Creative-Discovery Workshop on Droplets and Dripping

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Introduction - Discussion workshop

The goal of the workshop presented at the GIREP-EPEC Conference was to give participants a taste of the SCHOLA LUDUS alternative system of learning and teaching. Hence the discussion was not about what or how we should teach in general. Instead participants were able to experience a SCHOLA LUDUS creative-discovery workshop (CDW) that presented typical educational approach of SCHOLA LUDUS; it belongs to the typical educational forms of SCHOLA LUDUS and, in fact, it is a kind of discussion workshop too.

In Part 1, we out line the fundamentals of CDW [1], including the applied thinking tools that help teachers to prepare the workshop as a mean for effective teaching and learning tools. In Part 2, there is given a short description of the sample workshop performed at the GIREP-EPEC conference and conclusion notes to the workshop. The given workshop was prepared for upper secondary classes of physics but with some reduction it can be used also for pupils at lower secondary schools.

1 SCHOLA LUDUS Teaching and Learning Base

CDW Focus and Key Case

In general, the focus of CDW is on thinking about relevant simple experiments and definitions that centre learners round a given key case (KC). It is considered that creating definitions implies serious learning of the object, understanding what is really happening, what else can happen, what could happen if…

Experiments

To understand what is really happening we need experiments. Learners themselves must propose simple experiments related to the key case and find out its typical features, classify them, and separate its essential features. Those features that together enables us to make such universal definitions and accordingly defined subject; and which can be easily distinguished from others, are useful and help to treat the matter in issue efficiently. Thus it does not matter if the object is a process, a system or a concept.

Parallel Ideas

On an individual level the learning procedure is seen and experienced in different ways and this is an important point to be aware of in any learning process. There is a tendency of preference to give learners a ready and clearly formulated definition but the problem with this is that it can hinder learners to offer input, which might be outside of the realm of the given definition (Let learners to learn serious things.) In SCHOLA LUDUS, the process between the teacher and learner is a two-way channel for learning and it is important to be open to alternative perceptions, thus the CDW is based on different ideas and proposals. We put them together, treat them as parallel cases and, successively, on the base of parallel cases we make an agreement on the optimal advanced definition.

Knowledge with Values
The optimal definition must be simple and clear for further learning and handling. To create such a definition requires also to discover and to understand the value of the respective experiments and definitions whereby their values are closely linked with the undergoing process of defining. – How did we get the final definition? What was the starting point? Which aspects and attributes did we take into consideration and which factors did we neglect? What definition premises did we realize? What were the experiment conditions? In which way did we arrive at this definition? How did the considered model look like? – Thus, values are in general linked with the way we obtained the knowledge. Only if we are aware of this way we can understand the respective limits and restrictions of the definition and use it correctly and efficiently.

Alternative Teaching
CDW program is difficult to cover in one lesson and hence some arguments against it by teachers are “a lack of time”. But a SCHOLA LUDUS creative-discovery workshop usually involves several topics and many basic concepts that are taught in classic school physics (or any subjects in general), too. So we can solve the questions easily by systematizing them from time to time. Doing this, CDW represents one of alternative ways to teach and learn science effectively while the value of the gained knowledge from CDW is much higher.

Definitions
Probably the most unusual moment of the CDW with respect to the instant teaching and learning is that learners are asked to create their own definitions related to the matter. Of course, controlled by their teacher, they are directed to find out also the generally accepted definitions and gain insight of their merits. These merits usually stand out in comparisons with other definitions and just, due to these comparisons, the learners become aware of them. However, doing so, the learning process is not focused to find out the only one definition (the best one) but always the optimal practical one with respect to certain aspects of the key case (KC) and the respective context.

SCHOLA LUDUS Teaching and Learning Cycle (TLC)
In the process, the discussion relating to creation of definitions concerns, in dependence of the current level of TLC, alternatively, to the

1. KC description. We describe the observed processes and phenomena. What was seen, what happened, whereby the goal is to find out and define the first order problem.
2. KC mapping. We map the physical system from different aspects that results in sorted lists of attributes to point out respective problems. By the way, we meet with different concepts that need to be defined.
3. KC modeling. We create and/or deal with different functional models in order to discover the possibilities of the system, the system performance in dependence on concrete conditions.
4. KC bases. Neglecting the concrete conditions we abstract the general principles, laws, theories that govern the undergoing processes and phenomena.
5. KC generalization. We solve, discuss, and define different problems whereby the goal is to define, design criteria of a new system and to recognize the value of the gained knowledge. This is also the process of the knowledge quality change, from knowledge-information to conscious knowledge-tool that can be used by learners willfully.

