text similar to those in the boxes below:

"We have been studying energy efficiency in school and how much electricity is used by keeping electricity on with @EUGAIAProject" "I challenge you to post a drawing or picture about what you have learned using #PhysicsSoderhamnGAIA and #Sweden"	"Here is a meme I made about energy efficiency. My teacher wants me to share it and ask you to share too" #PhysicsSoderhamnGAIA #Sweden

Reporting on experiences and achievements overall in the cycle in a final updated version of the Portfolio, uploaded by the teacher in GAIA Challenge and social media.

5.6 After the end of the cycle: continuing long-term action

Continuation of long-term action for energy efficiency, using the GAIA Application to monitor the impact.

Annex I – Templates for monitoring the educational settings and circumstances in the pilot sites

Information sheet: Input into the GAIA educational/pedagogical design

A. Country of GAIA pilot activities

❑ **Greece**   ❑ **Italy**   ❑ **Sweden**

B. Coordinator of the GAIA pilot activities in this country

Project partner: _____

Contact person: _____[name], [email address], [skype id]_____

C. Technical project partner(s) involved

Partner(s) involved in GAIA technology deployment in the country: _____

In case of more than one, **Partner leading/coordinating technological deployment:** _____

Contact person: _____[name], [email address], [skype id]_____

D. Technological circumstances in the pilot sites

❑ (Almost) **the same technological circumstances in all sites** in the country (i.e. minor differences NOT requiring different activities in the various sites)

❑ (Considerable) **variation in technological circumstances among sites** in the country (i.e. major differences requiring different activities in the various sites)

Please explain in short: ___(referring to the provisions in the D1.1. design document)____

Availability of user devices (tablets/computers) and internet connection for use in GAIA's activities: ___[Type and number of devices available per site, any connectivity restrictions, any restrictions in use, e.g. legal restrictions re. handheld personal devices in schools, etc]_____

E. Educational circumstances in the pilot sites

E.1 Variability within the country

❑ (Almost) **the same educational circumstances in all sites** in the country (i.e. minor differences NOT requiring different activities in the various sites)

❑ (Considerable) **variation in educational circumstances among sites** in the country (i.e. major differences requiring different activities in the various sites)

Please explain in short (you will provide the details further below)**:** _____

E.2 Timing considerations

School/academic holiday periods in a year: ___[please name and state length in days/months and approximate starting and ending dates of each period]___

Non-holiday periods in the school/academic year during which GAIA pilot activities **cannot/should not be implemented** (e.g. end-of-year exams): _____ *(*Please indicate if this only refers to some of the age groups or pilot sites defined further below)*

E.3 List of pilot sites

[country_code][no.] _____

e.g. GR1 _____

GR2 _____

GR3 _____

…

E.4 Detailed information per site

(Please repeat for each pilot site)

Pilot site: [country_code][no.] _____

Students involved:

Age groups to be involved in GAIA pilot activities (please indicate all that apply):

❑ <10yrs   ❑ 10yrs   ❑ 11yrs   ❑ 12yrs   ❑ 13yrs

❑ 14yrs   ❑ 15yrs   ❑ 16yrs   ❑ 17yrs   ❑ 18+yrs

This/these age group(s) commonly named as: ___[e.g. 6th grade in primary school]___ *(*Please make sure to include information indicating to which education system level each of these groups belongs in the country: primary, secondary, post-secondary, tertiary education.)*

(Approximate) number of students to be directly involved in GAIA pilot activities per age group: _____

School staff involved:

GAIA pilot activity leader/coordinator/partner available within the school?

❑ Yes. Please specify: _____[e.g. head teacher, science teacher, ICT teacher, …]_____

❑ No. Activities in school to be led by representatives of Project Partner…_____

Role of 'building manager' played by: _____

Additional teachers to be involved in the GAIA pilot activities: ___[approximate number of teachers, by subject areas]___

Details of educational/pedagogical content and processes to be discussed and agreed:

❑ Through the national coordinator only

❑ Also possible through direct contact with school staff: ___[please give details]_____

Workshops/meetings with the teachers can/should:

❑ Be held in project partner's premises (teachers can move to project partner premises)

❑ Be held at a distance (e.g. via skype) without any significant expected problems

❑ Be held within the pilot site only (project partner visiting the site)

Restrictions or preferred periods for workshops/meetings within the school year: _____

Links of GAIA pilot activities to specific curriculum subject areas:

❑ **No particular preference** for links to any subject areas (the project will decide the areas)

❑ **Preferred curriculum subject area(s)** to which to link GAIA pilot activities: ___[e.g. science, environmental studies, ICT, engineering, etc]____ *(* If applicable, please provide information by age group, and mention links to existing work/ initiatives in the school)*

❑ **No link to curriculum** is possible or wished. GAIA activities will be independent from any other 'lesson'/learning goal/learning activity.

Preferred/possible GAIA activity implementation mode:

Please indicate below all those which apply and explain:

❑ As part of the usual teaching activities, e.g. during lessons, etc

❑ As additional activities outside the usual teaching activities, e.g.in an afternoon club/project, etc

❑ Including activities outside the school, e.g. at home, involving families/local society etc.

Details: _____

Stability of educational circumstances in the pilot site:

Any significant changes expected in the educational circumstances in this pilot site in the course of the preparatory and/or pilot activities – or between preparatory and pilot activities *(* Preparatory activities: 2016-2017; pilot activities: 2017-2018)*: _____

School activity plan template

GAIA School Code:	
Country:	
Name of the school:	

The physical space

Physical space in the school monitored in GAIA:	Number and kind of rooms or clusters of rooms:	
	Special characteristics and other information on the rooms:	e.g. use, windows, compass orientation, etc
	Local weather monitored?	

Sensors and meters

Available sensors, meters, other measuring instruments	Installed GAIA equipment:	what is monitored through the installed sensors and meters of GAIA
	Other equipment:	what else can be measured by teachers/students using other equipment (e.g. thermometers, etc)

User devices

Available user devices	Type of equipment with internet connection:	smartphones, tablets, computers…
	Place:	e.g. in lab, classrooms, …

	Limitations or restrictions in use:	
Devices of display or projection	Type of equipment with internet connection:	e.g. projectors, display screens, …
	Place:	e.g. projectors in classrooms, display screens in common spaces…
	Limitations or restrictions in use:	

Students

	Number of students:	
Students **directly involved** (considerable amount of GAIA activity):	Age of students:	
	Education level and grade(s)/year(s)/group(s):	

	Number of students:	
Students **indirectly involved** (informed about GAIA activity):	Age of students:	
	Education level and grade(s)/year(s)/group(s):	

Staff

	Name, position/role in school:	
Person acting as building manager	Will the same person probably be available to run GAIA activities in 2018-2019?	

	Name(s), specialization(s):	
Teacher(s) running GAIA activities in school year 2017-2018	Will the same teacher(s) probably be available to run GAIA activities in 2018-2019?	

School curriculum and schedule

Position of GAIA activities in relation to curriculum and school schedule	Subject area(s) and/or cross-curricular activities:	
	Place of GAIA activities in the school schedule:	e.g. during lessons, outside lesson hours ,…

Local community

Possibility for outreach and synergies with the local community	Local agents/communities that can be accessed and involved:	e.g. students' families, local authorities / initiatives, …

Themes

GAIA themes to be covered (preferably all!)	Use of lighting:	
	Use of heating or cooling:	

	Use of electrical and electronic devices:	
	Building and local characteristics (orientation, insulation, climate):	

Cycles in the school year

GAIA activities in cycles during the whole school year	Timing:	*Proposed:* 1st cycle: mid-November - December 2nd cycle: January – mid-February 3rd cycle: mid-February – March 4th cycle: April – May

Use of the GAIA Challenge

Use of the GAIA Challenge in the activities	Students' individual registration with GAIA Challenge:	Any problems foreseen?
	Set-up of the Mission Team(s) of the school in GAIA Challenge:	teams within a class / a whole class / an across-school team?... etc.
	Place and timing of GAIA Challenge use:	In classroom or not, in which lesson or other time frame, for how long, …

Use of the GAIA Application

Use of the GAIA Application	Different teacher accounts next to the central building manager one?	
	Student accounts for individual student access?	
	Possibility to use the GAIA mobile app?	
	Place and timing of GAIA Application use:	In classroom or not, in which lesson or other time frame, for how long, …

Annex II – Gamified learning content for the GAIA Challenge

A characteristic example of co-design with educators within the GAIA consortium is the development of the gamified learning content of GAIA Challenge. Educational content developed for this purpose by teachers in Ellinogermaniki Agogi (EA) was turned into game content, and structured into gaming tasks, based on game design and educational design considerations in the context of cycles of intensive co-design involving educators from EA and game designers and developers from OVOS. Some results of this process are presented in the present Annex for illustration purposes.

Structure of the gamified learning content

5 Knowledge Missions and 2 Action Missions, including 14 tasks and approximately 140 sub-tasks.

The key concepts:

GAIA agents (e.g. "EnEf agents", or "Energiers"):

- The individual participants of the Challenge (students, teachers)
- They work in teams (the 'Mission teams') to accomplish energy efficiency missions (the 'Missions')

Mission teams:

- The social unit in the Challenge
- The size of a Mission team may vary greatly: it can be a team within a class, a whole class, an across-school team, etc.

Missions and Quests:

- The action-and-content units in the Challenge
- There are five missions:
  - Three Knowledge Missions; these are open for everyone to play at any time
  - Two Action Missions; these are activated by a teacher for a Mission team, at the time chosen by the teacher.
- Each mission includes at least three quests:
  - Two main quests, providing content and guidance
  - One concluding quest, motivating Mission teams to share their relevant accomplishments with the whole GAIA community, by submitting a snapshot (in the Knowledge Missions) or a portfolio (in the Action Missions).

