Tame the Heat

8th grade interdisciplinary science course covering physics, chemistry and biology

Mingtong Zhang

Project Topic

1.1 Basic Ideas and Design Focus

Scientific subjects in basic education level are always taught separately, despite their intrinsic connections in logics and concepts. One challenge in science education is to integrate them into one interdisciplinary course, this is mainly what my project will target.[1]

There are mainly 2 hypothetical benefits from designing and implementing an interdisciplinary course, to become more effective, and to become more efficient in instruction. About the first benefit, an integrated and complete perspective, created by synthesizing perspectives of different traditional subjects together can help students understand the physical world more comprehensively. About the second benefit, there are currently lots of overlaps of content in traditional subject-specific teaching (at least in Chinese public high school), caused merely by the purpose to make school management easier, or to make teacher training faster, without considering whether it is a waste of time for learners to learn the same thing with different jargons in different subjects multiple times.

Note that there is a distinction between interdisciplinary and multidisciplinary. The latter is to combine different subjects with a single theme, in order to give more context to instruction. However, it will still teach knowledge subject by subject, without making concerted efforts to integrate different perspectives from subjects. Take water as an instance, the multidisciplinary may use one course to explain its properties and another course to introduce literature describing oceans. However, the interdisciplinary emphasizes to find and illustrate the connection between subjects, to synthesize a single and complete new perspective by integrating all the perspectives from different subjects, and to deem the knowledge from one subject as the result and prerequisite for learning another.

Therefore, the purpose of this project is to use interdisciplinary teaching in 8th grade level physics, chemistry and biology instruction, in order to harvest its 2 benefits, to make the instruction more efficient and effective. Interdisciplinary teaching is the means, and a more efficient and effective teaching is the end.

1.2 Design Overview in Practical Context

To take advantage of the benefits of interdisciplinary instruction, and to contribute more to the development of interdisciplinary instruction, I specifically chose Chinese 8th graders in Beijing. According to Chinese educational standards, this will be the first year they will have systematic access to all the traditional scientific subjects like physics, chemistry and biology. And generally Chinese 8th graders are confronted with heavy burden caused by their first encounter with those scientific subjects. Interdisciplinary instruction can ease their burden by both making a more effective instruction and making the learning process more efficient. Therefore, interdisciplinary instruction has great practical meaning for them.

The time and place for *Tame the Heat* is specifically set as during the summer vacation, and at a summer camp. This context in China might need a special explanation. Chinese summer camp is usually not about hiking, fishing or climbing. It is like an extra semester, during which students are organized in classrooms to learn knowledge to make preparation for their next

[1] This idea is also inspired by big ideas that *Instruction should vary between lateral transfer and domain specific knowledge if the domain is highly interdisciplinary*, since the science domains nowadays become more and more interdisciplinary, traditional domain-specific instruction is becoming obsolete.

semester. (That whether this kind of activity is proper is another issue. The issue here is under this condition, how to optimize the learning with the power of interdisciplinary instruction.) Thus a more effective and efficient instruction will definitely make them achieve more during the summer vacation, and save more precious vacation time to make the summer more restorative.

The context also justifies my choice of topic, to use heat as a theme to connect all knowledge for 8th graders from subjects of physics, chemistry and biology. For heat is the most salient feature in students' surroundings during the summer camp. It will put the domain knowledge close to students' daily life, and create connection between genuine problems and knowledge to be learnt. And heat is the basic phenomenon and energy in physics, the movement of molecules in chemistry, an important element in issues like global warming or biological cycle which constitutes the major concern in biology. Thus it is a great potential bond among all different but interlinked scientific subjects.

1.3 Content Coverage and Standards

All the relative content herein can be categorized into physics, chemistry and biology according to disciplines, and facts, skills and dispositions according to types[2]. And they are according to a published standard, The K-12 science frame work from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* The following is a basic overview about all the content for students to learn in *Tame the Heat* with an emphasis on introducing its connection to the relative standard. The *learners in context* and goal specification chapters will give detailed layout of all the knowledge and content.

1.3.1 Facts:

Students will learn the concepts and ideas about heat, the different ways of energy transfer and their features (physics domain), what is greenhouse effect (biology domain), various effects to generate or subtract thermal energy (chemistry domain), Major engines which harness thermal energy (physics domain). These parts are required by the standard in the following sections:

PS3.A for grade 8th:

The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and energy transfers by convection, conduction, and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures. Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

ESS3.A for grade 8th:

Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geological processes (link to ESS2.B). Renewable energy resources, and the technologies to exploit them, are being rapidly developed.

1.3.2 Skills:

[2] This kind of categorization is widely used in Big Ideas, though there are also other taxonomies to categorize what to learn, they usually do the categorization according to similar principles.

Students will learn basic calculation about specific heat capacity (physics domain), to identify and describe the mechanism of steam engine and inner combustion engine (physics domain), to analyze the bio-system in reference to heat as an energy (biology domain). Thes parts are required by the standard in the following sections:

PS3.B for grade 8th:

The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation.

LS2.B for grade 8th:

When molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material.

1.3.3 Dispositions:

Students will possess the idea to think about phenomenon in an interdisciplinary way, Interest in further science exploration, and a willing to protect the nature and view human and nature as a coexisting system. These parts are required by the standard in the following sections:

ESS3.C for grade 8th:

Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of many other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

1.4 Values and Meanings

Inter-discipline is significant for it enhances the transfer between different domains by building connection between them. Besides, real life problem cannot be solved by merely using the knowledge from any single natural subject. So my design is to choose a practical question highly associated with daily life as the context to contain all my learning content,[3] and use concepts from various associated subjects (according to the standard for the target learners and subjects) together to address problems while illustrating the inner connection between those concepts. Such questions directly generate motivation by targeting real-life problem and also lay the foundation for further science research during the problem solving process.

1.5 Resources and Support

I am once a half year internship teacher for 6th grade science, responsible for not only instruction but also course development. The knowledge is quite simple I am able to handle them. Besides, I also got help from Mrs. Yin, an elementary school science teacher in Chaoyang elementary school attached to Beijing Normal University, who guided my internship there, as a domain expert.

[3] There is an authenticity principle in Big Ideas suggesting *Understanding is revealed in performance. Understanding is revealed as transferability of core ideas, knowledge, and skill, on challenging tasks in a variety of contexts* inspiring this idea.

Teams in the Educational Technology Faculty of Beijing Normal University are also appreciated for reviewing my design and providing suggestions, especially Professor Wu Juan as a course design expert.

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Project Step A: Learners in Context

2.1 Context Considerations:

I did learner analysis in four different aspects, as the combinations of different traits in two dimensions: 1. to what extent is this trait a general feature of my learners as a group 2. to what extent can this trait be changed during the process of intuition. Thus there are 4 different kinds of learner traits to analyze, respectively changing similarities, changing differences, stable similarities and stable differences.[4]

	Similar with different individual learners	Different with different individual learners
Stable during instruction	Stable Similarities (e.g. - cognitive development stage of learners - social context of learners - physical development stage of learners)	Stable Differences (e.g. - different individual learning styles - different extents of mastery of prerequisite knowledge[5] - different temperaments and interests)
Changeable during instruction	Changeable Similarities (e.g. - general progress about course knowledge - norms, values and the feeling of belonging of the course - general dispositional progress of learners)	Changeable Differences (e.g. - individual progress about course knowledge - individual progress of dispositional learning goals)

Table 1. Four aspects of learner analysis

The results from the above four aspects of learner analysis will answer what is the general features of learners as a group, how to use these features and foster a course ambience with desired norms, values and belonging, as regards learners as a group, and what individual differences may exist among individual learners, how to cope with this variety to make instruction more adaptive, as regards learners as individuals.

2.1.1 Stable similarities

Stable similarity refers to the unchangeable part of traits of learners as a whole.

Considered as a group, there are 2 major features of my target learners, 8th graders from middle high school in Beijing, China:

1. Children Are Born Investigators

This idea is borrowed from the K12-framework which is the standard on which the course is based. Children (including teenagers) tend to learn faster from their spontaneous experience. Various kinds of inquiry learning are implemented here to fit this characteristic. This is

[4] This method of learner analysis is learnt and inspired by Professor Meifeng Liu in Beijing Normal University.

[5] Designs should make allowance for different individuals to assure achievability for everyone, as suggested in Big Ideas *All aspects of a course should be doable by the students, given their individual differences. If expectations are set too high or too low, students will not learn as well.*

especially suitable for 8th graders as they are experiencing the shift from a child to a teenager, with a great boost of self-confidence, desire to exploration and reasoning ability.