Preparation of TLC for CDW

Considering any SCHOLA LUDUS teaching we always deal with a key case. In the sample workshop droplets were the key case. The droplet was the object that we (in the role of a teacher) decided to use for getting learners in the school physical topic/theme/subject, represented here by the basic properties of liquids.

Having the droplet as the key case, the TLC gets more concrete features.

1. Observing: Playing with droplets – the small but magic amount of liquid.
2. Mapping: Doing simple experiments with droplets aimed to find out a definition what a droplet is. We can deal with a droplet on a base, hanging droplet, falling droplet, droplet in space…
3. Modeling processes: The biggest and the smallest droplets on a base. Interaction of droplets with surface (solid, liquid). Definitions of droplet.
4. Abstracting the principles: Basic liquids properties – surface tension, flowing, viscosity, etc. From macroscopic phenomena to microscopic forces and back to the macroscopic level. Droplets as complex dynamic systems.
5. Assessing the gained knowledge: Dripping from a faucet. Rain droplets. Design of a droplet timer. Introducing modern research related to droplets and unique modern technologies profiting from knowledge of droplets.

SCHOLA LUDUS Standard Scaffold of TLC

Deciding for a key case there is time to apply the SCHOLA LUDUS standard scaffold [2] of TLC. This scaffold consists of five stages that support the upper introduced five TLC levels: To any key case (supports the 1.level of CDW) we always use three kinds of sets of parallel cases (PC):

- one or several sets to support the education process of mapping (2. level),
- one or more sets to support the education process of modeling (3. level) and
- one or more sets to support the education process of abstracting (4. level).

And the scaffold ends with the top cases – TC (5. level).

Parallel Cases and Complexity

Looking back at any level we have got several parallel cases. They represent alternative cases but for several reasons we cannot treat all of them thoroughly at once (because of the complex character of matter, because of the abilities of our thinking process, and also due to lack of time). Neither can we treat them thoroughly with free standing. It is not the real goal (it would be time consuming and also boring). Yet we can show learners all these cases at the start of the teaching and learning process and profit very much from different kinds of parallel cases. The goal is to understand the complexity of matter. Obtaining one property from one case we can use it operatively in another case, and if learners have seen the parallel cases, any gained knowledge is embedded into relevant broader memory structure.

The parallel cases are used to stimulate understanding of the respective focus related the key case from the aspect of the respective level of the TLC. E.g. the parallel cases in one set are used not for learning in-depth each of them separately but to emphasize respective characteristics that are common and significant for the key case.

Thinking FOCUS

Having the current focus we keep it until we get the sufficient ideas and their values. Thus we use FOCUS also in the broader meaning of the teaching and leaning process and as an efficient thinking tool for making evaluations and decisions.

Originally, FOCUS was aimed as a **F**ormal **O**utput **C**oncerning **U**nique **S**olution [3]. Now we use it also in the preparatory phase for designing the process of learning:

First we recognize the possible learning *focuses* and *concepts* that could be used to approach the considered focus. Then we try to formulate *ideas* concerning the respective focus via the respective concept. Finally we sketch formulations of the *values* of these ideas with respect to the considered focus via the concrete considered concept. But the usage of the FOCUS means to think always about one focus and one concept and not simultaneously concern with more of them. Thinking in the way of FOCUS seems to lead in much more effective habit of mind than to develop and evaluate ideas to one focus via several concepts or even consider several focuses in parallel.

FOCUS as a thinking tool stands for referee. FOCUS is the precondition enabling us to use the parallel cases in TLC. It provides the thinking process over several cases towards the central focus, gaining ideas including their values. To develop formal thinking process with FOCUS means to profit from parallel method without creating chaos in the mind.

SCHOLA LUDUS Strategies of Teaching by Playing

During a learning process it is impossible to require from learners to see the real purpose of their learning from the beginning. Why do they have to learn just this? To avoid this question prematurely we endeavor the learning process as an adventure for learners and CDW has potential to become learners´ adventure. Making experiments and definition means playing for learners. In playing we use three basic teaching strategies: spontaneous playing, controlled playing and great creation playing. While the spontaneous teaching assumes rather individual initiative of learners shooting into unknown, the controlled learning is near to Vygotsky´s social teaching, and the great creation deals with awareness of the goals, knowledge, and collective responsibility.