The Knowledge Missions:

So, what's the challenge? (Introduction)

- Let's stay on this planet! (The need for energy efficiency)
- Let's GAIA! (Play GAIA to learn energy efficiency)

- Fasten your seatbelts! (First accomplishment in the Challenge: we are starting to GAIA! – Sharing accomplishments through snapshots)

Turn me off unless you need me! - I

- Light in the dark – I (The lights)
- Light in the dark – II (The lights)
- We did it: They are on with reason! (Sharing accomplishments through snapshots)

Turn me off unless you need me! - II

- Sleeping demons – I (The devices)
- Sleeping demons – II (The devices)
- We did it: They are on with reason! (Sharing accomplishments through snapshots)

What a school atmosphere! - I

- Hot or cold? – I (Heating and cooling)
- Hot or cold? – II (Heating and cooling)
- We did it: What a learning paradise! (Sharing accomplishments through snapshots)

What a school atmosphere! - II

- Building smartness – I (building orientation, insulation, local climate)
- Building smartness – II (building orientation, insulation, local climate)
- We did it: What a learning paradise! (Sharing accomplishments through snapshots)

The Action Missions:

Let's act for energy efficiency!

- Observe, experiment, act! (Action for behavior change in school)
- Let's 'wake up' the locals! (Synergies with the local community)
- Our GAIA actions (Sharing accomplishments through a portfolio)

Do-It-Yourself energy efficiency

- For beginner creators
- For master creators
- Our GAIA creations (Sharing accomplishments through a portfolio)

Example extract of the learning content developed for the GAIA Challenge

The learning content developed, as it was finally shaped after several iterations, is the final content of the GAIA Challenge. It can also be found at this link:

https://drive.google.com/drive/folders/0B2_d7G4Hd5pXbVEtUXdLOWRRdVU?usp=sharing

In this Annex, an example extract of this content, namely the content initially developed for the Mini-Trials, is presented below for illustration purposes.

Quest Name	Introduction

id	01_1
Type	Content
Name	**Hello and welcome!**
Content	Welcome to the first quest of the GAIA Challenge. From here on we will guide you through various topics on energy consumption in your everyday life at your school. That's right, we are talking about your school, your classroom and your school community. Because if you didn't know already, you will soon notice we are all part of the same energy ecosystem. Are you curious? Let's continue...

id	
Type	Content
Name	**What's a quest?**
Content	Do you see the small dots on the bottom left? That's your current progress in this quest. A quest holds multiple tasks, and each task is represented as a dot. As you can see, there are a couple of tasks ahead of you. A task can have various forms. Sometimes you simply need to pick the right answers from a list. But there are also tasks where you replace missing words in a text, search for something in an image, label areas in a picture or a chart or do some calculations. You only get points for correct answers. But don't worry, you can play a quest multiple times to improve your score.

id	
Type	Content
Name	**One more thing...**
Content	Take some time and think carefully before you submit your answers. There's no need to rush. Also, for some tasks you will have to do some research. You can use the internet to search for hints or ask your teachers and parents. Of course you can also play together with your friends.

id	
Type	Multiple Choice
Name	**Many ways to save energy.**
Content	 There are many ways to save energy. In the list below there are two items which are good practices and one item which does not help.
Question	Which of the following is NOT a way to save energy?
Answers	Good insulation of the building to increase protection from the cold. Using energy efficient light bulbs. Using more heat, so even in the winter, you can move only with your shirt on.
Solution	Using more heat also means using more energy. You shouldn't freeze at home, but consider wearing more than just a shirt in winter.

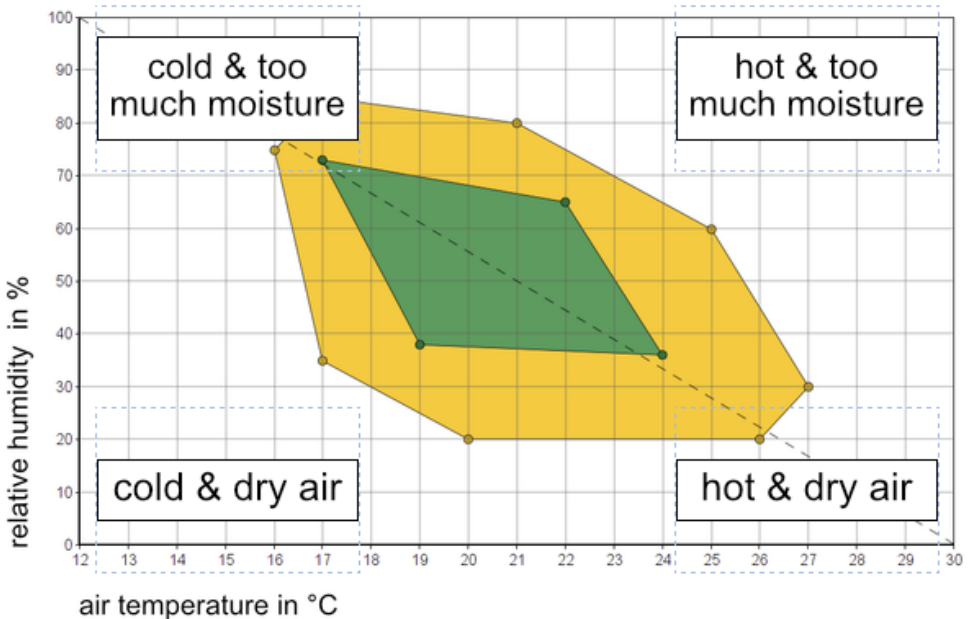| id	
Type	Multiple Choice
Name	**The energy of light beams.**
Content	When a light beam hits an object, parts of the beam get reflected and other parts are transformed into heat energy. Keep that in mind when completing the following statement:
Question	To avoid overheating in summer, buildings should be painted
Answers	in light colours. in dark colours. light or dark. It doesn't matter.
Solution	Bright colors reflect more light than dark colors. Consequently, dark objects heat up more (absorb more heat energy) than bright objects.

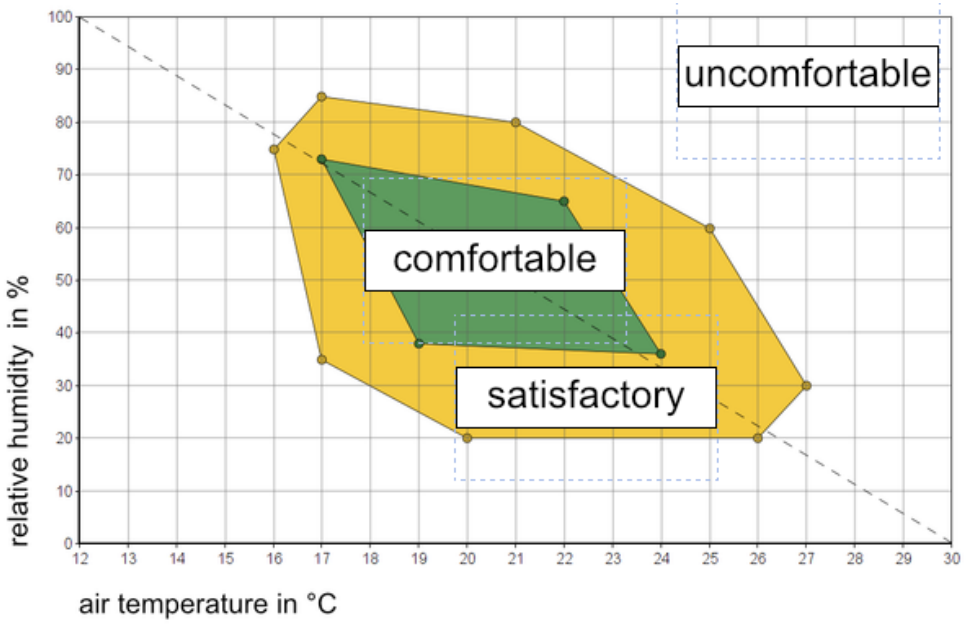Tip: You can also try this with your clothes. A white t-shirt will keep you cooler than a black.

Quest Name	Controlling the room climate

id	
Type	Content
Name	**Controlling the room climate**
Content	

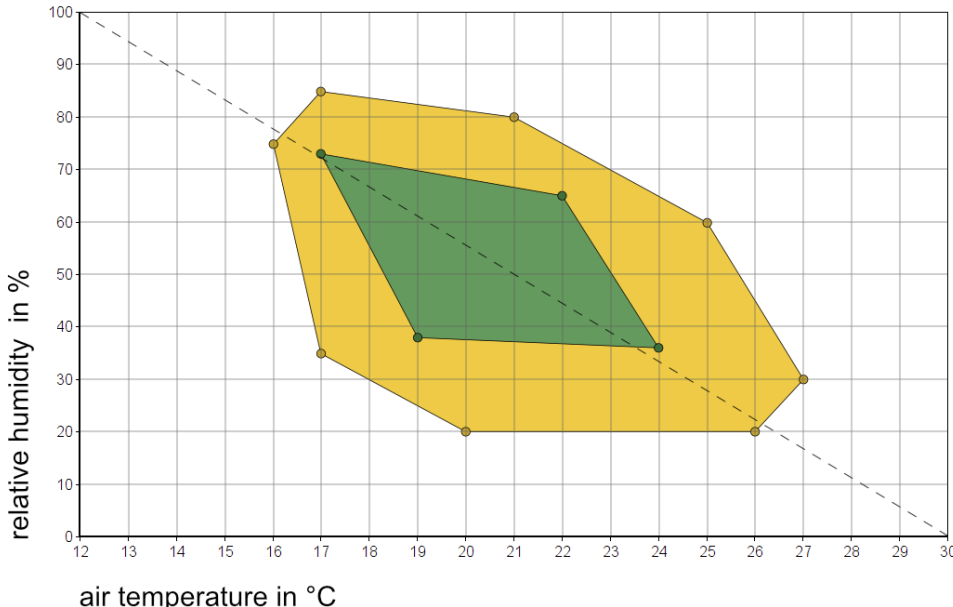| id	
Type	Content
Name	**How do we perceive temperature?**
Content	Did you know that the temperature (degree celsius) is not alone responsible for how we perceive temperature? There is another important factor involved: relative air humidity.