2.The Same Cognitive development level

As a general group, 8th grade teenager students' major cognitive characteristics are that from this period, abstract reasoning about logics becomes a dominant thinking method, and the ability to guide one's attention and perception toward purposeful target developed better. Learners become more suitable for inquiry-based teaching.

Besides, these students all have basic understanding about elementary level math and science, to meet the prerequisite knowledge requirement (as listed in the table below) for this course.

	Physics	Chemistry	Biology
Facts	1. temperature as a degree to describe heat 2. energy in nature and their different existing ways 3. concepts of mass of substances	-none (most Chinese school introduce chemistry course at exactly 8th grade)	1. earth as a planet, and sun as its light source 2. basic division methods of creatures
Skills	1. degree of Celsius, Fahrenheit and their meanings and transfer: \ C=(F-38)*5/9 2. Mass and its relevant metrics and calculation	-none	1. counting species within a given bio-system 2. distinguish different positions within a food chain

Table 2. Prerequisite knowledge for *Tame the Heat*

According to these features, conducting experiments gained more weight in the instruction, and inquiry-based teaching is widely used. All questions will be introduced by authentic difficulties in real life, and instructors will not ask the question, but will inspire students to raise questions by themselves by confronted them with those authentic problems. It is thus suitable to try interdisciplinary means of teaching on learners with these traits, for the abstract reasoning ability and scientific prerequisite knowledge required to learn several science domains at one time is first possessed at this stage, and breaking the walls among different domains grants a more spacious space to explore and build connection, which fits perfectly to the born investigator trait of learners.

2.1.2 Stable Differences

However, students in 8th grade is not at all a homogeneous group. There are individual differences among them. Some may have better aptitudes for concept learning, while others may be better at experiment operation. Some may prefer a learning guided by instructors, others may want to explore by themselves. Some may be more outgoing than others and always want to play

the leader role, others may be great executors. They can be respectively concluded as aptitude differences, learning style differences and temperament differences.

All activities taking the learners as a whole might face difficulties before those stable differences. However, grouping is the best way to cope with them. To give students the most flexibility to play their respectively desired roles while still achieving the same learning goals as a class, most of the tasks in *Tame the Heat* is group based. Groups are guided by instructors but organized by members themselves. Students with different but complementary stable traits will be grouped together to give each of them an indispensable and special role to make contribution to the whole, learn knowledge for themselves, and foster belonging.

2.1.3 Changeable Similarities

Students make progress while the course is proceeding. Though their learning styles and temperaments will remain the same during several days' instruction period, their knowledge, skills and even disposition is definitely alterable, and to alter them is exactly the purpose of instruction.

Tame the Heat both observes this kind of change as the evidence of learning, and adjust instruction according to this kind of change to optimize learning. For the first end, summative assessments are spread all over the course rather than centralized at the final stage of it, so as to give students and teachers a better view of their current general progress. For the second end, lectures and demonstrations are mainly put at the starting stage of instruction, as students learn more and deeper, more time will be devoted to experiments, group work and project, for they are more suitable learning ways for experts, which our students is gradually becoming during the course.[6]

As a general change, the overall atmosphere consisting norms and values is also fostered during the course. *Tame the Heat* asks for a productive, relaxing and unified atmosphere to motivate students[7], and give them the feeling of belonging to further arouse their potentials. Thus all the language in instruction and assessment will be refined accordingly, they must sound enlightening but not indoctrinating, and the awareness that they 8th graders are perfectly suitable to do science exploration will be conveyed by the course[8], to make students feel free to ask what they wonder, explore what they wish, and become creative without worrying about mistakes. Assessment tasks and rubrics are also designed accordingly. Project based on authentic problems will overwhelm quiz about rote knowledge as the main formative assessment of *Tame the Heat*. Students do their own making[9] show their achievement on learning goals and get grades.

2.1.4 Changeable Differences

Students change as the course proceeds. While the rate of changing might be different. Some students may learn quicker than others. To cope with the changeable differences, *Tame the Heat* added plenty of in-time formative assessments to give information to both students and instructors about their individually different current progress. And discussion and group work

[6] According to what I learned in E-learning class, worked example is usually more suitable for novices.
[7] The norms principle in Big Ideas suggests *Social interaction determines what and how people learn. Norms provide a guideline for how students and instructors interact in a learning setting.* It is a useful motivation to make students spontaneously learn more.
[8] This is one way to create belonging, to intervene learners' attributions about whether they belong, which is short but powerful.
[9] Making is especially beneficial as a way of learning for *People are exceptionally attentive to feedback that comes from their own productions.* And it also captures individual interests.

ensue. Students with different progress can help each other, and instructor may intervene based on the results of the previous assessment.

2.2 Course Structure

Based on the learners' features, knowledge to learn, and the general course purposes, course structure is organized.

The knowledge and their sequence is based on the previous knowledge they have, and the development stage in which they are. All previous science knowledge in elementary school is generally about introduction to phenomena, without too much explanations. Therefore, the unit deployment here also begins with simple and common phenomena of heat, and gradually dip deeper into the concepts and mechanism behind them. Heat itself as a natural phenomenon, belongs to the domain of physics, and involves lots of basic concepts such as energy, temperature, considered as the basic fact knowledge of this course. After the static phenomena of heat, a more complex dynamic phenomena of heat transfer will be introduced, this also belongs to physics, and involves more skill knowledge like specific heat calculation. From the micro physics properties of heat, the course then go deeper to its usage, this will make the topic go more macro as shifted to the different methods of cooling and heating, here reactions and substances used to absorb or release energy will be introduced, which belong to the domain of chemistry. With the pre-mentioned knowledge as preparation, the scope go more macro to machines around us using heat-relative knowledge, such as air conditioner, combustion engine and steam power, they are systems with every kind of knowledge congealed inside, both physics and chemistry. Here we can notice that the walls between domains have been shaken, for learners can never understand those complicated systems by concepts from only one domain. Finally the course go to the most macro, most complicated system, and what is most relevant to us, the biology system, in which heat transfer, in the form of energy transfer from sun, to plants, then to animals also plays a fundamental role to explain complicated phenomena like climate change. This obviously belongs to the domain of biology, and is actually explained by basic ideas from physics and chemistry! The interlinkage among domains is quite obvious and clear when you come here. Throughout the whole process, not only knowledge and skill is learnt, but dispositional changes like attentiveness of interlinkage between domains can be naturally built.

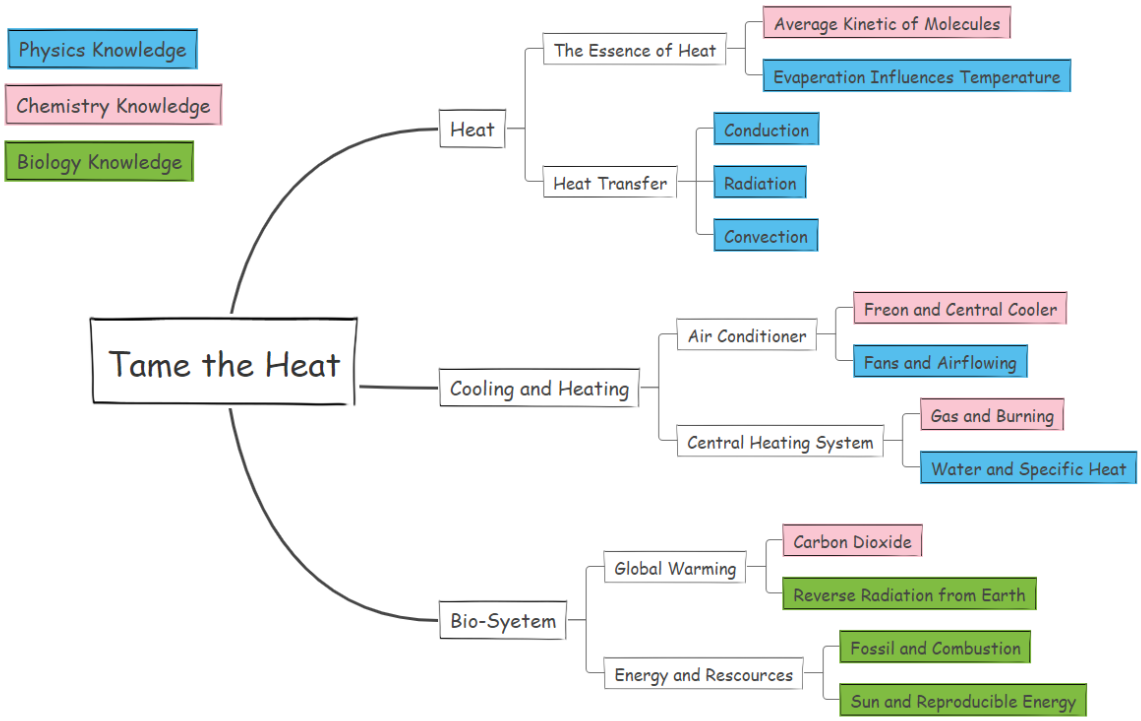


Figure 1. Knowledge Structure of *Tame the Heat*

The above shows a basic structure of the course. Knowledge from different subjects are illustrated by different colors. Different units may mainly involve different disciplinary knowledge, and heat is the topic to connect them.