Lateral Thinking and Creativity

Learning by playing with parallel cases creates a fruitful environment for lateral thinking and development of learners' creativity. However for developing serious creativity the environment is not sufficient. In the frame of CDW we need to use consciously various thinking tools and techniques based on lateral thinking as are de Bono´s PMI (Plus-Minus-Interesting), OPV (other people's view) [4], Six Thinking Hats [5] etc.

2 CDW on Droplets and Dripping

Understanding CDW as an alternative SCHOLA LUDUS way of teaching science, the prime task is to choose a suitable key case. The key case has to be attractive, simple, easily available, surprising for learners.

There are several expressive advantages of the choice of droplet as the KC and our focus for teaching. It is familiar for learners, available, cheap, clear, apparent, simple handling for experiments and, in addition – magic. Yet, this mysterious feature must be discovered. It appears only if the learners get enough space to play with it, to observe it, to think about it, to fulfill the creative thinking process.

There is always a gap between the preparation of the TLC and the concrete CDW realization, and hence there are always more possibilities to realize the workshop. The gap is caused by learners´ preconceptions that are unknown at the beginning of the workshop. We have to gain them at the beginning of the workshop and we modify them during the process in a desired way.

1. Evocation of Preconceptions – Observing

Learners are asked to draw-sketch different droplets. Later we provide them with a set of droplets at different situations downloaded from Internet for further inspiration (See Fig. 1). Alternatively, learners could find photos by themselves.

The teaching goal of this phase is to open learners´ minds/memories at the right place for further knowledge construction. They also recognize that a person does not have to understand a droplet meant by another person as a droplet.

Fig 1. And what about these bodies?

2. Preconceptions versus Reality – Mapping

Next task is to create previously visualized droplets. Learners have at their disposal cups with different liquids, different tools to drip a droplet with and various materials that could be used as a base for droplets. They recognize that it is not easy to create a droplet of certain expected characteristics.

The goal of teaching on this level is to link the relatively final state of a droplet on the base with its creation process. The result of the process depends on several factors that does not have to be necessarily expressed but at the end learners usually recognize them: the liquid source – used dripping tool, the amount of the liquid; the space in which the drops are falling – its composition and the distance between dripping tool and the base; surface properties of the base – material, structure; the way of dripping. From variety of ideas there arises a common question: ”In fact, what is really a droplet?”

3. Approaching the Limits – Modeling

Concerning creation of the definition, learners are involved in the process seriously. “What are the possible shapes of a droplet on the base? Is each small amount of liquid a droplet? Where are the limits of a droplet? What is the difference between droplet and non-droplet states?”

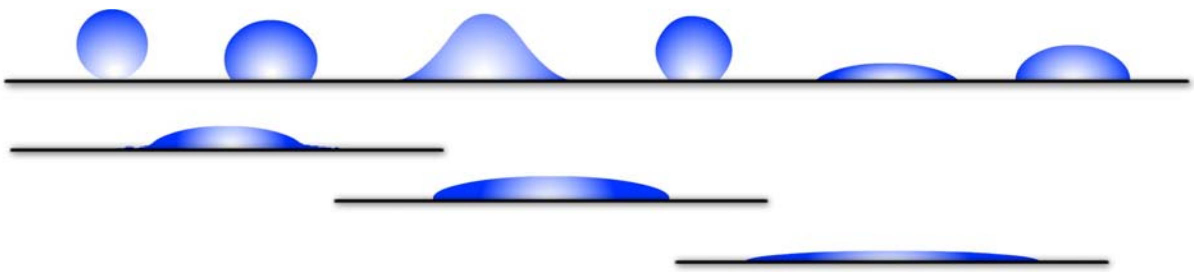


Fig 2. Which of these sketches represent a model of a droplet?

To find out the answers they initiatively make different simple experiments. One learner joins his definition with dripping process from a straw – the drops are those small amounts of liquids that just spontaneously drip from a straw and touch the base without fall.

Another learner finds out dynamic definition related droplet destruction: Droplet on a base is a small amount of liquid that keeps en masse also when you blow into it or push it gently. Etc.

We (as teachers) have prepared also our versions. Here the first teaching goal is to develop the process of modeling. Learners recognize that to build up a definition means to approach, step-by-step, physical limits of the KC, i.e. to approach the borders conditions of its existence.