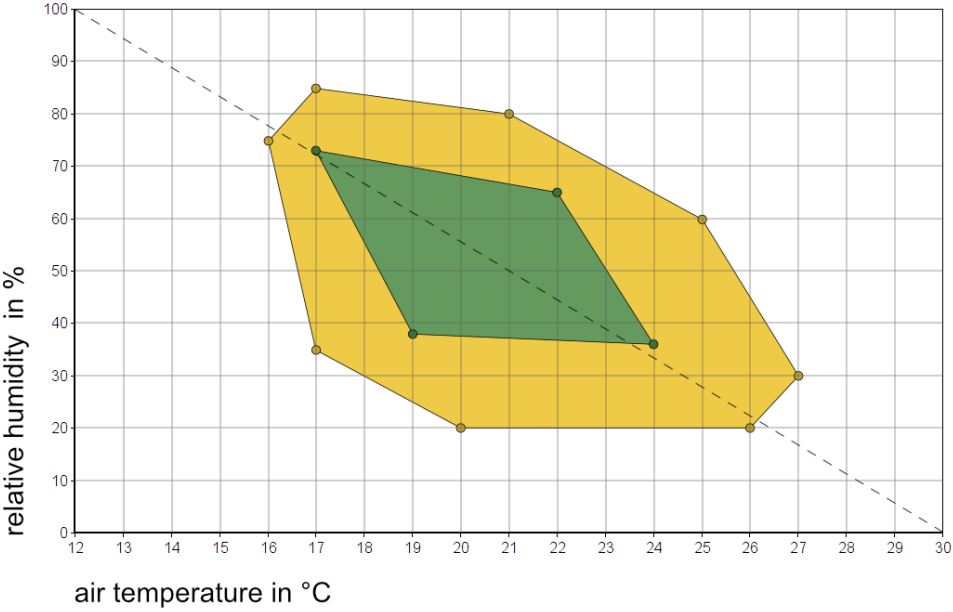| id	
Type	Image Drag & Drop
Name	**The relationship of temperature and humidity (1)**

Content	Take a close look at the following chart. It shows the relation between air temperature (in °C) and the relative humidity (in %). We will take a closer look at the green and yellow areas in the next task. For now, we just want you to figure out what the axes mean. Can you drag the labels onto the correct spots?
Solution	The X axis ranges from 12°C (rather cold) to 30°C (hot). The Y axis goes from 0% (no moisture in the air) to 100% (very much moisture in the air)

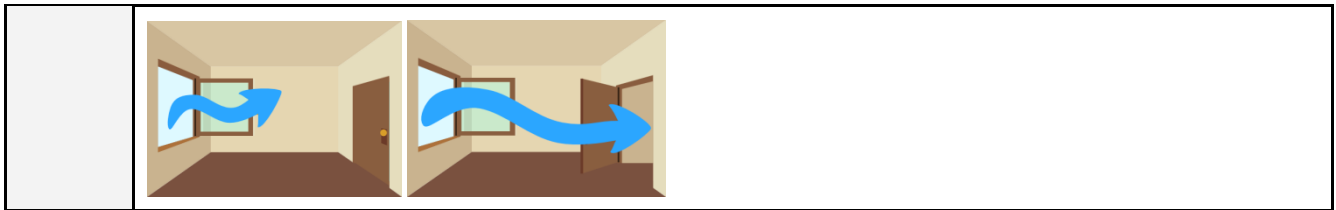|	
id	
Type	Image Drag & Drop
Name	**The relationship of temperature and humidity (2)**
Content	Now that you know how the chart is read, guess what the areas mean. Put the labels onto the correct spots.
Solution	The green area is usually considered as the most comfortable relation of air temperature and relative

humidity. The yellow area is also considered satisfactory and the white area is generally described as uncomfortable.

id	
Type	Multiple Choice
Name	**The relationship of temperature and humidity (3)**
Content	Let's try this one more time.
Question	If a room has 30% humidity and 17°C temperature, the humidity - temperature relationship is considered ...
Answers	comfortable satisfactory not good - dry air not good - too much moisture
Solution	30% humidity and 17°C temperature is generally perceived as uncomfortable - especially due to the dry air.

id	
Type	Multiple Choice
Name	**The relationship of temperature and humidity (4)**

Content	
	In the previous case the we had 30% humidity and 17°C.
Question	What would you suggest that should be done to improve the room climate?
Answers	place some type of humidifier
	place some type of dehumidifier
	set the thermostat lower
	set the thermostat higher
Solution	We increase both the relative humidity and the air temperature in order to rise the perceived temperature to a comfortable level.

id	
Type	Image Multiple Choice
Name	**Quick natural ventilation**
Content	You are in the same room for a long time and the air gets stuffy and hot. You want to open a window to let some fresh air in. What would be the quickest ways?
Question	Pick the two fastest ways of natural ventilation:
Answers	
Solution	To establish quick natural ventilation, it is important to open the windows as wide as possible. Ideally you should also open the door to allow for free passage of air (cross ventilation).

id	
Type	Image Magnifier
Name	**What a waste of energy!**
Content	Somebody was careless here and made a mistake in this classroom. It is now causing an inefficient use of energy. Can you spot the mistake?
Image	
Solution	The curtain covers parts of the radiator. Keep the radiator free from large objects, blankets or curtains. Otherwise the warm air gets blocked and cannot heat up the room.

id	
Type	Calculation
Name	**Only 1°C difference**

Content	Reducing the temperature in a central heating system by only 1°C prevents a lot of CO_2 emissions.
Question	Guess how many kilograms that would be per year.
Answers	min: 100 max: 600 correct: 200-400
Solution	Reducing the temperature by only 1°C prevents up to 300 kg of CO_2 emissions per year.

id	
Type	Multiple Choice
Name	**Outside temperature (1)**
Content	Complete the following statement. Tip: We already learned that a major part of the energy consumption in a typical household is caused by heating.
Question	Energy consumption decreases when the...
Answers	Outside temperature decreases. Outside temperature fluctuates. Outside temperature increases.
Solution	The higher the outside temperature, the less energy you need to spend on heating.

id	
Type	Multiple Choice
Name	**Outside temperature (2)**

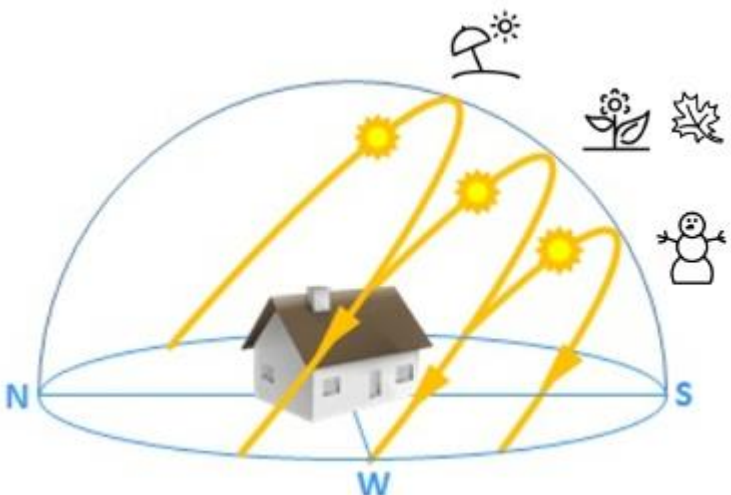| Content	
	Complete the following statement.
	Tip: We already learned that a major part of the energy consumption in a typical household is caused by heating.
Question	Energy consumption usually increases in...
Answers	spring summer autumn winter
Solution	The outside temperature is low in winter. Therefore more energy needs to be spent on heating.

Quest Name	Optimizing lighting conditions

id	
Type	Content
Name	**Optimizing lighting conditions**

Content	

id	
Type	Multiple Choice
Name	**Energy and light**
Content	A major part of the energy consumption in a typical household is caused by heating and lighting. Complete the following statement.
Question	When natural light increases, energy consumption…
Answers	decreases. is not affected. increases.
Solution	As a rule of thumb, when natural light increases, you need to spend less energy on heating and lighting and the overall energy consumption usually decreases.

id	
Type	Multiple Choice
Name	**Room layout**
Content	The building's orientation can be used for passive heating and cooling. The sunlight also affects the room illumination. However, because of the changing rotation and movement of the earth relative to the sun, the incidence of sunlight changes with the seasons.

Question	Which orientation is best for a classroom in winter?
Answers	to the north to the east to the south to the west
Solution	Windows on the south side guarantee a lot of sunshine in winter. Therefore, south-oriented rooms benefit from a better warming during the winter months.

id	
Type	Calculation
Name	**Energy-saving bulbs to the rescue!**
Content	Compared to traditional incandescents, energy-efficient light bulbs (such as halogen incandescents, compact fluorescent lamps and LEDs) have multiple advantages. Typically they use about 25%-80% less energy than traditional incandescents. They also last much longer than conventional bulbs.

Question	How many times longer does an energy saving bulb typically last compared to traditional incandescents?
Answers	min: 2 max: 10 correct: 7 - 10
Solution	Usually they last up to 10 times longer than conventional bulbs. Some types can last even longer.

id	
Type	Calculation
Name	**The ecological damage of incandescents**
Content	You need to burn 180 kg of coal to produce enough energy to power a 100 Watt lamp for 12 hours a day for 365 days a year.
Question	Burning 180 kg of coal release a lot of carbon dioxide (CO2) which causes the greenhouse effect. Guess how much!
Answers	min: 100 max: 700 correct: 400-500
Solution	Burning 180 kg of coal produces 450 kg of carbon dioxide.

id	
Type	Multiple Choice
Name	**Coal and CO2**
Content	You just found out that burning 180 kg of coal produces 450 kg of carbon dioxide. But wait - isn't there something wrong here?
Question	How can something be more heavy AFTER burning than BEFORE?
Answers	It can't. The editors made a mistake. It can. But it's a really weird formula that no one understands except of theoretical nuclear particle physicists with the age of 140. I know! It's because carbon dioxide consists of more atoms than carbon! CO2 usually eats too much dinner when released in the air and is therefore also know as "Chunky Dioxide"
Solution	Carbon in its pure form weighs about ⅓ of it after burning. During the burning, carbon atoms combine with oxygen atoms (actually, one carbon atom with 2 oxygen atoms, therefore carbon-dioxide). The 2 oxygen atoms make the substance heavier, and voila - CO2 is 3 times as heavy as coal.

id	
Type	Calculation
Name	**The ecological damage of incandescents (2)**
Content	We just found out that 450 kg of greenhouse gases are caused by 100 Watt incandescents over a whole year if they stay on for 12 hours a day.