Project Step B: Goal Specification

Conceptual Knowledge: C.C	Procedural Skills: C.P	Dispositions: C.D
Meta-Level Conceptual: M.C	Meta-Level Procedural: M.P	Meta-Level Dispositional: M.D

Table 3. Categorization of different kinds of goals

Different colors are used herein to distinguish different types of goals.

And my course mainly focus on conceptual and dispositional goals, which together make a great contribution to the central target of subject integration. To A certain degree, procedural skills are also involved to get a better understanding of concepts by operating them.

3.1 Goals about Facts

C.C.1 Know three transfer way of heat in nature (PS3.A&B)

a. Convection (Air flowing as a way of heat transfer called convection. It means due to the density, hot air and cold air have a tendency to flow toward each other hence uniform their temperature.)

b. Conduction (students will know direct contact between subjects as a way of heat transfer called conduction)

c. Radiation (students will know heat cause radiation, which possesses the form of visible and invisible lights, and they gradually transfer the heat to nearby objects in the form of energy)

(After the course, students will understand the concepts of convection, conduction and radiation and be able to give examples from life to them respectively)

C.C.2 Know several dominant methods for cooling and warming (PS3.B)

a. Basic air conditioner function (students will be able to qualitatively explain the mechanism of AC: it uses fans to inhale inside air to the central cooler, which makes itself cold by chemistry reaction involving usually Freon, and then exhale them back to the room.)

a.1. The chemical property of substances in AC

(Freon, a compound substance with its boiling point as low as around 30°C, consisting of mainly carbon and chlorine)

a.2. The basic structure of traditional AC

(Central cooler, inside fan and outside fan)

a.3. Which transfer way of heat is applied in different parts of AC

(Convection when air is exhaled and inhaled by AC)

b. Mechanism of central heating system

(A central heating system uses chemical reaction of burning usually by natural gas to create heat as a kind of energy. It is then transferred into water by conduction, for water has a large specific heat to contain more energy in the same amount of substance. Water then flow to radiator to give heat to the radiator by conduction, radiator heat its nearby air and the air heat the whole room by convection.)

(After the course, students will be able to give a simple explanation to common cooling methods like AC, and say correctly what specific domains and concepts are involved in daily cooling or heating facilities.)

C.C.3 Know the concept of global warming (ESS3.A&C)

a. What is global warming (students will have basic concepts about global warming, a phenomenon of average temperature of the earth goes up for more carbon dioxide enhancing the absorption of heat by the reverse radiation from the surface of earth.)

b. Its main reasons (more carbon dioxide enhancing the absorption of heat by the reverse radiation from the surface of earth)

C.C.4 Know the essence of heat

a. What is the essence of heat (students will be able to tell that heat essentially means the average kinetic energy of every molecules within a substance)

b. Evaporation as a way to influence temperature (Evaporation is the phenomenon that the existence form of substance shifts from liquid to gas, it will decrease the temperature of nearby substances)

M.C.1 Attentiveness of how much knowledge they know about science

(Students will be able to enumerate all the knowledge they now know about scientific subjects covered in my instruction, and check do I know the properties and reasons behind it when confronted with a new relevant thing.)

M.C.2 A well-organized structure (map) in their brains to store the knowledge

(Students will be able to draw a diagram or a flow chart to illustrate and accommodate all the knowledge they learnt)

3.2 Goals about Skills

C.P.1 Understand and identify different heat transfer in life

(After the course, students will be able to categorize the transfer of heat in their life. The behavior will be like facing air flowing and categorized and convection, contact of substances with different temperature and conduction, light both visible and invisible as radiation.)

C.P.2 Calculation about specific heat

a. Use specific heat to calculate energy needed to warm a certain substance (students will be able to quantitatively do the calculation about specific heat, that means given a kind of substance and its specific heat, students can tell how much energy is needed to heat it to a certain temperature. If s means specific heat, t is the degree of temperature to be changed, and m is the mass of the substance, then the energy needed, e, to complete this change is calculated as: e = tms)

b. Identify what material is better in different conditions (students will be able to use calculation and number comparison to tell under a given condition, like to make some products feel less cold in cold condition, a material with high specific will be the best choice)

(After the course, students will be able to quantitatively calculation issues about specific heat, and use the calculation to explain why its easy to heat something than others.)

C.P.3 Distinguish among various kinds of engine power

a. fossil energy

a.1. the property of fossil energy

a.2. the pros and cons of fossil energy

(energy by boiling coals, oil and natural gas which is made from fossils of ancient animals, they are cheap and easy to exploit, but limited and polluting)

b. Clean energy
b.1. the definition of clean energy
b.2. the property of clean energy
b.3. the pros and cons of fossil energy
(energy like nuclear power, wind turbine and hydraulic power, they are not polluting but either risky or pretty expensive.)
c. Reproducible
c.1. the definition of what is reproducible
c.2. the distinction between it and irreproducible
(energy which can be exploited forever without exhaustion. only energy from wind, water fusion and geothermal are considered reproducible.)
d. Irreproducible
d.1. the definition of what is irreproducible
d.2. the distinction between it and irreproducible
(energy which has a limitation of exploitation and will not be generated during a considerably long period. All energy which is not from wind, water, fusion and geothermal are considered irreproducible, including fission.)
(After the course, students will be able to categorize a common power source in life)

M.P.1 Self-examination of the calculation and categorization about heat.
(Students will check whether I did it right when doing heat-relevant calculation and categorization, and examine the process and result of themselves.)

3.3 Goals about Dispositions

C.D.1 Analyze natural phenomenon in an interdisciplinary way
(After the course, students will foster the thinking pattern of consider a phenomenon from perspectives of different subjects)

C.D.2 Attentiveness of global warming and environment protection
(After the course, students will spontaneously consider and concern about global warming and build an awareness of environment protection.)

C.D.3 Initial guess about the same origin of different science subjects
(After the course, some initial ideas that maybe different subjects like physics and chemistry actually address the same thing in different scopes, which is important in advanced science study, will be germinated.)

C.D.4 Interest and curiosity in science
(Students will become more interested in science)

C.D.5 Attentiveness of the close connection between science and life
(Students will really know science is useful for it guides techniques in life)

M.D.1 Be attentive of the changes in their own thinking models
(Students will be able to articulate all the changes in their opinions and mode of thinking after the learning)

Project Step C: Assessment Design

4.1 General Assessment Overview

The assessment of my course focus mainly on evaluating the awareness of interdisciplinary thinking, and other dispositional goals like interest and curiosity about science, awareness of the use of science in daily life and so on. To achieve this, the assessment will consist mainly authentic problem solving and individualized project. This does not mean the basic element of facts and skills will be omitted. Instead, to solve authentic problem means to make contextualized application, which really reveals understanding and skills by performance under various challenging tasks.[10] Besides, assessment by project highly involves making, which are motivations for more learning, and makes students more attentive to feedbacks to enhance the effects of formative assessment.

Based on the consideration above, there will be one final individual project as the main summative assessment, and 2 in-class group works plus several quizzes.

A brief diagram of the assessment design is like the following:

Learning objectives (cognition changes required)	Evidence (behaviors suitable to infer learning)	Criteria (How can behaviors be considered as an inference of learning)
Conceptual Goals (C.C.1-4)	- quizzes (main evidence) - team work, project (other evidence)	- Students clearly answer questions regarding relative knowledge - Students use their comprehension of knowledge to inspire innovation and enhance efficiency in team work and project
Procedural Goals (C.P.1- C.P.3)	- teamwork (main evidence) - quizzes (other evidence)	- Students efficiently and effectively solve the teamwork authentic problems - Students answer skill relative questions in quizzes correctly
Disposition Goals	- individual project (main evidence) - self-assessments - self-explanation questions in quizzes (other evidence)	- Final Project is innovative and an organic combination of science knowledge from different subjects they learned before

Table 4. General Assessment Overview

The assessment is made by combining various ways.[11] Quizzes in traditional way and instruction appear alternately throughout the whole course as a formative assessment to help students bet more understanding about concepts and do self-evaluation. They are totally

[10] *Assessment for understanding must be grounded in authentic problem-based tasks.*（UbD, p153）

[11] *Reasonable people understand a single test score does not define student learning. We must improve assessment systems and replace high-stakes, pass-fail testing policies with a system of multiple measures to evaluate student growth. The result: better teaching and learning that will benefit all students.* (BTTS, NEA Policy Brief, 2011)

formative and focus on knowledge rather than extrinsic rewarding like scores.[12] The teamwork and final project serve as both formative and summative assessment, start by small project with the help of team, students may at an early stage find their problems and adjust to cope with them. Based on the experience from teamwork project, they may better choose their topics and make their designs in final individual project. I deem this as a self-adaptive feature of the assessment design.