"A small amount of liquid on a base is a droplet, when the ratio of its height "a" to its mean diameter "b" is greater than e.g. 1/5." (See Fig. 3.)

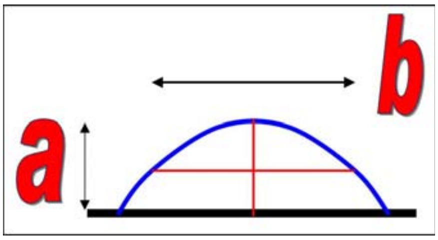


Fig 3. Characteristic proportions of a droplet.

"A small amount of liquid on a base is a droplet when contact angle is higher than 90 degrees and the surface around the droplet is not wet." (See Fig 4.)

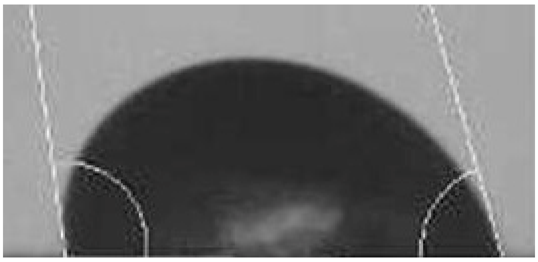


Fig 4. Droplet and contact angles.

"A droplet has fully plump top surface. If there is a bit more liquid and the top becomes flat - this is not a droplet anymore." (See Fig. 5)
The learners can be asked to modify this definition –

"If we add little more liquid to a droplet on a base and its height does not change – this is not a droplet anymore."

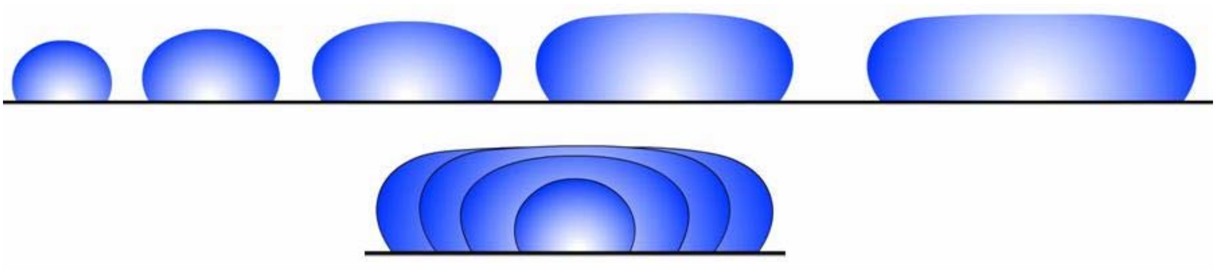


Fig 5. Droplet does not change its height anymore.

"Each compact small amount of liquid which hits a base and does not spilt or sink into the base is a droplet on a base." (See Fig. 6)

Fig 6. Spilt droplets.

Definitions as Parallel Cases

Let us compare these four definitions (see Fig 7) from the point of physics[1]:

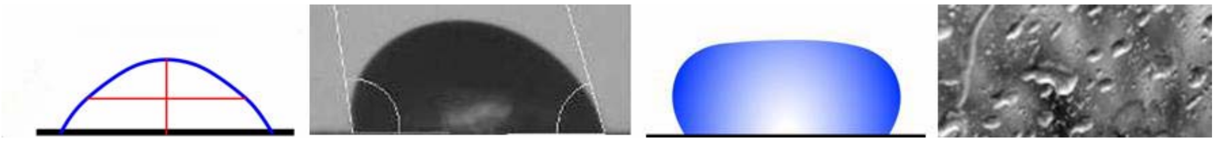


Fig 7. Different definitions of a droplet.

The criterion of the first definition of the droplet given by certain portion between the characteristic width and height seems simple but has no physical support.

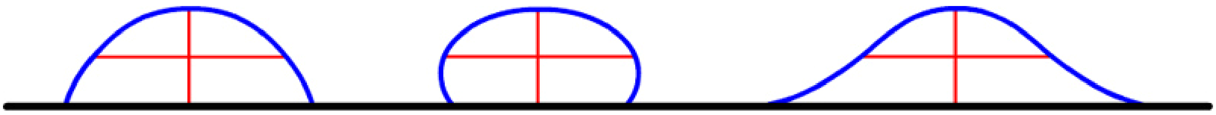


Fig 8. The same definition suits for all cases.