Question	Guess how many kilograms would you approximately save a year when you switch off just five lights when you do not need them?
Answers	min: 200 max: 500 correct: 350-450
Solution	You would save approximately 400 kg of CO2.

Quest Name	Appliances in your school

id	
Type	Content
Name	**Appliances in your school**
Content	

id	
Type	Multiple Choice
Name	**Stand by me**
Content	Household usually hold electronic devices such as Computers, TVs and DVD Players, used on a daily basis. However, these devices are not required to run all day, so you turn them off.

Question	But what actually happens when you press the red button on the remote?
Answers	It switches into sleep mode (stand-by). It powers off completely. It does not consume any power anymore. It does still consume a little energy. It does still consume a lot of energy.
Solution	Most electronic devices such as PCs, TVs and remote controlled devices switch into sleep mode (also called stand-by mode). Many devices signify this mode with a small red colored light. Be aware that even in this mode the device still does consume some little energy.

id	
Type	Image Search
Name	**Appliances in your classroom (1)**
Content	Pick the appliance in this room which is responsible for most of the CO2 emissions per hour of use.
Image	
Answers	air conditioning unit computer + screen lamps
Solution	The air conditioning unit is responsible for most of the CO2 emissions.

id	
Type	Image Search
Name	**Appliances in your classroom (2)**
Content	Pick the most energy consuming electrical device in this room.

Image	
Answers	air conditioning unit computer + screen interactive whiteboard
Solution	The air conditioning unit is the most energy consuming electrical device in this room. Remember: Air conditioning units require a lot of energy. Use it only if you really need it.

id	
Type	Multiple Choice
Name	**Energy vampires (1)**
Content	A computer can be an "energy vampire". It sucks a lot of energy, even when not used.
Question	What do you do when not using your computer for more than 4 hours?
Answers	Nothing, just keep it running. Keep the computer running but turn off the screen. Put the computer into sleep mode and keep the screen on. Shut down the computer completely and turn of the screen.
Solution	When turning off only the screen the computer will still consume a lot of energy. When you are not using your computer for more than 4 hours you should shut down the computer completely and also turn off the screen.

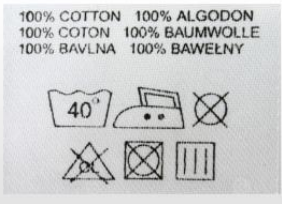| id	
Type	Multiple Choice
Name	**Energy vampires (2)**
Content	Tip: There is not just only a single solution to this question.
Question	When you are in the middle of doing some work at your computer but you have to step away from it for one hour, what should you do?

Answers	Nothing, just keep it running. Keep the computer running but turn of the screen. Put the computer into sleep mode and turn off the screen. Shut the computer down completely and turn of the screen.
Solution	When you leave the computer only for a short amount of time it is not necessary to shut it down completely. In sleep mode the state of your current session will be saved. When you wake up your computer you can continue from where you left. In sleep mode a computer consumes much less energy than when you just leave it running. However, it is okay to shut down the computer. While during the startup and shutdown process, a computer draws slightly more power than in idle mode, this difference is usually not significant.

id	
Type	Calculation
Name	**Energy vampires (3)**
Content	A school computer with associated screen consumes about 0,15 kW (kilowatt) when switched on. In some classrooms, there are 20 such computers. Tip: Do not guess but calculate the answer.
Question	How much energy in kWh (kilowatt-hours) do these 20 computers consume in a year if they are turned on day and night the whole year?
Answers	min: 10000 max: 30000 correct: 25920 - 26280
Solution	0,15 kW x 20 computers x 24 hours x 365 days = 26.280 kWh

id	
Type	Calculation
Name	**Energy vampires (4)**

Content	A school computer with associated screen consumes about 0,15 kW when switched on. In some classrooms, there are 20 such computers. Tip: Again, you need to calculate the solution.
Question	How much energy (in kWh) would be saved in a year if they are only turned on when they are actually used, which is 4 hours per day 180 days per year?
Answers	min: 10000 max: 30000 correct: 23760 - 24120
Solution	0,15 kW x 20 Computers x 24 hours x 365 days = 26.280 kWh minus 0,15 kW x 20 Computers x 4 hours x 180 days = 2.160 kWh (used energy) = 24.120 kWh (saved energy)

id	
Type	Multiple Choice
Name	**The EU Energy Label (1)**
Content	You might have spotted it already on the dishwasher, refrigerator or washing machine at your home: The energy label.
Question	Why do some products bear an energy label?
Answers	To facilitate comparison between products that consume more or less energy To show the price of the product To indicate where to place the socket of the product
Solution	The energy label allows a simple comparison between products to find out which one consumes more or less power.

id	
Type	Image Multiple Choice
Name	**The EU Energy Label (2)**
Content	Did you know there even is an official energy label regulated by the European Union?
Question	Which of the following labels is the official EU Energy Label?
Answers	[✓] , [X] ,

	[X] , [X]
Solution	The EU Energy Label is easily recognizable at it's blue edges, the EU flag and the distinctive color classification.

Quest Name	**Everyday knowledge**

id	
Type	Content
Name	**Everyday knowledge**
Content	
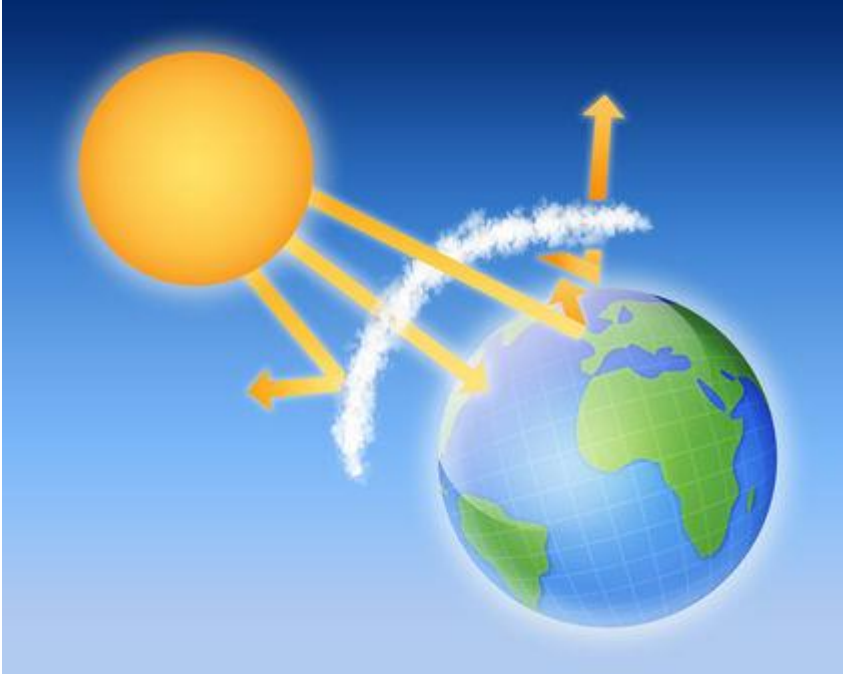
id	
Type	Image Multiple Choice
Name	**Energy sources (1)**
Content	While there is no way to create energy from scratch, there are multiple ways to transform energy from various forms into electrical power. Some of these energy sources are limited and some of them are renewable.
Question	Which of the following is a renewable and sustainable energy source:

Answers	[✓] biomass , [X] coal , [X] nuclear power , [X] oil
Solution	Biomass is a great renewable and sustainable energy source. Some people also consider nuclear power a renewable energy source by definition. However, the accompanying nuclear waste (and the uranium deposit) makes it a non-sustainable energy source.

id	
Type	Image Multiple Choice
Name	**Energy sources (2)**
Content	Here are some more energy sources. This time we need you to figure out which one is NOT a renewable energy source.
Question	Which of the following is not a renewable energy source:
Answers	[✓] natural gasoline , [X] solar energy , [X] wind , [X] water
Solution	Natural gas occurs beneath the earth's surface and is a limited resource on our planet.

id	
Type	Image Multiple Choice
Name	**Energy sources (3)**
Content	Often we do not have the opportunity to use choose from every energy source. From the energy sources listed below, can you find out which one is best suited for heating a building?
Question	Which of the following energy sources should be preferred for heating a building?