Assessment Type	Assessment name	Assessment contents	Formative/Summative	Goals	Time (frequency)
Quiz	Quiz about heat transferring	Questions on basic concepts with forms of multiple choices, self-explanation questions and feedback	Formative	**C.C.1 Know three transfer way of heat in nature** **C.P.1 Understand and identify different heat transfer in life**	1st day, 3rd day 5th day
	Quiz about cooling and warming methods	Well-constructed question about calculating and analyzing energy required to change the temperature of a certain object, open-ended question of explaining the mechanism of daily warming or cooling methods	Formative	**C.C.2 Know several dominant methods for cooling and warming** **C.P.2 Calculation about specific heat** **C.D.5 Awareness of the close connection between science and life**	2nd day 4th day 6th day
Project	Lego electric fan design team work	Use knowledge learned by now to design and make an electric fan with Lego circuit board, test its cooling ability and explain the result	Both	**C.P.1 Understand and identify different heat transfer in life** **C.D.1 Analyze natural phenomenon in an interdisciplinary way** **C.D.4 Interest and curiosity in science**	Start from 4th day and end in 2days
	Final Individual Project, cooling machine design	Final Project to design a cooling machine, requiring that to be efficient and effective, environment friendly and energy saving, the report and explain of idea is as important as implementation	Summative	**Comprehensive assessment of all conceptual goals** **Comprehensive assessment of all procedural goals** **C.D.1-5**	6th-7th Day
Self-Evaluation	Self-assessments	In the manual designed to guide the course, there is a self-	formative	**M.C.1 Attentiveness of how much knowledge**	Every Day

[12] So as to avoid *cause a performance goal which forms an obstacle for students to make further progress* (Dweck, 2000).

		assessment step on everyday, students think about their gains and questions today		**they know about science** **M.C.2 A well-organized structure (map) in their brains to store the knowledge** **M.P.1 Self-examination of the calculation and categorization about heat.** **M.D.1 Be attentive of the changes in their own thinking models**	

Table 5. Assessment List[13]

4.2 Specific Assessments

There are 3 types of assessments on the above list, respectively quiz, project and self-evaluation, each type will possess a complete sample so as to make a clear illustration.

4.2.1 A sample for quiz assessments:

The following is a complete example of quiz-kind assessment. It is what is in the first line of *Table 5. Assessment List*, quiz about heat transferring.

Protocol
This is given to students after the instruction about heat transfer in the 1st day, its media might be paper or electricity, in the form of a formative assessment. No strict time limitation is set, students may handle this individually or seek help from others. A certain discussion session is set after this formative assessment to conclude and answer those questions.
Introduction Words by Instructor
The content of it will be first introduced by instructor, in a kind and soft tune in order to set a clear distinction between the following quiz and an overwhelming summative assessment, to make sure students make full use of this quiz to learn knowledge rather than pursing performing well. The following is an example of what instructor may say at this moment: "Hi, the following quiz is a great method to guide you to learn the material we just talked about better! This is a quiz telling you want you are supposed to master, rather than something to check whether you mastered something or not. It is excellent if you find you do not perform perfectly on this quiz, so you can use the mistakes to pin point where you need to pay more attention and learn more." Note: This is only an example to illustrate what kind of information instructors are supposed to convey to students. Instructors are not asked to say the literarily same thing.

[13] *Assessment should be like a scrapbook rather than a snapshot* (Ubd). It means it is better to have a series of assessment based on contextualized application. Thus different assessments are spread throughout the whole instruction process rather than centralized at the final stage.

<table>
<tr><th colspan="2">Assessment Content</th></tr>
<tr><td colspan="2"> 
As you can see, there are 3 very common phenomena pictured, respectively the light from sun, a candle which is at the very moment of getting lighted, and hot air moving above the bonfire. You may notice heat transferring exists in all these three phenomena. Please answer the following questions using what you learnt.</td></tr>
<tr><td>Questions</td><td>Reference Answer</td></tr>
<tr><td>Consider the above three way of heat transfer, label the transferring way for each of them.</td><td>Sun-Radiation
Candle-Conduction
Bonfire-Convection</td></tr>
<tr><td>For each of the transferring ways you labeled, what is the feature of it</td><td>I labeled radiation, conduction and convection.
Radiation is the transfer of heat by light both visible and invisible, it need no direct contact between substances and usually has a very low transferring rate, unless the radiating substance is extremely heated.
Conduction is the transfer of heat by direct contact, it will always be unidirectional, from the hotter to the colder.
Convection is the flowing between air with different temperature, hot air is less dense and always go up, hence creates a heat exchange with the above cold air.</td></tr>
</table>

Give more examples of each transferring way you just labeled	Radiation-Microwave Oven Conduction-Engine Cooling Water, Oven Convection-Central Heating System, Electrical Heater
Learning Goals Covered	
C.C.1 Know three transfer way of heat in nature **C.P.1 Understand and identify different heat transfer in life**	
Expected Behaviors and Criteria	
Students will answer each question with or without reference to textbook or internet, or help from others. This is highly conceptual, so there is no scaffoldings for this kind of question. But in the implemented interface (if it is conducted in an electric device), students will be able to ask for hints from the system, and the hints use multimedia principles to give illustration to students. The last 2 questions are open-ended, students will communicate their answers in class. The answer to conceptual knowledge questions should be correct (i.e. the labeling must be exactly the same as the reference answer). However, in the explaining and example raising question, as long as the answer makes sense, it is acceptable. It does not matter how quick students get the right answer, a complete self-explanation on reasoning is better than a quick answer.	

Table 6. Quiz Example

4.2.2 A sample for project assessments:

The following is a complete example of project kind of assessments in team the heat. The example is Lego electric fan teamwork.

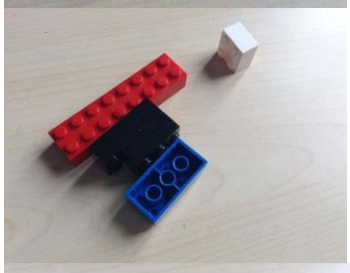
Protocol	
This is given to students after at the 4th day of the whole instruction, as a both formative and summative team work. Everyday there will be a certain period for this assessment, or better to say, activity. Group members can also decide to use any free time to do this if they want. Instructors will answer any questions from different groups but will never set a certain time to talk about concrete ideas to all groups so as to leave space for innovation.	
Procedures	
Introduction by Instructors and Requirements	**Lego Block Parts Given**

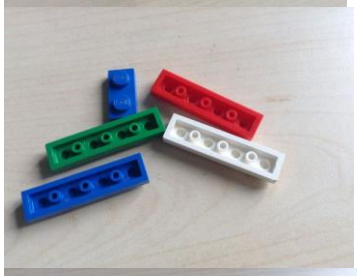
Description:
As we learned different methods of cooling and heat transfer ways as mechanism behind them, can you draw upon your knowledge to make your life better?

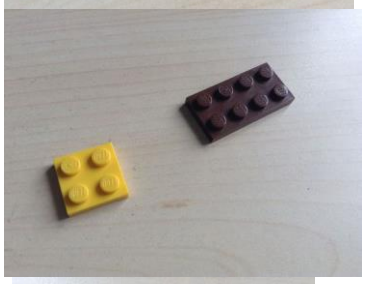
Given the Lego parts on the left, you got the chance to create one electric fan to cool your zone! Cooperate with your team members, make a design and implement it!

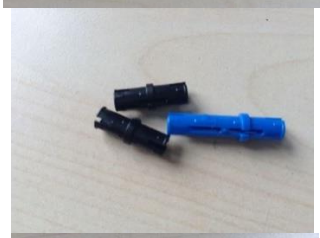
You may try different combination of parts, size of fan and test their different effectiveness. Always take into consideration that a design should try to achieve more effectiveness with less consumption of energy.

Finally, Explain your ideas and the mechanism behind your design so everyone may appreciate your newly acquired design ability from interdisciplinary knowledge!

