4.2 Case study 2 (CS2 Hungary)

Concept focus	Evolution of legorgs as a model for natural selection
Inquiry skills	Planning investigations Forming coherent arguments
Scientific reasoning and literacy	Scientific reasoning (organisation and interpretation of data)
Assessment methods	Classroom dialogue Teacher observation Worksheets
Student group	**Grade:** 11th grade (upper second level) **Age:** 15 years **Group composition:** co-ed; mixed ability, included students from an advanced maths group and students with special educational needs and emotional and behavioural disorders (EBD). **Prior experience with inquiry:** Yes, the teacher has taught the group for 6 years and they have carried out inquiry activities individually or in groups as a part of project work and they had regular lab sessions.

This case study details implementation in an alternative secondary school, with students' ability ranging from those in an advanced maths class to students with dyscalculia. The teacher evaluated students' skills in *planning investigations* and *forming coherent arguments*, and their *scientific reasoning* capabilities, in particular through collection and interpretation of data. Assessment was guided by performance levels in the teacher's scoring rubric, and the students' received oral feedback on their work.

(i) How was the learning sequence adapted?

The inquiry activity was implemented with very little modification; the students worked with the original student worksheet, which was translated into Hungarian. Since we unfortunately did not have as many Lego bricks as was needed for the activity, the bricks had to be replaced by colour cardboard pieces in the second and third rounds of selection (100 pieces in 5 different colours for the five groups). Another modification was that we ended the activity after 3 generations because it had already taken up several class periods (5x45 minutes).

I could freely reveal the purpose of doing the activity to the students since they had worked on a few inquiry activities before and had also participated in education theory and subject-specific instruction research. This gave them motivation and presented a challenge. They were looking forward to trying the unit. They worked in heterogeneous groups (mixed ability and gender). Cooperation did not present a problem since they had been working together for a long time.

Their enthusiasm flagged, however, once they had deciphered what they had to do. It was difficult for them to keep following the pre-defined steps and rules in this strictly structured activity. This was especially a challenge for students with SEN or EBD. I also had to make sure that students with dyscalculia had their own group. However, the question of "why are we doing this" kept them motivated and they very much wanted to find out what would come out of the activity.

The legorgs were pushed on a sheet of white paper, which prevented them from slipping and made marking their movements easy (Figure 1). We discussed what errors and difficulties could be expected in the measurement task. Measurements required a great deal of precision from the students.

Evolution and population genetics are topics covered in this school year, and the pre-test questions were discussed in classes that took place before the activity. The questions were revised as a whole class discussion at the end of the unit implementation. It is difficult to complete this activity in 45 minutes class periods, because we had to start over, tidy up and recall the previous session again and again.

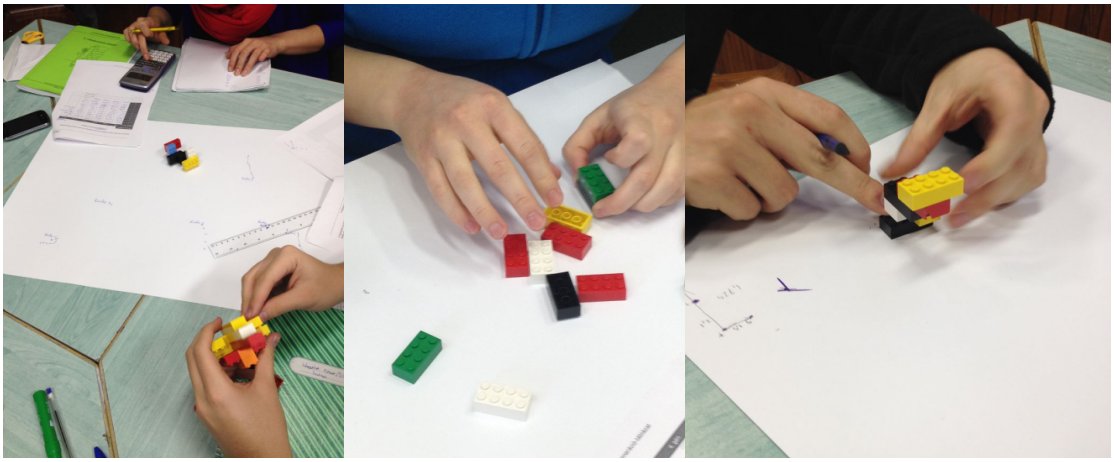


Figure 1: Measuring fitness, building and moving the legorgs

(ii) Which skills were to be assessed?