The second definition deals with the typical physical characteristics of liquids – the contact angle. The definition is simple, clear but not satisfying. It does not consider the amount of liquid.

The third definition is uniquely determined by physics, the boundary between the droplet state and the non-droplet state is finite and the things for discussion are the zero value of the force of surface tension in direction of gravity and our possibility to determine it.

The forth definition is vague (see Fig 6.), but we have opened the door for a new problem – as a new concept here, we have spilling.

To support learners' effort for systematic definition, we can provide them with the task: „Try to create the biggest possible droplet on the base". They soon discover that to get the biggest droplet they have to get the smallest one.

[1] Physics represents here the concept, see upper the FOCUS.

Definitions as Ideas

All "definitions" represent our ideas with respect to FOCUS. All of them relate to our focus – "droplet" and to our concept – "physics". To fulfill the FOCUS we must still determine their values for us – for me as the learner, for my future learning; for me as the teacher to teach learners better; and for us in general, how we can use these definitions. "Which of these definitions is universal? Do we really need a universal physical definition of a droplet? What should be the value of the physical droplet definition at all?

Successively: "How many definitions of a droplet on a base we have got considering physics as the concept?" "How many systematic definitions did we find?"

It seems here we must combine the definition established on the contact angle and the definition established on the flat top (and doing this, the separate definition avoiding the splitting is not necessary) etc. – "The size of droplets can be important in the world of technology…"

Teaching notes:

- Here is a teaching danger to start to deal with technology as a new concept. Technology is a very important concept that we only mention here and promise the learners to deal with it later!
- From teaching and learning point of view, looking backwards, the particular definitions were important but at the end, we have to consider all the detected features together.

From the physical point of view it is interesting that according to our assumptions, for example, the contact angle of liquid on an open base does not depend on the amount of liquid, neither on the droplet history, how the droplet got to the base. Learners can verify this by experiments using goniometer and by data in physical tables. They can find out that the contact angle represents typical mutual characteristics of liquids and solid surface that depends on actual temperature and air pressure. This is evident. Yet – how is this possible? The formation of the droplet is a self-development process governed by inner forces of the matter and gravity!

4. Discovering the Principles - Abstracting

We can describe droplets and their typical features on the base but what are the principles that allow liquids to become droplets – large droplet balls on the ISS station, fog and rain droplets, dripping, emulsions…?

Here, our actual focus is "the principles of droplets". The used methodology can be seen from next Fig. 9 – Fig. 12:

Though all the time we deal with the same KC – the droplet, to underline the nature of droplets we use four parallel cases of different characteristics – bubbles, steel ball, droplet and grains of sand. Then, introducing any concept we refer first to our KC and underline its features with respect to the same features but at different bodies.

First (Fig. 9, the left column), learners are asked to list the outer, macroscopic features and phenomena of these bodies. After this the discussion turns to their relevant inner forces (Fig. 9, the right column) whereby we have to take into account also the inseparable gravity force.