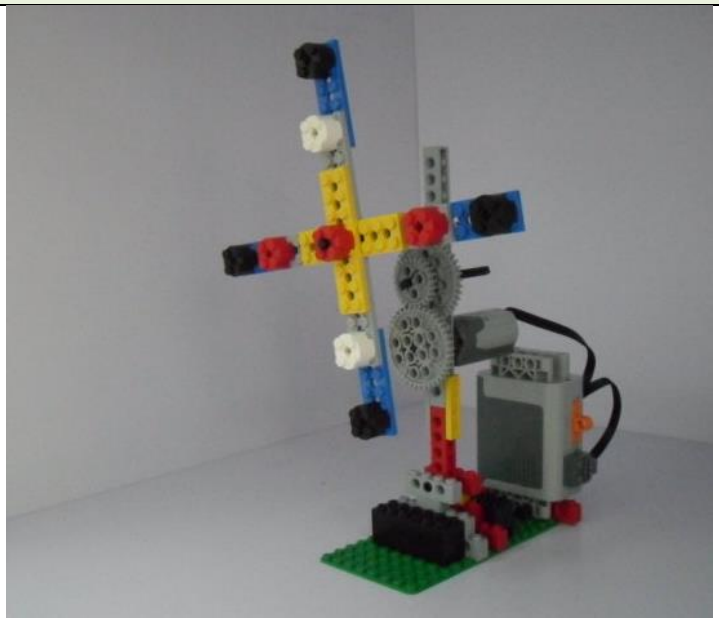








Reference Example



This is the electric fan made by our group. It uses the energy stored in its battery to make people cooler. Its mechanism is like this: The energy stored in

battery is transformed as electric energy, and further transformed into the kinetic energy of the fan by electromotor. The movement of fan causes the movement of air, and by convection, it transfer the heat in its nearby air to somewhere else! Besides, as the flowing of air will enhance evaporation and evaporation absorb heat, this can also make people cooler by more causing evaporation.
Learning Goals Covered
C.P.1 Understand and identify different heat transfer in life **C.D.1 Analyze natural phenomenon in an interdisciplinary way** **C.D.4 Interest and curiosity in science**
Expected Behaviors and Criteria
Goal and Role: As a student with basic interdisciplinary idea and knowledge, your goal is to design an electrical fan with Lego circuits and blocks so that can effectively cool a small area for you and your team. • Audience: Your target audience is all other students as curious and feel the same hot as you. • Situation: Your main challenges are (1) Complete a design, then implement it (2) There are lots of ways to cool people, which ones are used by you fan? (3) Support your design with ideas explained by knowledge. • Product: An implemented electric fan design, besides an introduction of it involving its basic mechanism. • Standards (Criteria): Your design should be effective, and the explanation of its mechanism must be physically meaningful. Using experiment to prove that your design can do a great job with quantitative calculation will be excellent. To introduce the general mechanism and make a qualitative experiment about the effectiveness is also good.

Table 7. Project Assessment Example

4.2.3 A Sample for Self-Evaluation Assessment

The following is a complete example of self-assessments, the only assessment with a type of self-evaluation.

Protocol
Students will take a little time to do this kind of assessment every day during the 7 days' mini summer camp course of *Tame the Heat*. It is supposed to be done at the very over of one day's learning, to give students opportunity to view back and evaluate what they got, what they feel in every aspects of the learning life. It will be completed individually and there is no time limitation to it, after the completion it will be reported to instructors every day. As a formative assessment, its result will have no influence on students' grades, but to give students and instructors more information about the progress of students' meta-cognitive learning goals.
Introduction Words by Instructor

A productive and meaningful working day is just over, at this very moment, it is pretty beneficial to examine and conclude your exploration during the whole day. As we have a manual helping you to do this better and quicker, let us grade ourselves according to it! As learning is the changing in cognition, what did you learn today? Introspect what is changed in your thinking mode? Can you handle the problems better than before? What new facts do you find? Write them down and review what you wrote before. There must be new discoveries!

Note: This is only an example to illustrate what kind of information instructors are supposed to convey to students. Instructors are not asked to say the literarily same thing.

Assessment Content

The self-evaluation is designed as a Likert-type scale. It is hard to generally grade what I did during a day, but it will be more feasible to break the question apart to multiple specific questions and finally get the answer as the average of them.

Please check to what degree do you agree with the following statements	Strongly disagree	disagree	neutral	agree	Strongly agree
I can enumerate all the factual knowledge I learnt today					
I can draw a conceptual map to clearly illustrate the factual knowledge I learnt today					
I did the experiments well today					
I did all the calculation fluently with correct sequence of steps					
Today's experience made me to think a part of the world in a different way					
I feel I belong to the group and class, we learnt together					
I am satisfied with the overall ambience of today's class					
As the point for strongly disagree is 1, and it increase each time by one to 5 for strongly agree, what point did you get today out of 35					

Learning Goals Covered

M.C.1 Attentiveness of how much knowledge they know about science
M.C.2 A well-organized structure (map) in their brains to store the knowledge

M.P.1 Self-examination of the calculation and categorization about heat. **M.D.1 Be attentive of the changes in their own thinking models**
Expected Behaviors and Criteria
For this assessment serves as a formative self-evaluation, there is no strictly a kind of criteria to judge its result. Basically, students are supposed to get as high an average point as they can, which can be used to infer that they are clearly aware of what they got from day's learning, and the meta-cognitive goals of *Tame the Heat* is achieved smoothly. If the point for an item is found to be 3 or below, it means students have no awareness of his or her progress regards of this item, either due to little progress is made or the student lacks a proper way of meta-cognition. In this case students may get help from intervention of instructors.

Table 8. Self-Evaluation Assessment

Project Step D: Instructional Design

5.1 General Description

5.1.1 Physical Environment:

Since all this course is designed as a science-theme summer activity, the physical environment for this can be school, laboratory or library, wherever suitable for science instruction, experiment, exploration and group work. Besides, a hot weather and common cooling methods everywhere as living instruction examples from daily life. Special props for this will include: 1. Handbooks for guidance and give illustration to basic ideas to assist instruction and learning 2. Lego blocks, circuit boards, and all the equipment for middle school level scientific experiment design.

5.1.2 Social Environment:

1. A productive and relaxing atmosphere in all students: as groups, students may feel relaxed and motivated to discuss questions together, feel free to ask any questions they deem valuable and work with each other.

2. Discipline to a certain extent and a respect to instructors: as the organizer of all learning activities, teachers have authority to a certain extent, which will not make students feel too much pressure or unwilling to share ideas, but can guarantee the necessary order for all learning activities. (to get effectiveness from organization while not doing damage to engagement)

5.1.3 Routines:

Tame the Heat is a 7 days mini summer camp course, so it is responsible to design activities for a whole day for students, rather than merely designing courses lasting for several hours. Except for the first introduction and grouping day, and the final Project day, the remaining 5 normal days of *Tame the Heat* will have the same daily loop of:

1. Warm up discussion about progress, questions to answer and the specific learning purpose today 2.theme instruction 3. Group work time 4. Self-evaluation time

The above loop is called the big loop, though every step of it can be considered as a process of learning, the most significant step and the step where instruction really happens is the 2nd step, theme instruction. 5 normal days of *Tame the Heat* will provide 5 theme instructions, with topics respectively of the essence of heat, heat transfer, cooling and heating methods, global warming and energy, to construct the course structure illustrated in *Figure 1. Knowledge Structure of Tame the Heat.* One theme instruction may consist of one or two sessions about different main topics relevant to the theme, and session is the basic constitution unit of instruction in *Tame the Heat*. Different sessions with different topics may have different content, but the theme-general schedule of sessions remains the same as the following:

1. Triggering and introduction: with questions presented by former discussion, or with examples from students' life, instructor introduces or prompt students to propose the topic for today.

2. Purpose clarification: after the introduction, in the form of conclusion, clearly clarify the purpose for today's learning, let students know what they will get from this class.

3. Lecture on basic concepts: give lectures on basic concepts involved in today's topic to perceptually weapon students the necessary knowledge to address the problem. But not do it too

further, the task of really solving the problem and digging deeper is left to students' critical thinking and innovation.

4. Group activities[14]: with the basic ideas taught before, students try to implement the concepts on real problem they proposed in step 2. They will build a systematic method to address the problem based on concepts as conceptual goals, supported by experiments[15] they designed, or consummate their former questions to dig the topic further with the inspiration of the learnt concepts. Most procedural goals will be practiced at this step.

5. Report, presentation and conclusion: students as groups share the results they got from step 4, usually in the form of presentation, helped by conclusion from both instructors and students themselves, get a better idea about how to solve the real problem brought out by themselves with the concepts and procedures they are supposed to learn.