Answers	
	[✓] natural gasoline , [X] nuclear power , [X] oil , [X] coal
Solution	If no renewable energy source is available, natural gas is a good way for heating buildings. It has lower carbon dioxide emissions than e.g. oil and coal.

id	
Type	Multiple Choice
Name	**The danger of carbon dioxide**
Content	We are sure you've already heard about the greenhouse effect. It occurs when certain gases in the Earth's atmosphere (the air around the Earth) entraps infrared radiation. This makes the planet become warmer, similar to the way it makes a greenhouse become warmer. Carbon dioxide is the most significant long-lived greenhouse gas.
Question	For how long can carbon dioxide last in the atmosphere?
Answers	6 - 12 months 50 - 200 years 1000 - 2000 years
Solution	Carbon dioxide lasts 50-200 years in the atmosphere and accounts for about 80% of all greenhouse gases in

	our atmosphere. This makes it the main contributor to the dangerous greenhouse effect.

id	
Type	Image Drag & Drop
Name	**Green energy buildings**
Content	Did you know that there are buildings which produce their own energy (with solar panels, mini wind turbines or even small geothermal power systems)? They are categorized into different classes depending on how much energy they generate relative to their energy consumption. Drag and drop the labels of the building types onto their corresponding bar in the chart below: building types regular building (not optimized) zero-energy building energy plus building near-zero energy building ■ energy consumption ■ energy generation
Solution	Buildings which produce more energy than they use are called energy plus buildings. They even feed the surplus electricity into the public power grid. Zero-energy buildings generate approximately the same amount of energy they consume. Near-zero energy buildings almost generate the same amount of energy they consume.

id	
Type	Multiple Choice
Name	**A simple trick**
Content	Here is a very simple way to save a little energy every day without sacrificing comfort. Finish the following statement:
Question	A quick and easy way to save energy in the classroom is to...
Answers	close the door of the classroom. put the thermostat for heating to a lower level even if it is cold. cover the windows with long curtains so that heat cannot escape.
Solution	Closing the door of the classroom will reduce the air exchange and thereby contribute to keep the room's temperature on the same level.

id	
Type	Multiple Choice
Name	**How to stay cool (1)**
Content	There are several ways to control the temperature of a building. But different situations require different measures. Let's imagine it's a hot summer day.
Question	When the outside temperature is high the most energy efficient way to cool a building is...
Answers	fans. air conditioning. cross ventilation.
Solution	If the outside temperature is higher than the inside temperature, you should keep the windows closed. Fans are also not very efficient when it comes to cooling as they only bring air into motion instead of cooling it. Air conditioning units, however, are actually a great way to cool the air temperature.

id	
Type	Multiple Choice
Name	**How to stay cool (2)**
Content	Now, let's imagine it's a moderate to cool evening in autumn but the building's inside temperature is still hot from the sunshine during the day.
Question	When the outside temperature is low the most energy efficient way to cool a building is...
Answers	fans. air conditioning. cross ventilation.
Solution	In this scenario the best way to cool the building is to open the windows and let in fresh cool air.

Annex III – Examples of adapted context-specific educational scenarios

This Annex provides the scenarios developed for the pilot activities in the Technical High School of Söderhamn (pilot site SE20, Sweden) and in Sapienza University (pilot site IT19, Italy), as examples of the adaptation of the generic core scenario of GAIA to the local educational circumstances.

Adapted educational scenario for the Technical High School of Söderhamn (pilot site SE20, Sweden)

The building of the school in Söderhamn has been described in detail in the Deliverable D1.1. Regarding trials for GAIA, the focus in the past few months has been on defining the groups/classes that will participate in the first limited round of trials for the project in the coming months, as explained in Section 4 of this document. Since the school is essentially a partner in the GAIA consortium, in the main trial phase, the numbers mentioned in the table below will be further increased.

For this specific school, due to the fact that it has a number of technical classes, the consortium selected the option of utilizing the GaiaPi hardware, which can be assembled by the students of the high school themselves, as part of their technological curriculum, in addition to the rest of the GAIA educational content to be used. The school has purchased the respective component parts to complete the assembly, along with the students using 3D printers to build enclosures for the nodes.

The GaiaPi nodes will be used in conjunction with the existing BMS and respective hardware that exists in the building. The software integration of the school's BMS has progressed, and the GaiaPi nodes will offer a detailed view on the environmental conditions inside the classrooms of the building.

The physical space

Physical space in the school monitored in GAIA:	Number and kind of rooms or clusters of rooms:	2 regular classrooms, 4 science labs and 1 computer lab (CAD studio) on two floors of the building
	Special characteristics and other information on the rooms:	Room 120, physics lab, windows facing to the east. Used by several different classes.
		Room 121, physics lab, windows facing to the east. Used by several different classes.
		Room 123, classroom, windows facing to the north and west. Used by several different classes.
		Room 220, biology lab, windows facing to the east. Used by several different classes.
		Room 221, biology lab, windows facing to the east. Used by several different classes.
		Room 222, classroom, windows facing to the west. Used by several different classes.

		Room 223, computer lab (CAD) windows facing to the west. Used by several different classes.
	Local weather monitored?	Yes, outdoor temperature in the BMS.

Sensors and meters

Available sensors, meters, other measuring instruments	Installed GAIA equipment:	In all of the rooms there is an Environmental Comfort Meter device: Temperature Sensor (ºC) LM35 Relative Humidity (%RH) Illuminance Sensor (level) Motion detection Sensor PIR Sound Pressure Level (level)
	Other equipment:	No plans to use other equipment for measurements

User devices

Available user devices	Type of equipment with internet connection:	All students and staff have their own laptop PC provided by school (W10). Most of them have their own smartphones. In room 223 there is 24 desktop computers for CAD.
	Place:	See above.
	Limitations or restrictions in use:	No limitations
Devices of display or projection	Type of equipment with internet connection:	Projectors in every room in the building. Displays (Smart tv) in common areas for information.
	Place:	See above.
	Limitations or restrictions in use:	No limitations

Students

Students directly involved (considerable amount of GAIA activity):	Number of students:	200 students at this phase of the project. 400 in early spring.
	Age of students:	16-20
	Education level and	First, second, and third year of upper secondary

	grade(s)/year(s)/group(s):	school.

	Number of students:	800 students including the 600 above.
Students indirectly involved (informed about GAIA activity):	Age of students:	16-20
	Education level and grade(s)/year(s)/group(s):	First, second, and third year of upper secondary school.

Staff

	Name, position/role in school:	Lars Sjögren
Person acting as building manager	Will the same person probably be available to run GAIA activities in 2018-2019?	Yes

	Name(s), specialization(s):	Joakim Gunneriusson, teacher in math and physics. Glen Uppegård, teacher in math and physics. Most of the other teachers at school has a minor part in the project during the period their students is involved, around 60 persons.
Teacher(s) running GAIA activities in school year 2017-2018	Will the same teacher(s) probably be available to run GAIA activities in 2018-2019?	Yes

School curriculum and schedule

	Subject area(s) and/or cross-curricular activities:	Mostly science courses like physics or general science.
Position of GAIA activities in relation to curriculum and school schedule	Place of GAIA activities in the school schedule:	Introduction during lessons and then in class and in their own time.

Local community

	Local agents/communities that can be accessed and involved:	The whole school community (800 students and 90 teachers) will be informed by the students and teachers directly involved in the GAIA activities.
Possibility for outreach and synergies with the local community		

		The principal will inform the local municipality about the results.

Themes

GAIA themes to be covered (preferably all!)	Use of lighting:	Yes
	Use of heating or cooling:	Yes
	Use of electrical and electronic devices:	Yes
	Building and local characteristics (orientation, insulation, climate):	Yes

Cycles in the school year

GAIA activities in cycles during the whole school year	Timing:	Proposed: Phase 1: Sept-Oct 17 Phase 2: Nov-Dec 17 Phase 3: Feb-Mar 18 Phase 4: Apr 18 Phase 5: May 18

A theme per cycle? Suggestion:

Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Students building and installing Raspberry Pi	3 year students start to play the GAIA Challenge. Science students gets a lecture in energy of the future by a university professor at a study visit to the University of Uppsala. Science students get a lecture of the BMS by our BM. Science students keep track of the	1-2 year students start to play GAIA Challenge. Science students analyses data from the RasberryPI and write a report including suggestions for actions to act greener.	Missions in GAIA challenge released to all students involved in GAIA. Dissemination of the results from the RasberryPI and the knowledge based on the report made by the students.	Evaluate the GAIA Challenge and name the winner of the game. Prize ceremony!

	RasberryPI.			

Use of the GAIA Challenge

Use of the GAIA Challenge in the activities	Students' individual registration with GAIA Challenge:	No problems yet.
	Set-up of the Mission Team(s) of the school in GAIA Challenge:	Every class will get their own team.
	Place and timing of GAIA Challenge use:	Introduction in class, then mostly in spare time.

Use of the GAIA Application

Use of the GAIA Application	Different teacher accounts next to the central building manager one?	Yes, for Joakim Gunneriusson.
	Student accounts for individual student access?	No
	Possibility to use the GAIA mobile app?	No
	Place and timing of GAIA Application use:	Mainly in class with the science students.

In Sweden, the Swedish National Agency for Education makes plans for all national programs. These programs contain approximately 25 courses with accompanying curriculums. The National Agency for Education designs these syllabuses. It is then the task of the teachers to design the teaching activities in such a way that the objectives of the program plan and curriculum are achieved.

In the GAIA project SK will specially focus on two programs: The Natural Science Program and the Technology Program. SK will especially associate the project with the courses in Physics and Natural Science. Teachers attach program goals and syllabuses to those. The areas SK intends to involve GAIA in are underlined.

Because SK wants GAIA activities to give our students as much as possible, it's important for SK to do the activities in the right time. What the right time is, every teacher must decide because it is precisely the teacher who knows his students the best. It is therefore very difficult for us to provide a detailed schedule of our activities. But a rough plan is as follows:

Autumn 2017: All students play GAIA-challenge.

Autumn 2017: Some classes run any other activity that fits in. Examples are attached to this document.

Spring 2018: All students play GAIA-challenge.

Spring 2018: Some classes run any other activity that fits in. Examples are attached to this document

Example of activities

Your shower

Task:

Find out how much energy is required to heat your shower water for an entire year, how much it costs and how much you should be able to save.

Method:

1. Study your shower for a week and answer the following questions:
a) How long do you shower in funds?

b) How many times do you shower in a week?

c) About how many minutes do you shower for a whole year?

2. Now you need to figure out how much water you consume every minute of your shower. How to do this you need to think out on your own. Answer the following questions:

a) How much water do you consume every minute of your shower?

b) How much water does your shower consume for a whole year?

3. To heat 1 litre of water 1oC, approximately 1.2 Wh of energy is needed. You will now find out how much energy is required to heat your shower water for an entire year. To do that, you must in any way measure how hot your water is before it warms and how hot it is when you shower. How to do this you need to think out your own. Answer the following questions:
a) How hot is the water before it is heated? (The coldest water you can get out of your crane)
b) How hot is your shower water?
c) How many degrees did your water heat?
d) How much energy does it take to heat 1 litre of your shower water?
e) How much energy is needed to heat your shower water for a whole year?
4. Your shower water has been heated in some way. For simplicity we assume it has been heated with a simple electric water heater. It simply adds energy through the electric mains. 1kWh electricity from the mains today costs just over 1 kr with all taxes and fees. How much does the heating of your shower water cost for a whole year if we assume that the water is heated with an electric water heater?
5. Could you reduce your shower time? Estimate how much energy and money you should be able to save on your shower for a whole year.