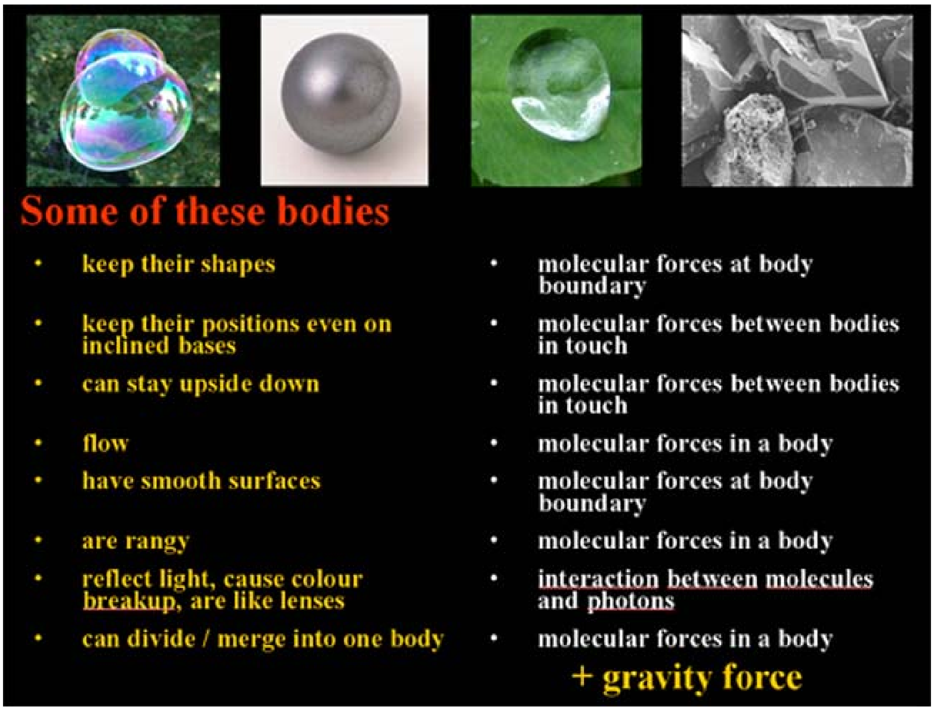


Fig 9. Methodology.

Categorizing the microscopic forces (Fig. 10, the left column), learners can stepwise distinguish and/or we can introduce them relevant physical concepts describing basic physical processes (Fig. 10, the right column). After all, we can discuss the relation between these processes and the outer physical changes of bodies (Fig. 10, bottom) while the key concept here is “the change”!

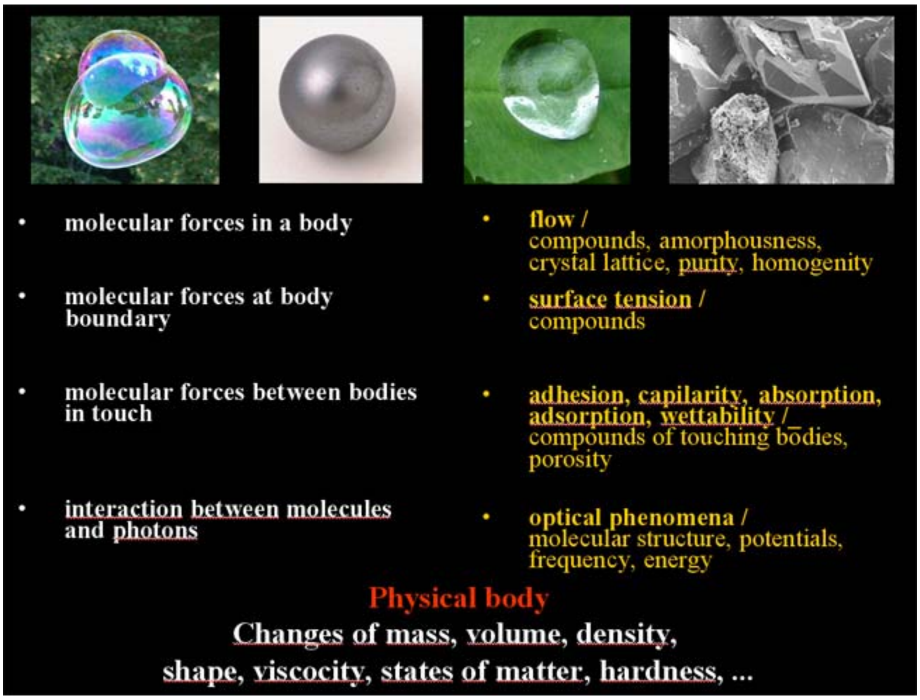


Fig 10. Methodology.

Having the concept of "change" and the respective "forces" there is time for discussion about the basic difference between the liquid and solid bodies from the point of view of complex systems (Fig. 11).

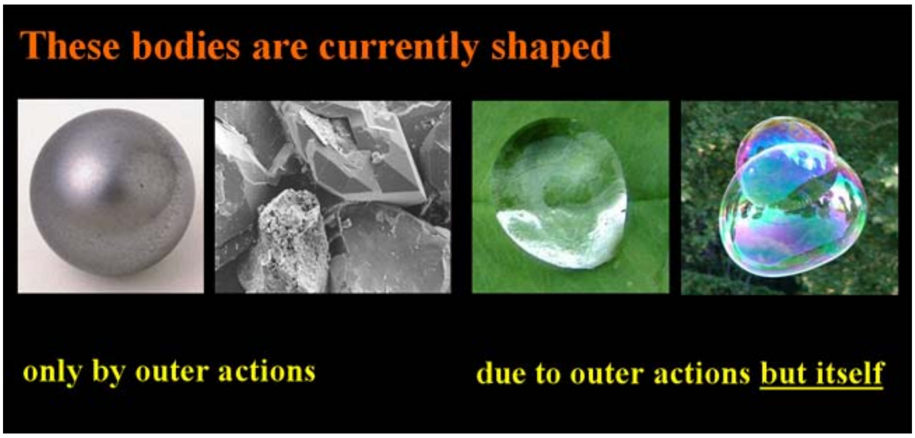


Fig 11. Methodology.