5.2 Instruction alignment with WHERETO

Unit Plan to Include Key Design Elements
• Where & Why: by the triggering and instruction session, students are always clear where they are and what specific thing should they get after the imminent learning activities. They are fully motivated and knows why to learn because all questions are proposed by themselves and based on their daily life.
• Hook: 1. Learning purpose is not something external forced upon students, but brought out by students after inspiration and introduction, so they will always face genuine problem solving which is more attractive 2. Hand-on work is always there, from experiments to design, they are hooked by making. 3. Personal connections about the topic of heat to their everyday life and individual participation in group work. 4. Differing perspectives introduced by instructors in lectures, such as the dispute about the existence of global warming.
• Equip: the lectures, handbooks, group members and experiment equipment
• Rethink / Reflect / Revise: there are steps about presentation and discussion in my routine, they are the best opportunities to get revision from peers, instructors and themselves.
• Evaluate: 1. Formative assessments are useful for students to evaluate their progress during the learning process. 2. Daily discussion in daily routine gives the opportunity to clarify where they are currently, where are they heading for and even make comparison between their progresses and their peers'.

[14] The group activity part here is not the same as the 3rd step of the big loop, group work time. This part is about group discussion and group experiments which may last a number of minutes in theme instruction. The 3rd step of the big loop, group work time is the time in a day set specially for group projects. It may last for a number of hours.

[15] It is better to do something right after the boring lecture! *Abstract concepts in real-world situations. Hands-on experiences are fun and mentally nutritious that can increase engagement.* (Hand-on Principle from Big ideas)

• Tailor to Context & Learner Characteristics: Students bring out questions and generate genuine problems as a class, then dig it deeper or solve it as groups, this leaves enough space for different individuals to play different roles. The whole instruction is therefore students-focused, teachers play only the roles of organizer and reference.
• Organize to Optimize: Genuine problem solving, innovative project design is hard to complete if the content is covered only in superficial level. Besides, in class routine there are always steps of digging the initial problem deeper and give it discussion based on critical thinking.

Table 9. Instruction Alignment with WHERETO

5.3 Approaches in Instruction:

Direct instruction:

Lectures to all students in every class about basic concepts.

Special instruction to groups given their specific questions.

Facilitation:

The introduction to topic, guiding students to propose genuine questions in a constructivism way.

In class routine step4 students design experiments to support their answers to the genuine problem under the guidance and help, but not the orders of instructors.

Guided Discovery:

Presentation and discussion parts.

Triggering and introduction.

Coaching:

Feedbacks of all formative and summative assessment.

Instructor's feedback after all presentations.

5.4 Instruction Sequence

day	length	Schedule	Goal
1st	30 minutes	Pre-assessments on prior knowledge	**M.C.1 Attentiveness of how much knowledge they know about science**
	60 minutes	Group dividing according to individual style and prior knowledge level Lectures on problems about the prior knowledge	**M.C.2 A well−organized structure (map) in their brains to store the knowledge**

	60 minutes	Questions on problems based on prior knowledge and hard to tackle with knowledge from single domain, guided discovery of the idea of interdisciplinary	**C.D.1 Analyze natural phenomenon in an interdisciplinary way** **C.D.3 Initial guess about the same origin of different science subjects** **C.D.5 Awareness of the close connection between science and life**
2nd		The Essence of Heat Theme Instruction	**C.C.4 Know the essence of heat**
	60 - 90 minutes	Session1, Average Kinetic of Molecules	
	60 - 90 minutes	Session2, Evaporation Influences Temperature	
3rd	60 - 90 minutes	Heat Transfer Theme Instruction	**C.C.1 Know three transfer way of heat in nature** **C.P.1 Understand and identify different heat transfer in life**
4th		Cooling and heating methods theme instruction	**C.C.2 Know several dominant methods for cooling and warming** **C.C.4 Know various engines relevant to heat** **C.P.2 Calculation about specific heat** **C.D.5 Awareness of the close connection between science and life**
	60 - 90 minutes	Session1, Air Conditioner	
	60 - 90 minutes	Session2,Central Heating System	
5th		Global warming theme instruction	**C.C.3 Know the concept of global warming** **C.D.5 Awareness of the close connection between science and life** **C.D.2 Awareness of global warming and environment protection**
	60 - 90 minutes	Session1, Carbon Dioxide	
	60 - 90 minutes	Session2, Reverse Radiation from Earth	

6th		Energy theme instruction	**C.P.3 Distinguish among various kinds of engine power** **M.P.1 Self-examination of the calculation and categorization about heat.**
	60 - 90 minutes	Session1, Fossil and Combustion	
	60 - 90 minutes	Session2, Sun and Reproducible Energy	
7th	N/A	Final project workshop. Presentation and discussion. Instruction not to the whole class but specifically to different groups and individuals if required.	**C.D.5 Awareness of the close connection between science and life** **M.D.1 Be attentive of the changes in their own thinking models** **C.D.4 Interest and curiosity in science** **M.C.2 A well-organized structure (map) in their brains to store the knowledge** **M.P.1 Self-examination of the calculation and categorization about heat.**

Table 10. Instruction Sequence

5.5 Instruction Sample

The following is a complete example of a theme instruction session: session 2, evaporation influences temperature, of the essence of heat theme instruction in the 2nd day.

Instruction Goals		
Goals: Know the phenomenon of evaporation (**C.C.4.b. Evaporation as a way to influence temperature and** a part of **C.C.2 Know several dominant methods for cooling and warming**) Understand the mechanism of this cooling method (a part of **C.P.1 Understand and identify different heat transfer in life**) Get the factors influencing the rate of evaporation by experiment (a part of **C.C.2 Know several dominant methods for cooling and warming** and **C.D.4 Interest and curiosity in science**) Knowing that they know relevant knowledge about evaporation when it is time to retrieve it from memory. (**M.C.1 Attentiveness of how much knowledge they know about science)**		
Instruction Process		
	Actions of instructors	Actions of students

Step1: introduction of evaporation (0-10min)	Introduction and intriguing: Welcome! This day is our first attempt to Tame the Heat with knowledge! Let's get fully armed by domain knowledge! Some groups are asked to mop the floor to keep our classroom clean this morning, right? Look at the place you mopped, it was once wet, but touch it, it is dry now! Can you also feel the floor becomes not only dry but cooler? I know it is hot today, while it is not a good idea to lay on that part of floor to get rid of the hot weather. But we can utilize this phenomenon to design some better cooling methods! So what do you think make it cooler while drier? 	Listening, discussion and answering.[16]
Step2: purpose clarification (10-15min)	The water on floor was once in liquid form, it disappeared because it becomes invisible gas, and this phenomenon is called evaporation. These several days we can find vehicles owned by the city splash waters on our roads, nearby pedestrians will feel cooler from this. In this course, let us figure out why and how to use this phenomenon to Tame the Heat.	Answering, listening, building a concept map in mind with open slots to be filled by later study

[16] These common methods are also systematically concluded by the principle of Listening and Sharing in Big Ideas, *Doing things with others can be very motivating, but it also takes cooperative skills. Done well, students maintain joint attention, listen, share, coordinate, and try to understand one another's points of view. This can help learners exchange information and develop a multifaceted understanding.*

		
Step3: concepts lecture (15-25min)	A lecture to illustrate the relationship between temperature, energy and heat, may use flash or application to further show the relation between molecule movement and temperature, and why the process of evaporation take water molecule and heat away.	Listening, discussion, asking questions
Transition words	Now that we basically understand the mechanism of cooling by evaporation, sometimes we will go to beach or pools in summer, at those time, we will not feel cool even with lots of water on our bodies when the air is static, but with the help of breeze, we suddenly feel colder, why? We will then dig deeper to the factors influencing the rate of cooling by evaporation. As excellent explorers, we will definitely find something valuable![17]	
Step4: group activities (25～50min）	Deep Thinking: Yes, evaporation take heat away, but given that the rate of evaporation is different, we will definitely feel cooler to different extents. Experiment Exploration: Certain equipment is given to groups, like plates, wet tissue, alcohol burner, matches, water and guidance handbook. You want to design experiment to figure out what influences the rate of evaporation and how it works.	Group activities (Activity as reference: Within a group, students may spontaneously divide themselves to different roles, like designer, experiment operator, and recorder. First they raise hypothesis together by discussion with a form which might be brainstorm. According to the hypothetical factors which may influence the evaporation rate got by their previous discussion, they may conduct an

[17] *Yes I can refers to self-efficacy — people's belief that they have what it takes to accomplish a goal.* (ABC, 631)

		experiment in their previously divided roles to verify it. Take a group hypothesizing temperature as the factor influencing evaporation rate, they may use the equipment given to them to design a controlled trial, with water on 2 plates, with the only difference of different temperature, observe the evaporation rate of 2 plates and record them. During the whole process, there will be no active intervention from instructors to students unless students decide to seek help from instructors.)
Step5: report presentation and conclusion (50min-60min)	Organize presentation to report the findings of each group, draw conclusions for the entire class and conclude the results of the entire class explorations.	Report, present, discuss and listen (Activity as reference: A group hypothesizing temperature may report what inspired them to get this hypothesis, how they did an experiment to test it, and whether the result is for or against the hypothesis. Finally, they may turn the hypothesis into a conclusion like higher temperature has negative/positive/no influence on the evaporation rate of water. They may then ask questions they found during group activity to the whole class, and answer questions from other students and instructors about their experiment.)