Lights in the classroom

Task:

Find out how much energy lights in room 121 consume over a year, how much it costs and how much we should be able to save.

Method:

First, you need to find out how much the lights are consuming when they are lit. In each lamp there are two fluorescent lamps of 36W each. These then consume 72W when they are lit. However, there is a power source for each luminaire consuming closer to 30W when the lights are on. You can thus expect a luminaire to consume 100W when it is lit. Answer the following questions:

a) How many luminaires are there in the classroom?

b) How much do they consume when they are lit?

2. To find out how much energy they consume in an entire year, you need to know how many hours they are lit. We have installed sensors in the room that show when the lights have been lit or not. Data from these sensors can be found on the page:

Answer the following questions:

a) How many hours was the light in the hall lit last week?

b) How many hours will it be in a whole academic year? (36 weeks)

c) How much energy do the lamps use during a full year if they are lit as much as last week?

3. To find out how much we should be able to save by keeping the lights out, you need to know how long they were lit unnecessary. On the schedule page you can find the schedule for room 121 last week. Answer the following questions:

a) How many hours was there a lesson in the hall?

b) How many of these were during daytime when the light should not be ignited?

c) How many hours did the light need to be lit?

d) How much energy would the lamps consume in a whole academic year if they were only lit when needed?

4. The lamps are powered by electricity from the electric mains. The school pays about 1 kr per kWh of electricity we consume. Answer the following questions:
a) How much money could we save in a school year if the light in the room is only lit when needed?

b) How much would it represent for all the school classrooms if we assume they are used in the same way as this room?

Programs SK will engage more than others in GAIA

The science program

Goals of the program

The science program is a university preparatory program. After graduating from the program, students will have knowledge of higher education studies, mainly in science, mathematics and technology, but also in other fields.

The education will develop students' knowledge of contexts in nature, the conditions of life, physical phenomena and events and chemical processes. In biology, physics and chemistry, the outside world is described in models developed in a interaction between experiments and theory. The education will also develop students' knowledge of mathematics. Mathematics is a separate subject with its particular nature, and it is also an aid whose concepts and symbols are used to design models in order to understand and analyze relationships within other subject areas. The education should stimulate students' curiosity and creativity as well as their ability to analytically think.

Through the education, students will develop a science-based approach. It includes the ability for critical thinking, logical reasoning, problem solving and systematic observations. Students should therefore be given

the opportunity to develop an ability to evaluate different types of sources and to distinguish claims based on scientific or non-scientific basis. Understanding of natural science is based on interplay between theory and practical experience. Experiments, laboratory work, field studies and other comparable practical elements should therefore be central to the education.

The education should contain an idea-historical perspective, which means that the ideas and theories of science are studied as part of a historical process. Students will be given the opportunity to develop interest in science issues and will receive current research findings in relevant areas. The education should provide an understanding of how mutual science has influenced and influenced each other and, in particular, highlighting the role of science in sustainable development issues. Students will also be given the opportunity for ethical discussions about the role of science in society.

The language is a tool for communication, but also for reflection and learning. The education should therefore develop the students' ability to argue and express themselves in advanced writing and speech situations related to science and mathematics. Students should also be able to understand, read and rewrite and discuss basic natural sciences in English.

In science and mathematics, data collection and computations are essentially computer support. The ability to search, sleep, process and interpret information as well as acquire new technology is important for natural scientists and mathematicians. The education should therefore be used to using modern technology and equipment.

The education should promote student responsibility and cooperation, and encourage them to see opportunities, try to solve problems, initiate and translate ideas into practical action.

The technology program

Goals of the program

The technology program is a college preparatory program. After graduating from the program, students will have knowledge of university studies in mainly engineering and natural sciences, but also in other fields.

The education will develop students' knowledge and skills in technology and technology development. It will also highlight the role of technology in the interaction between man and nature with regard to sustainable development. Furthermore, the education will develop students' knowledge of physics, chemistry and mathematics with a focus on technical processes. In technology, students will examine, describe and systematise different characteristics of technical objects and processes. In physics and chemistry, students will examine, describe and systematize different phenomena in nature as well as make connections to technical processes. Mathematics is a language and a tool for understanding, expressing and analyzing contexts in the field of technology. The technical area of expertise addresses both existing technology and the development of new technologies.

The education should show links between the different parts of technology development processes and help the students understand the entire chain of technology development in a sustainable society. Technology development involves analysing needs, developing an idea, designing, constructing, producing, using, selling and recycling.

The education should be based on an ethical and responsible approach to technology, and critical, creative and constructive thinking should be promoted. In education, students should be given the opportunity to develop the ability to search, choose and process information with source-critical awareness. The education should also contain creative and problem-solving working methods and provide opportunities for students

to develop a multidisciplinary approach. Theory and practical application will co-operate and the education will provide students with knowledge and skills in collaborating with others. As the development of technology often takes place in project work, the education should provide knowledge about project work and skills in working in projects, both individually and in groups. Central to technology development is to analyze, model, simulate, evaluate, develop, see relationships, draw conclusions and argue based on the results. The education should therefore develop students' ability to analyze and understand technical systems.

The education will further develop the students' communicative skills in speech, writing and visualization. This implies, among other things, conveying views, explaining contexts and documenting, and using expression forms adapted to different audiences and understanding the specific role of communication in the field of technology. The education should provide knowledge about interactive and digital media so that students can present technical content and produce models. The education will provide students with knowledge and skills in English in a technical context, so that they can develop their communicative ability, thus acquiring technology and technology development.

Entrepreneurship and entrepreneurship are part of processes where technology develops and should therefore be included in the education. The education should encourage students to develop new and creative solutions for creating and meeting changes. It will clarify how the development of products and services locally and globally can be done in a sustainable manner.

The education will be based on both women's and men's experience in relation to the technology and will provide knowledge of how beliefs and traditions govern man and woman views. Students will also develop understanding of people's different conditions in relation to technology and technology development. The education should provide an understanding of how mutual development and development affect and influence each other. It will also explain how the technology of the past has affected our time and how our technology can affect the future.

Adapted educational scenario for Sapienza University (pilot site IT19, Italy)

GAIA application set includes educational games, social networking applications and "monitoring-advice provisioning" applications. The heterogeneity of the persons involved in the GAIA community in terms of age and technical skills makes not possible to conceive scenarios, which fit well with them. With respect to the other schools involved, students and teaching staff of the University should participate using a different approach.

Sapienza will join to the trial process involving their students through the realization of development projects able to extend the functionalities of the GAIA platform with the aim to improve usability and get energy saving. The activity plan has been realized with reference to the GAIA educational framework. The framework is compound by four steps: (i) Awareness where we have a focus on the on the importance of energy saving in daily life, (ii) Observation where we start monitoring and analyzing energy data, (iii) Experimentation in which we try short-term actions in our daily habits and behaviors and see the impact on energy efficiency and (iv) Action in which, based on our short-term actions, we decide to take long-term actions to achieve better energy efficiency results.

We will adapt this framework in order to better suit our needs and the type of people involved (i.e. undergraduate). In this chapter, for each step of the framework, we depict the activities to perform along with timing information and persons involved. Some indicative scenarios will be also presented.

Step 1 - Awareness

We think the best solution to get on board as much people as possible and widely spread the GAIA objectives is trying to inform and draw the attention of the major numbers of persons within the community. With this aim, we already had a first workshop in Sapienza where we presented a quick overview of the project.

We plan to have more technical lessons in which deeply explains the GAIA architecture. The students involved are attenders of "Seminar in Software and Services" class. Following table shows the persons involved during the process.

Organization	Role	Persons
Sapienza, University of Rome	Professors	Massimo Mecella Leonardo Querzoni
	Researchers (PhD)	Andrea Marrella Francesco Leotta
	Students	About 200 persons following class of "Seminar in Software and Services "
Over	Research & Development	Mariano Leva Matteo Zaccagnino Andrea Lanna Giuseppe Bracone Daniele Buonanno Fabio Di Sabatino

We will dedicate short timeframe to the project during multiple lessons (e.g. 20-30 minutes). The themes covered during the lessons will be:

A general and quick overview of the GAIA project and the IT-infrastructure. Here we will focus on the project objectives, the building involved as well as the different applications developed.

GAIA IT-Services. We will have a look on all the services of the infrastructure; data acquisition, authorization and authentication, analytics, recommendation engine and the building knowledge base. We will introduce the main design choices and the technologies utilized. Given the complexity and the heterogeneity of the Sensors/Actuators deployed, we will leave out from the explanations, the low-level details related to the communication process.

Being the most important topics for the realization of students' project we aim to dedicate more timeslots (at least three) to these arguments.

Applications. We will have a closer look on the application developed with particular attention to the social game and the building manager application.

The Seminars of Software and Services will be held at DIAG, room B2, each Friday in the slot 11:00am to 13:00am. Seminars will begin in 2018, March 2nd and end in 2018, May 24th.

Step 2 - Observation

The GAIA education framework foresees in this phase the first approach of the students with the energy monitoring aspects. They monitor and analyze the energy consumed to better understand how it can be used more efficiently, without impairing the function and comfort inside a facility.

We want that our students cooperate to the coding of the GAIA platform. Therefore, in this observation step they not only start to have a look at the data monitored within the buildings they daily live, but they also need to better understand the code behind each software module. We plan, after the first set of theoretical lessons, to have another small set of internal meetings each of one dedicated to a specific architecture component.

Students can attend only the meeting they are interested more, and they would like to work on. Of course, teachers could need an external help to better tackle the internal meeting. Skype sessions with the consortium partner which developed and worked on the software component could be organized to facilitate this task. In this way, meetings will be realized with a lower number of participants allowing to the educational staff to better follow them.