Going on the level of complex systems learners become conscious about the importance of the view on the level of a whole body, body parts, collective phenomena and the body from the point of view of order and chaos. Considering any level, we always emphasize collective phenomena (Fig. 12).

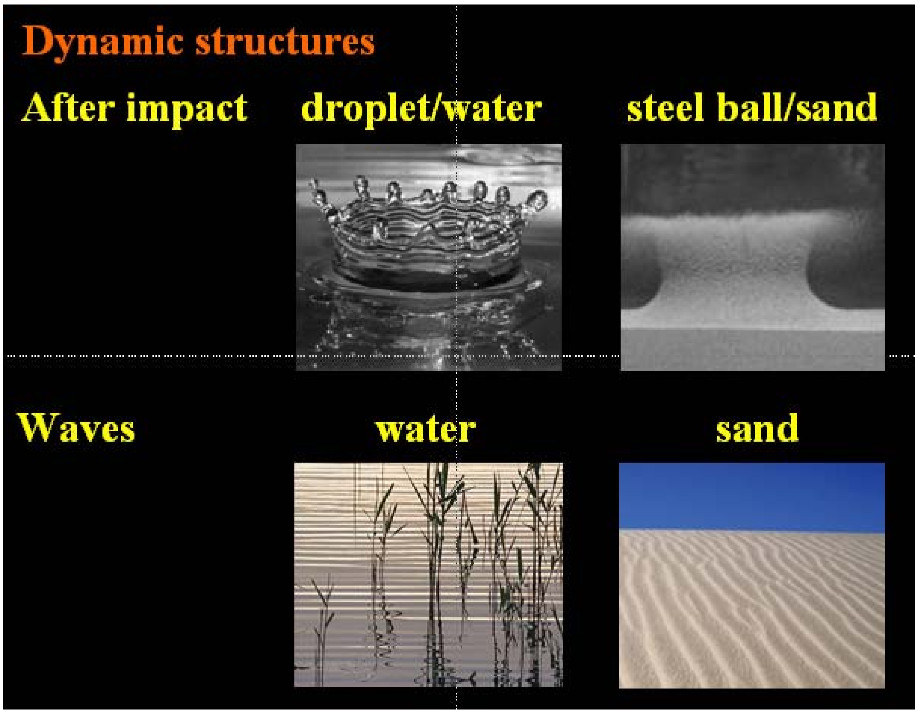


Fig 12. Collective phenomena (picture of a steel ball impact taken from [6]).

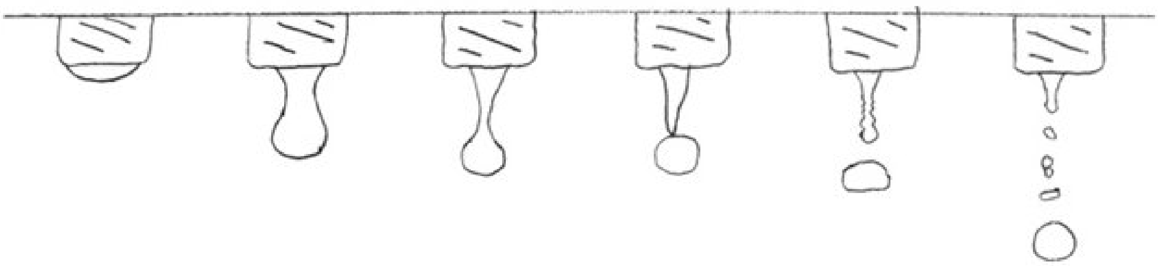
5. Top cases – Assessing the Gained Knowledge

We have already learnt a lot about droplets. Here is the time to start with top cases to assess the learning process. According to the interest of the learners, we have prepared known but in the form of slowed-down record, a surprising dripping process, task to design a simple droplet timer and rain phenomenon. Another set of tasks relates examples with droplets from current science research and modern technology. Among numerous we use for example droplets bounded in capsules – MICRONAL® PCM and the GORE-TEX® Fabrics. Each of these cases has the same focus – “droplets” but they have different concepts and allows passing to new physical focuses.