Table 11. Instruction Sample

Evaluation Research Design

6.1 Implementation Evaluation

This instruction is designed to guide teachers to instruct in an interdisciplinary way, rather than to control teachers in every detail so as to make them mere executors of a plan. Initiative of teachers is expected during the implementation to give full play of the core design ideas and leave more space to make the instruction more adaptive to different practical situations.

6.1.1 Fidelity Evaluation for Teachers

However, it is still necessary to, to a certain extent, check whether the design is excellently implemented by instructors, which is known as fidelity evaluation for teachers. The point for this kind of check is about whether the ideas are implemented, whether the spirits behind it is reflected, rather than rigidly evaluate the implementation step by step in every detail.

To make the check interfere the implementation process as less as possible, we may not observe or supervise the instructors during their instruction. Surveys on students is used as the method to check instructors' implementation of the instruction.

The survey will be given to students and teachers after the instruction is over. It directly asks the implementation situation of the past instruction. To get a clear and concluding result about how the instructor implemented *Tame the Heat*. Main questions of the survey are like the following:

To students:

1. Do you think your individual needs and style are considered during the instruction?

2. Are you satisfied with your grade? What part of activity do you think contribute the most to your final grade? Please list all the methods you think your instructor used to evaluate your performance.

3. Please briefly draw a flow chart of all the steps your instructor used in daily instruction, and what is the most salient feature of each step.

4. Do you actively participate in the instruction, make spontaneous contribution to your group, and find a kind of belonging to your class community?

To instructors:

1. Do you think you considered and tried to meet all different individual styles among your class? Please list some individual differences you encountered and your way to adapt to it.

2. How do you grade your students? Please list all the methods you used to evaluate their performance and what is the thing you value the most in each method.

3. For every instruction goals, please list how did you teach your students respectively.

For they are basically same questions from the different perspectives of students and teachers, afterwards, I will check the alignment of students' answers, instructors' answers and the original design. The better they are aligned, the better the design is implemented, and the better students participate in the instruction and assessment as anticipated.

6.1.2 Fidelity Evaluation for Students

The fidelity evaluation for students care whether students of *tame the heat* actively participate in the course activities as what the design anticipate them to do. There are two ways to do this kind of evaluation: to observe and to ask.

Teachers will observe the progress and behavior of students while the instruction is proceeding, so as to know whether students participate well. The indicators can be class discussion, activity participation and assessment results. Moreover, there is a real-time survey as part of the assessment which directly involves the fidelity of students. The real-time survey is what will be given to students every day to give real-time feedback on the progress of instruction, the survey in Table 8. Self-Evaluation Assessment. Its purpose is to ask students' feeling toward the instruction and their gains from it. As a reference to how well the instruction is participated by them.

Teachers are supposed not only to observe, but to ask directly to students about their feeling and attitude. Questions like "do you feel engaged and why" will be raised at the discussion time every day to give teachers way to track students participation.

6.2 Impact Evaluation

The major concern of this design is about how to use interdisciplinary instruction to ease the burden to Chinese middle school students without changing any goals in their current standard, (Though the standard might be too strict.) and the cardinal assessment in the standard is massive standardized examinations about knowledge. Therefore, that students impacted by *Tame the Heat* will perform better in those standardized exams is considered as the evidence that the instruction is effective as regards this concern.

The effectiveness of interdisciplinary instruction has 2 aspects, the higher effectiveness of learning the content which will be covered in *Tame the Heat* itself, and the effectiveness improvement on relevant domain learning by experiencing interdisciplinary instruction. The former means people will learn the same thing faster by an interdisciplinary way rather than traditional subject-specific way, the latter means after interdisciplinary instruction, people will learn new knowledge from relevant domains better because interdisciplinary instruction gives them beneficial metacognition change. Thus I designed two different experiments respectively, one to evaluate the effectiveness improvement for the same content, and another to evaluate the effectiveness improvement for future learning.

6.2.1 Efficiency Improvement for the same content

- Research Question

  For the same content (Chinese 8th graders physics, chemistry and biology education standards), can an interdisciplinary way teach students with better effectiveness?

- Experimental Design & Methods

  1. Choose a certain number of Chinese 8th graders with roughly similar academic abilities.
  2. By a pretest, further choose students with the same academic ability within the pre-mentioned group, divide them into 2 groups.
  3. For the experiment group, use my interdisciplinary summer course to instruct them. And use a post-test to test their performance after the learning.
  4. For the control group, during the same seven summer camp days, toward the same content from domains of physics, chemistry and biology, use a traditional subject-specific instruction to teach them and use the same post-test to test them after the instruction.
  5. Compare the post-test results of experiment group and control group.

- Data Collection & Scoring

The pre-test is designed base on Chinese educational standards, to test the ability and knowledge of students in domains of physics, chemistry and biology, before the experiment has begun. Students will be categorized into several groups after the pre-test. Students in one group all have similar performance in pre-test, which suggests they are in the same level when it comes to the knowledge to be covered in the next instruction. Experiment subjects are members of the group which has the most members and whose members' academic ability can meet the prerequisite requirements to learn those which will be taught later.

The post-test is also based on Chinese educational standards, it will cover all the content in the knowledge structure of *Tame the Heat*. (As what is shown in *Figure1*. *Knowledge Structure of Tame the Heat*.) Its form is a quiz, and the score will be quantitatively counted.

- Hypotheses and Related Predictions

If the comparison of post-test results indicates that the average score of the experiment group is better than the control group in post-test, it can be inferred that this interdisciplinary teaching method can increase the effectiveness of instruction.

If the comparison of post-test results indicates that the average score of the experiment group is worse than the control group in post-test, it can be inferred that this interdisciplinary teaching method cannot increase and might decrease the effectiveness of instruction.

If the comparison of post-test results indicates that the average score of the experiment group has no significant difference than that of the control group in post-test, it can be inferred that this interdisciplinary teaching method has no significant influence on the effectiveness of instruction.

- Assessment of Design Quality

Sampling

The required sample size should be big enough to make the results reliable but not too big to make the experiment still feasible. According to my previous experience and literature review, I think no less than 20 people in both control and experiment groups is fine.

The academic abilities of people in control and experiment groups should be the same to guarantee a successful variable control.

Validity

Since what we want to evaluate herein is to what extent interdisciplinary instruction can impact the effectiveness of learning, the validity of this evaluation specifically means how well the designed experiment can test the correlation between learning effectiveness and interdisciplinary instruction. It can be valued by internal validity and external validity.

The internal validity values whether there is a clear correlation between independent variable and dependent variable which will not be affected by any other factors. The independent variable here is the existence of interdisciplinary instruction and the dependent variable the effectiveness of learning inferred from the scores of students in standardized exams. For the experiment is a controlled trial with everything remaining the same in both experiment and control groups except for the existence of interdisciplinary learning. It can exclude any influence to the post-test score other than whether students are taught in an interdisciplinary way, hence get a good internal validity.

The external validity values how well can the result of evaluation be generalized to broader groups. There is a small defect of the sampling to be mentioned. For I have to choose

subjects from only volunteers who wish to participate the summer camp, rather than from all Chinese 8th graders, the sampling might contain more people who are interested in science for those people are usually more willing to join such a summer camp. This might have an inescapable negative influence on the external validity of this evaluation.

Reliability

Reliability mainly concerns how consistent the test results will become when the test is used on similar groups multiple times.

In this evaluation, the fidelity of instruction implementation is guaranteed by pre-mentioned surveys. So if it will be implemented multiple times, each time will possesses the same quality. And the post-test is a massive standardized exam for Chinese 8th graders qualified by Chinese official educational standard, this is an exam designed by professional instructors and widely used in China hence is also considered reliable.

Equity

The prerequisite knowledge mastery degree of subjects, and the content to learn for all the groups are the same to ensure a good equity.

	Arrangement		What to Observe
Experiment Group	Summer Vacation	Post test	Average score from standardized exam A
	Take interdisciplinary instruction, *Tame the Heat*	standardized exam A[18]	
Control Group	Take the subject-specific instruction about the same content as what experiment group will learn	standardized exam A	Average score from standardized exam A

Table 12. Impact Evaluation Experiment 1

6.2.2 Effectiveness Improvement for future Learning[19]

○ Research Question

Whether taking my interdisciplinary instruction will make students more effective in their future learning about the domains covered by it, even if confronted with totally different knowledge from what is taught in my instruction.