Depending by the students and the component of interest, we roughly predict two/three lessons of one hour each could be enough for an in-depth study of the software component. Practical lesson will be organized where students with their personal computer and will look the programming code. Beside the internal meetings, students in this phase will also have a first look to the data acquired from the devices currently deployed inside the buildings. They could start using building manager application and they could also have a look to the real installations site to also figure out the "hardware side" of the infrastructure and physical connections of the devices utilized.

Step 3 - Experimentation

In this phase students finally start to experiment innovative solutions and functionalities to add into the GAIA ecosystem. They could personally think a new functionality to integrate in the GAIA platform or the teacher could assign a project to them.

This will be the longest stage of the entire process. Students will have a whole academic year to complete the task. An iterative approach will be followed during the developing of the new functionalities and intermediate prototype will be released to check, along with faculty researchers and the OVER GAIA team, the status of the project and prevent any problems could happen in future.

In addition to new features, students will be also encouraged to look innovative ways to improve performances aspects (e.g. efficiency, scalability etc.).

A simulation environment for each component of the platform is available and released from the consortium to allow third-party developer to write and test their own code.

Follow some example of projects they will be proposed to students during the classes on the GAIA platform.

Example of projects

A huge amount of data must be displayed through the GAIA platform and in particular by the Building Manager Application. Multidimensionality and heterogeneity of data makes their interpretation difficult. Without proper visualization techniques, we may loss relevant information. The student is invited to adapt existing visualization techniques or think and implement new ones with the aim to improve the data interpretation process.

Identify and implement new anomaly and prediction algorithms to enhance capabilities of the actual sub-module.

Analyse data with the aim to identify common energy patterns in the buildings. Find whether bad habits exist or not identifying any energy waste and on this basis, provide new behavioural changes suggestion to put within the recommendation engine.

Step 4 - Action

This is the last stage of the process. Once the project has been intensively tested and is ready for the production phase, a new version of the platform, including the new component, is released.

The new functions developed will be run in all the buildings involved in the GAIA projects. New benefits could be get not only in terms of energy efficiency but also in terms of performance and usability of the existing tools.

The technological partner of the consortium will be involved to deploy the new components within the GAIA IoT infrastructure. As the previous phase the educational staff has the task of facilitating the relationship among students and partner of the consortium.

All the actors involved in the educational activities will be in touch, also after the ending of the project, to check if energy efficiency results as positive as expected.

Expectations and Results

All the process will take place during Seminars of Software and Services (DIAG, room B2, each Friday from 11:00am to 13:00am). The table below summarizes date in which each phase will be carried out.

Phase and Theme	SCHEDULE
Awareness – focus on general GAIA concepts, IT infrastructure and applications overview	March 16, 2018
Awareness – a deep view on GAIA IT services. Acquisition, Data Storage, Analytics and Recommendation Engine module	March 30, 2018. Meetings done by appointments with small set of students will follow on interested modules.
Awareness – a deep view on the GAIA applications (the serious game and building manager application)	April 13, 2018
Observation – how to look and analyse energy data	April 27, 2018
Experimentation – design and implementation of new functionalities	From June 2018 to September 2018 (it could extend to the whole academic year
Action – solution deploy and benefits analysis	From October 2018

After lesson of March 30 and until to April 13, we plan to organize small meetings only with the interested students and consortium partner involved, deal with specific software components.

We expect to get from trials in Sapienza at least a new project, among those ones proposed by teaching staff, to include into the GAIA infrastructures, by the end of academic year (deadline for the delivery of the project by the students).

Annex IV – Material for GAIA educational activities

The detailed educational approach and methodology of the project presented in this document is exemplified through several teaching and learning materials produced by the project and proposed to school communities for adoption or adaptation. As these are outputs of an ongoing process of development and continuous refinement, they are presented in this deliverable through examples only. In order to avoid a long Annex with content that is continually evolving and would only be up-to-date at the time of delivery, the updated current picture of teaching and learning materials is made available to the reader in the project website, in the section on 'Educational Material'. Here, a small part of the educational materials produced for use in the context of the activities with the GAIA Educational Lab Kit is included as an illustrative example.

Example materials for activities using the GAIA Educational Lab Kit

[Continued on the next page]

GAIA

1st WORK SHEET (FOR TEACHERS)

Level: Novice

TEMPERATURE – RELATIVE HUMIDITY GAIA LAB KIT

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1: What is thermal comfort?

✳ According to the American Society for Heating, Refrigeration and Air Conditioning (ASHRAE), thermal comfort is defined as a state whereby a person does not want any thermal change in the indoor environment and is pleased with the prevailing conditions.

✳ Thermal comfort is not only about winter conditions, but about conditions throughout the year.

Keywords:

Temperature, Relative Humidity, thermal comfort, heat index, discomfort index

Tools:

• The Internet
• Other class material/notes

37 °C   34 °C

Hot ← → Cold

✳ **Cooling mechanisms**
  ○ Sweating
✳ **Heating mechanisms**
  ○ Trembling

✳ **Cooling** starts when the body's internal temperature exceeds 37 °C
✳ Defense against **hypothermia** begins when the skin temperature drops to 34 °C

Σελίδα **1** από **5**

2: What are the ideal conditions for thermal comfort in different buildings (e.g. houses, schools, hospitals, restaurants, etc.) in winter/summer?

Είδος Εφαρμογής	ΧΕΙΜΩΝΑΣ		ΚΑΛΟΚΑΙΡΙ	
	Θερμοκρασία (°C)	Υγρασία* (%)	Θερμοκρασία (°C)	Υγρασία* (%)
Κατοικίες (κύριοι χώροι)	21-23	30-50	24-26	40-50
Κτίρια Γραφείων και Εκπαίδευσης	20-22	30-35	25-26	45-50
Κτίρια Νοσοκομείων	23-24	40-50	25-26	45-55
Κτίρια Ξενοδοχείων	21-23	30-35	24-25	30-50
Κτίρια Καταστημάτων και Τραπεζών	22-23	30-35	25-27	45-50
Εστιατόρια, χώροι αναψυχής	20-23	30-40	23-27	50-60
Βιβλιοθήκες, Μουσεία	20-22	40-50	22-23	40-55
Βιομηχανικοί χώροι εργασίας	20-23	30-35	25-29	45-55

3: What are the factors determining the comfort conditions of an individual in an interior?

✳ The air temperature
✳ The average radiant temperature of the surfaces surrounding the space
✳ The relative humidity
✳ The speed of air
✳ Clothing
✳ The metabolism
✳ Local thermal discomfort

Thermal comfort can be achieved by altering one or more of the above parameters.

4: What should be the conditions for each of the above factors to achieve thermal comfort?

Air temperature: Air temperature should be appropriate to facilitate the transfer of heat from our body freely. Most people feel comfortable when the ambient temperature is between 22 °C and 27 °C. It depends on the age, clothing, sex, age and activity of the people in the room.

Indoor surface irradiance: The temperature of the interior surfaces of the room should be as close as possible to the room air temperature. We feel cold in winter from cold surfaces by radiation, while the opposite by radiation from hot surfaces in the summer.

Relative Humidity: It is the ratio of the amount of water vapor that the air contains, to the maximum amount of water vapor it can contain. High relative humidity slows down heat dissipation by evaporation, while low relative humidity accelerates it. Low relative humidity creates a feeling of cold and drying of the skin, discomfort. Most people prefer a relative humidity between 40% and 60%.

Air velocity: Air movement helps to remove humid and warm air near human skin, thus helping to reject heat by transfer and evaporation. Air movement should not be high because it causes dissatisfaction. In inhabited indoor areas with people, the speed of air should not exceed 0.15m/s in winter and 0.25m/s in summer. Air velocity may be higher in large spaces where there are people with intense activity.

Clothing: Clothing is thermal resistance (insulation) between the skin and the environment. In warm environments, we wear lightweight (low resistance) clothes that do not absorb heat, while in cold environment heavy clothing (high resistance).

Metabolism: It is the rate of transformation of chemical energy into the work and heat of an organism. Metabolism depends on the body's activity.

Local thermal discomfort:

Local air currents: They cause a sense of heat loss.

Asymmetric radiation: Asymmetric radiation temperature causes dissatisfaction. The hottest ceilings and cold walls cause the greatest resentment.

Vertical temperature difference: The vertical difference in air temperature in a space between the level of a person's legs and head should not exceed 3°C to avoid local discomfort.

Floor temperature: Acceptable floor temperatures between 19-29 °C.

Thermal environment sensation	Cold	Cool	Chilly	Comfortable	Warm	Hot	Too hot
PMV Factor	-3	-2	-1	0	+1	+2	+3

5: Which factors influence the air temperature inside a building?

- The external environment
- The orientation of the building
- Building materials and thermal insulation materials of the building
- The ventilation mode of the building (mechanical or physical)
- The way of design, construction, operation and maintenance of a mechanically ventilated building
- The way of designing a naturally ventilated building
- The way of design, construction, operation and maintenance of the heating system and the cooling system of the building
- The type and number of electrical equipment, office equipment or equipment in the building that produce heat (eg PC screens)
- The way the building works and the ventilation, heating and cooling systems of the building users

6: In what conditions of air temperature and relative humidity a person feels comfortable?
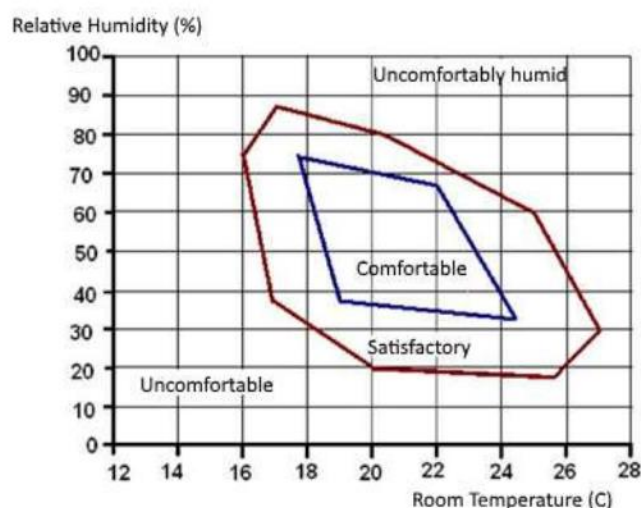
7: What is the PMV (Predicted Mean Vote) comfort index?