For example, in the case of dripping the first task is to observe again and again the slowed-motion record of water dripping process from a faucet and visualize its evolutionary phases (Fig. 13).

Try to sketch water dripping from a faucet.

Compare your sketches with photos of the dripping process in the presentation.



Title the phases! Give us a simple short physical characteristic for each phase!

Fig 13. Example from a work sheet.

Here we emphasize the process repetition that is controlled automatically and ask learners to give physical explanation of this. As a practical industrial example we mention ink printing technology and learners can assess their gained knowledge by solving a timer task - design an optimal time measuring device by taking advantage of dripping! Soon, they recognize that the main problem here is accuracy. “How can we arrange the physical conditions for it?”

Theoretically, on the base of gained knowledge, to construct a timer seems a simple task but in practice it is difficult and problematic.

When dealing with concept of droplet formation and droplet fall we can jump to the topic of raindrops, discuss the processes determining the shape of falling droplet, we can find its dependence on droplets size. In addition, we can break effectively the myth of the tear-shaped raindrops.

Velocity of a falling droplet can be another new focus - all droplets represent parallel cases and we can perform stroboscopic observation of falling droplets or indirect observations of water rings caused by the impact of droplets on water surface.

Conclusion

Designing the given CDW our goal was not only to show the SCHOLA LUDUS methodology of a CDW but also a SCHOLA LUDUS alternative way to build up a new educational conception for physics and science in general.

As Teplanova wrote in her book [1] the SCHOLA LUDUS goal is education for future. We operate in an open system of thinking. We start with real phenomena, make simplifications to get basic knowledge, discover complexity and progress to a new reality. We always deal only with one focus but with several concepts – ways. We always construct the learners´ knowledge on their preconceptions. Our subjects and instructions are interdisciplinary and the main common subjects are complexity and creative thinking. Our highest value belongs not to facts but to wit. Teaching and learning are pleasant activities.

To start with SCHOLA LUDUS approach we recommend to realize that anything we learn has first only the value of information. Hence, what we need to add is the real value. Usually in textbooks learners can find some of them in the form of ready knowledge applications, modern technologies etc. However value in our meaning differs from that usually considered. It does not mean ready examples of the respective knowledge usage. Learners themselves have to find out the value in the way of their discovery and appreciate it.

We are convinced that looking for optimal definition in the way of the SCHOLA LUDUS CDW the learners gain in-depth cognition as well as skills of the ways of scientific research and skills of creativity and collaboration, too. Let us emphasize the individual and common agreement over the described matter.

A few drops by CDW participants at GIREP-EPEC Conference: Tratnik Miran from Gimnazija Nova Gorica (Slovenia) – he was playing, but seriously, he has learnt something about droplets. Kazachkova Nataliya from Kharkiv Educational Centre for Gifted Students (Ukraine) was shocked by our playing at the beginning, at the end she promised to try our approach at home.

Acknowledgements

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Footnotes and References

[1] The SCHOLA LUDUS fundamentals are thoroughly described in the book, up to now published in Slovak only): Teplanova, K., Ako transformovať vzdelávanie - stratégie a nástroje SCHOLA LUDUS na komplexné a tvorivé poznávanie a myslenie. (“How to Transform Education – Strategies and Tools of SCHOLA LUDUS for Complexity-Creative Teaching, Thinking and Learning.”) Methodological-pedagogical centre Bratislava, 2007.

[2] Consider Vygotsky´s scaffolding (see for example “Vygotsky´s Educational Theory in Cultural Context”. Edited by Kozulin, A., Gindis, B., Ageyev, V.S., Miller, S., Cambridge University Press, 2003.)

[3] Similar to: Edward de Bono´s formal output (In: de Bono, E., Serious Creativity, Using the Power of Lateral Thinking to Create New Ideas. APTT, Inc., 1993.

[4] De Bono, E., Thinking Course, Powerful tools to transform your thinking. BBC BOOKS, 2004.

[5] De Bono, E., Six Thinking Hats. Little, Brown, New York, 1986.

[6] Lohse, D. et al: Impact on Soft Sand: Void Collapse and Jet Formation, Phys. Rev. Lett., 93, 19, 198003-1, 2004