○ Experimental Design & Methods

1. Choose a certain number of Chinese 8th graders with roughly similar academic abilities.
2. By a pretest, further choose students within the pre-mentioned group with the same academic ability, divide them into 2 groups.
3. For the experiment group, use my interdisciplinary summer course to instruct them. And use a post-test to test their performance after their next semester.

[18] This means a standardized exam designed according to Chinese educational standard for 8th graders, covering the knowledge from physics, chemistry and biology in the knowledge structure of *Tame the Heat*

[19] Though the idea of this evaluation is innovative, it is not as feasible as the last evaluation due to its implementation will require a very long time period.

4. For the control group, do nothing during the summer vocation, let they undergo the traditional subject-specific instruction of the same content during their next semester, and use the same post-test after the end of that semester to test them.
5. Compare the post-test results of experiment group and control group.

- Data Collection & Scoring

The pre-test is designed based on Chinese educational standards, to test the ability and knowledge of students in domains of physics, chemistry and biology, before the experiment has begun. Students will be categorized into several groups after the pre-test. Students in one group all have virtually the same performance in pre-test, which suggests they are in the same level when it comes to the knowledge to be covered in the next instruction. Experiment subjects are members of the group which has the most members and whose members' academic ability can meet the prerequisite requirements of my instruction.
The post-test is also based on Chinese educational standards, it will cover all content taught by physics, chemistry and biology courses in the semester after their next semester. It is not exactly the same thing they will learn in *Tame the Heat*, but from the same domains. The form is a quiz, and the score will be quantitatively counted.

- Hypotheses and Related Predictions

If the comparison of post-test results indicates that the performance of the experiment group is significantly better than the control group, by itself it directly shows the effectiveness of learning of my experiment group in the next semester is better. Plus the only change in my experiment group is they took an interdisciplinary instruction previously, it can be inferred that this interdisciplinary teaching method can make people become more effective in future learning to knowledge from the same domains.
If the comparison of post-test results indicates that the experiment group do the same or worse than the control group. It means taking my interdisciplinary instruction cannot help people become more effective in future learning about the same domains.

- Assessment of Design Quality

Sampling
The required sample size should be big enough to make the results reliable but not too big to make the experiment still feasible. According to my previous experience and literature review, I think no less than 20 people in both control and experiment groups is fine.
The academic abilities of people in control and experiment groups should be the same to guarantee a successful variable control.
Validity
Since what we want to evaluate herein is to what extent interdisciplinary instruction can impact the effectiveness of learning, the validity of this evaluation specifically means how well the designed experiment can test the correlation between learning effectiveness and interdisciplinary instruction. It can be valued by internal validity and external validity.
The internal validity values whether there is a clear correlation between independent variable and dependent variable which will not be affected by any other factors. The independent variable here is the existence of interdisciplinary instruction and the dependent variable the effectiveness of learning of relevant domain knowledge inferred from the scores of students in standardized exams. The experiment should be a controlled trial with everything remaining the same in both experiment and control groups except for the

existence of interdisciplinary learning. But actually it is impossible to ensure both control and experiment group can experience the identical next semester, their teachers, classmates and schools must be different and they all have unavoidable influences on the effectiveness of learning. So it is hard to guarantee a perfect internal validity for this evaluation.

The external validity values how well can the result of evaluation be generalized to broader groups. There is a small defect of the sampling to be mentioned. For I have to choose subjects from only volunteers who wish to participate the summer camp, rather than from all Chinese 8th graders, the sampling might contain more people who are interested in science for those people are usually more willing to join such a summer camp. This might have an inescapable negative influence on the external validity of this evaluation.

Reliability

The reliability mainly concerns how consistent the test results will become when the test is confronted to similar groups multiple times.

In this evaluation, both control and experiment group will experience the learning of their next semester, but I have no control over the quality of their next semester. Due to different teachers, schools and special incidents may happen during the next semester, the quality of their learning might be very different. So it is still hard to guarantee the reliability for this evaluation.

Equity

The prerequisite knowledge mastery degree, and the content to learn for all the groups are the same to ensure a good equity.

	Arrangement			What to Observe
Experiment Group	Summer Vacation	Fall Semester	Post-Test	The average score of Standardized Exam B
	Take interdisciplinary instruction, *Tame the Heat*	Go school normally	Standardized Exam B[20]	
Control Group	Learn nothing about relevant knowledge	Go school normally	Standardized Exam B	The average score of Standardized Exam B

Table 13. Impact Evaluation Experiment 2

[20]This means a standardized exam designed according to Chinese educational standard for 8th graders, covering the knowledge from physics, chemistry and biology in students' next semester, which is not the same knowledge they will learn during *Tame the Heat*, but is from the same domains covered in *Tame the Heat*

Project Reflection

Product Reflection

1. Alignment

I set my goals according to the standard I chose, and set all the assessments and instructions specifically according to different goals. There are clear diagrams to illustrate this kind of alignment. Thus, personally, I have no great difficulty dealing with the alignment of all those 3 parts of course design. But I did learn the significance of assuring alignment of goals, assessments and instructions by the process of illustrating how I aligned them multiple times. And by this kind of exercise, I am quite aware of the common pitfall of intuitively designing a class from its instruction part without considering what to instruct and how to evaluate the results.

2. The Implication of the Age Level I choose

The implication is first reflected by the goals I choose. There are specific mappings between every certain age state and a certain level of domain performance requirement. Since I chose 8th graders, all the learning goals are set accordingly. There are also implications on the teaching methods I use. To meet the *born investigators* trait of my target age group, I used more experiments and guided exploration to replace lectures.

3. Big Ideas Exemplification

Though not every big idea is covered in my course, I still take advantage of lots of big ideas collected in our EGIA course. In the justification part of assessment and instruction, there are more detailed mappings.

4. User-Friendliness

In this report, the ideas of all my 5 parts are clearly suggested. However, to make it really practical, I think users still need more specific examples, instead of my current format of one example for one type of assessment and instruction. So users will find it feasible to implement this.

5. Requirement for Educators

The interdisciplinary instruction proposes a high requirement for its implementers. This is also a reason it is very hard to implement and still not quite popular. To become a qualified instructor of my course, a teacher need a comprehensive knowledge of all middle school level physics, chemistry and biology, plus a basic understanding of backward instruction design.

6. Innovations

The biggest innovation, and the one I am proudest of, is I make a leap from multidisciplinary instruction to interdisciplinary instruction. About the detailed differences between them, I mentioned it in previous parts. Generally, in my design, I innovatively considered how to use perspectives from different subjects to create an optimized new understanding to a phenomenon.

7. Peer Feedback

Some mentioned I make no clear distinction between interdisciplinary and multidisciplinary, so I give a clearer explanation about them in my later versions. Sharon (definitely not a peer) also gave a precious advice about another possibility of evaluation, which is to evaluate the long-term efficiency influence by interdisciplinary instruction to learning in the same domains. I took this as the foundation of my 2nd impact evaluation experiment.

Process Reflection

1.Pros and Cons

my strengths include it is practically meaningful and quite innovative. However, its main weakness is it makes too high a requirement for instructors to know different knowledge from different domains, and use them to conduct experiments and design projects, and its evaluation experiments require a long time to be finished. In a nutshell, it is not super practical.

2. Challenges and Solutions

There are legionary challenges. I can even not recall all of them.

The most significant are two. One is when I am writing the impact evaluation part, two great ideas come to my mind, one is feasible but less innovative, another is very inspiring but less practical. For it is very hard to sacrifice one and choose another, I decided to write both but note their pros and cons respectively. Another is how to make a clear illustration of what knowledge in *Tame the Heat* is from physics, chemistry and biology to give concrete example of my interdisciplinary ideas, otherwise there will only be ideas and general description. I finally chose to use mind map drawing Application to finish this job.

Besides, it is also challenging to design a proper sequence so I can effectively combine content from all 3 science subjects I am going to cover. It needs lots of domain knowledge and test. I worked through them by the help of teachers in Chinese schools and universities. Besides, I myself am familiar with the target domain knowledge because of my relevant tutor experience.

3. Next Plan

I get lots of precious practice of instruction design from this project. As I mentioned above, its main weakness is it is still not quite user-friendly (to put it more clear, implementer-friendly) and practical, for a lack of enough specific examples. This is definitely something can be solved by more work. If there is a chance, I plan to complete this design by adding more assessments and instructions, so as to practically implement this in a small scale to test its hypothesis.

References

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