The PMV is a 7-point scale and is the average estimate of thermal comfort by people in a given room. The zero value is the value at which the person feels comfortable with the thermal conditions. It is a complex mathematical function with parameters such as temperature, humidity, room air velocity, average surface temperature, clothing, and activity. It is based on a statistical analysis of the behavior of a large sample of people of different age and gender.

$$PMV = (0{,}303 * e^{-0{,}036 M} + 0{,}028) * [(M-W) - H - E_C - C_{res} - E_{res}]$$

8: What is the Heat Index (HI)?

The heat index is a measure of whether air temperature combined with relative humidity rates affect the sense of comfort or discomfort of the population, as well as the consequences the human body may have. When the heat index increases, the feeling of comfort is reduced and a feeling of discomfort gradually develops.

$$HI = -42.379 + 2.04901523T + 10.14333127R - 0.22475541TR - 6.83783 \times 10^{-3}T^2$$
$$- 5.481717 \times 10^{-2}R^2 + 1.22874 \times 10^{-3}T^2R + 8.5282 \times 10^{-4}TR^2 - 1.99 \times 10^{-6}T^2R^2$$

Where T is the hourly average air temperature in degrees Fahrenheit and RH is the hourly relative humidity value. To convert degrees F to C we use the formula: *C = (F - 32) * 5/9.*

9: What is Discomfort Index (DI)?

The discomfort index is intended to express the satisfaction of the non-human being with the environment and the prevailing conditions. It is a purely empirical indicator based on a wide range of observations and is a function of the temperature and humidity of the atmosphere.

The calculation of the discomfort index is given by the following relation:

$$DI = Ta-0.55 (1-0.01 RH) (Ta-14.5)$$

Where:

➢ Ta is the hourly value of the average air temperature in degrees Celsius and Celsius
➢ RH is an hourly relative humidity value

The limits of the Disability Index (DI) and the corresponding ratings are as follows:

30.0 < DI	Heatwave
26.5 < DI < 29.9	Too hot
20.0 < DI < 26.4	Warm
15.0 < DI < 19.9	Neutral
13.0 < DI < 14.9	Cool
-1.7 < DI < 12.9	Cold
DI < -1.7	Too cold

10: According to the above, visit the BMS and monitor the temperature and relative humidity for a specific school day and answer the following questions:

➢ Are the ideal conditions of thermal comfort in your school building according to the answer to question 2?
➢ Calculate the discomfort index according to the answer to question 9 for all rooms with sensors installed.
➢ The values of the discomfort indicators you found in what descriptions correspond to the answer to question 9?
➢ If the ratings are different, try to justify this difference based on your answers to questions 4 and 5.
➢ Are the temperature and relative humidity conditions ideal according to the answer to question 6?
➢ Calculate the heat index based on the answer to question 8.

!: Indicative links - sources with temperature-humidity information:

- http://www.meteo.gr/pdf/deiktis_thermotitas.pdf
- http://www.eap.edu.gr/dat/3D03A263/file.pdf
- http://www.eap.edu.gr/dat/8DD9A37A/file.pdf
- https://repository.edulll.gr/edulll/bitstream/10795/1497/11/1497_01.pdf
- %25B9%25CE%25BA%25CE%25AE%2520%25CE%2586%25CE%25BD%25CE%25 B5%25CF%2583%25CE%25B7.pptx&usg=AOvVaw2J3ETYO_B2EnmAI0H7u49n
- http://dspace.lib.ntua.gr/dspace2/bitstream/handle/123456789/3815/frangisf_comfor t.pdf?sequence=3

GAIA

Controlling Power Consumption

1st Workshop
Level
Beginner

Power Workshop

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1: Using the Geany development environment, open the file **GAIA-Workshop4.1.py** located in the directory of your school and have a look at the code.

2: Plug in the **Micro USB** cable in the LED Rings and connect them to the **USB Port** of the Raspberry Pi (Image 1).

3: Connect the LCD screen (Image 3) to the GrovePi+ (Image 2) using the correct cable to the connector labeled **"screen"**.

!: Our goal in this lab is to observe the energy consumed in the school building at the moment of the workshop and if possible reduce it using simple actions.

Main Ideas – Keyworks:

Raspberry Pi, GPIO, GrovePi+, Arduino, LED, Switch, LCD screen, Button, 3 phase electrical installation, energy consuming appliances, electrical current, power consumption, Watt, Ampere.

Lab components – Preparation:

- Raspberry Pi
- GrovePi+
- LCD Screen
- Button
- Connector Cables
- Arduino board & 3 LED rings

Image 1 The LED rings for the exercise

4: To run the program select for the application menu the option Build and then Execute or simply press the button F5 on the keyboard.

!: In the LCD screen you can see the current in Amperes and the current power consumption. in Watts. Values are updated every 30 seconds from the central data services of GAIA using the sensors installed in the main junction box of your building.

Image 2 The GrovePi LCD screen

Image 3 The GrovePi board

Σελίδα **1** από **3**

5: Discuss with the members of your team and try to find the appliances that consume the highest electrical power in your building. Take a note in the next page of at least two of them and share your opinions with the other teams of your class.

?: Which appliances of your school do you think that are the most power consuming;

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6: Based on the discussion with the rest of the teams decide which two appliances could severely affect the power consumption of your building.

7: **You have a mission!** One person from each team will form a new search team that will try to find those appliances in your building and switch them off. You have two minutes to locate them.

8: The rest of you should note the electrical current and the power consumption in the table of page 3 as they appear in the LCD screen. Please remember that the values are updated every 30 seconds.

9: **You have a mission!** The search team will go again to the energy consuming appliances. This time you will switch them on. You have two more minutes to do this.

10: The rest of you should not the electrical current and the power consumption in the table of page 3 as they appear in the LCD screen. Please remember that the values are updated every 30 seconds.

11: Once the research team returns to the workshop area try to find the percentage of reduction in the values when you switched the appliances off.

12: You will need to use some mathematics for that. Consider that the 100% of the power consumption is the initial value you noted from all three phases. You should calculate the percentage of the change of the power consumption based on your actions. The mathematical formula to do this I the following:

Total change = |Sum of new value for all 3 phases – Sum of initial values for all 3 phases |

*The **initial value** and the **new value** is the one you noted in the table of page 3.*

13: In the table of page 3 for every time instant, circle the electrical phase that represents the highest power consumption. Can you explain why?

Electrical Phase	Time	Electrical Current (Ampere)	Power Consumption (Watt)	Comment
				Initial Value
				Initial Value
				Initial Value
				New Value
				New Value
				New Value
				New Value
				New Value
				New Value

?: What is the power consumption of the lights in your school?

Once you note the values of the sensors installed in the main junction box of your school, following the suggestions bellow, try to reply to the questions:

- Switch the lights on in 3 rooms of the building and note the total power consumption. After that, switch the lights off and note the new power consumption. What is the difference in the two states (lights on and off)?
- What is the increase in the power consumption by the switched on lights? Calculate this by comparing the values of the total building power consumption.
- When you switch the lights on, which one of the 3 phases increased?

GAIA

Controlling Power Consumption

2nd Workshop
Level
Beginner

Power Workshop

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1: Through the Geany environment, 🍵 , open the GAIA-Workshop4.2.py file in your school folder and see the code in the programming environment.

2: Insert the Micro USB cable into the LED strips and connect them to the Raspberry Pi USB port (Figure 1).

3: Connect the LCD screen (picture 3) to GrovePi + (figure 2) by inserting the appropriate connection cable into the socket with the label "screen" and the two buttons in the slots with the "button" and "button2".

!: Our goal in this workshop is to observe the amount of energy our building consumes during the day and if we can do something to improve it.

Main Ideas – Keyworks:

Raspberry Pi, GPIO, GrovePi+, Arduino, LED, Switch, LCD screen, Button, 3 phase electrical installation, energy consuming appliances, electrical current, power consumption, Watt, Ampere.
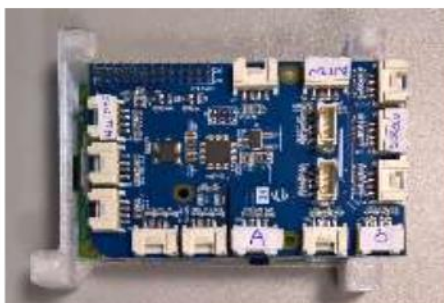
Lab components – Preparation:

- Raspberry Pi
- GrovePi+
- LCD Screen
- Button
- Connector Cables
- Arduino board & 3 LED rings

Image 1 The LED rings for the exercise

4: To run the program, select the Build menu and run the Execute command or press the F5 button.

Page **1** of **2**

!: On the LCD screen you can see the Ampere intensity and the average instantaneous power consumption in Watts in one hour starting from the current time. Each time you press the button, the values are refreshed and take you back one hour. You can move up to 24 hours back to see which day's day becomes the longest and the lowest average instantaneous energy consumption.

The indications you see are Watt current consumption and were recorded by the whole school building for all three phases separately. Remember that each time we press the first button, we change the recording time by one hour (for example, one moment we see the average instantaneous consumption value at 8, another one presses the average instantaneous consumption at 9 coke). Using the second button we see the power consumption in Watt for each phase separately or the total average instantaneous consumption of the three phases for the time.

> !: Each LED ring visualizes a current phase.

> ?: Do you see a different number of LEDs turned on/off in between strips? Why;

5: Record the measurement values by following the instructions above and answer the following questions:

- What is the time of maximum average instantaneous power consumption in your school building and at what stage of the current?

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- Can you think of the most likely reasons why the maximum average instantaneous power consumption occurs at that particular time and at this stage? Can you think of ways to reduce it?

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