The skills identified for assessment in this case study were *planning investigations* (including carrying out an investigation), *scientific reasoning* (organisation and analysis of data), and *forming coherent arguments* (communication). The students' received oral feedback on their work. The formative assessment was guided by the criteria in the scoring rubric (Table 1).

Table 1: Assessment scale used in CS1 Hungary

Assessed skill	Emerging	Developing	Consolidating
Planning investigations **Carrying out an investigation**	Cannot interpret the tasks without help but manages to do the measurement with some help although not always accurately.	Can interpret the tasks without help, carries out the measurements making sure that they measure in exactly the same way every time.	Quickly understands the tasks, is consistent with measurements and discusses the validity and problems of measurements.
Scientific reasoning (analysis and interpretation)	Identifies sources of error in analysis. Cannot draw conclusions without help.	Identifies sources of error in analysis. Can draw conclusions.	Identifies sources of error in analysis, discusses their effects on results. Formulates conclusions with accuracy and in great detail.
Forming coherent arguments (communication)	Spots unexpected events but cannot account for them.	Spots unexpected events and tries to find an explanation.	Spots unexpected events and can offer an explanation.

(iii) Criteria for judging assessment data

I expected the groups to be able to understand the instructions on the worksheet and carry out the tasks. If they have a problem, they should be able to ask another group or the teacher for help, but they should also be able to work without help.

They should avoid mistakes as much as possible and keep working without interruptions. They should be able to link the data from the simulation to the theory of evolution and population genetics.

I decided on formative assessment and assisted the students' work with oral reinforcement and feedback. The best achieving groups were also rewarded with a grade. Due to the shortage of time, the students sent their answers to the questions electronically. The assessment focused on the students' data organisation skills and their skill in *forming coherent arguments* (analyse and interpret data, identify errors and explain them).

(iv) Evidence collected

Teacher opinion

The project required a high degree of discipline from the students, which was observed to be easier for the girls. It was therefore a positive feature that boys and girls worked together in the groups. The girls tended to measure the movements, while the boys were better at building the legorgs.

About half of the class attend the advanced maths programme. These students were better at the interpretation of the steps of the activity and the coordination of the group's work than at the interpretation. This group, who never missed a session, were the first to finish the measurements. Since natural science is not their main area of interest, however, they were less successful in answering the questions.

The activity required a great deal of discipline, precision and the application of prior knowledge from the students. Since my students have low tolerance of monotony, they had to make a lot of effort to carry out the tasks. They got discouraged occasionally. They regained their motivation, however, when it was time to find solutions to problems or think logically. Every student was successful in interpreting the task without help. There were some inaccuracies in the measurements but these were always corrected and the calculations were even double checked by the students. One group measured fitness in four steps, rather than five (Figure 2b). This group worked with these data throughout the activity and only realised their mistake at the third generation, by which time they did not want to change anything.

Students always attempted to give an explanation for unexpected events because they were interested in new and surprising things. One group did not have time to draw a graph of their data because they worked more slowly than others. The other groups did well. In my opinion the activity can only be given to a very motivated group of students who can work together without difficulty. The best opportunity for this activity would be a special advanced class or after-school programme where it could be completed from beginning to end.

The students wanted an explanation of what the objective of the activity's authors was why they thought that these methods would be a good demonstration of the effects of mutation, natural selection and adaptation.

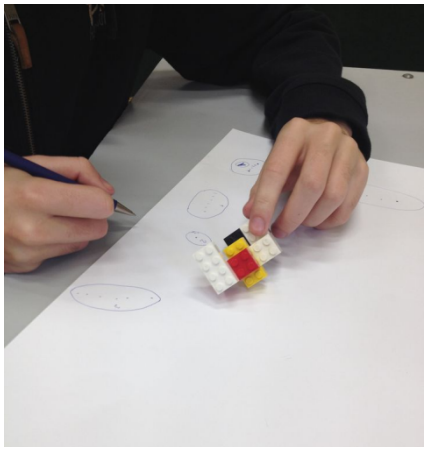
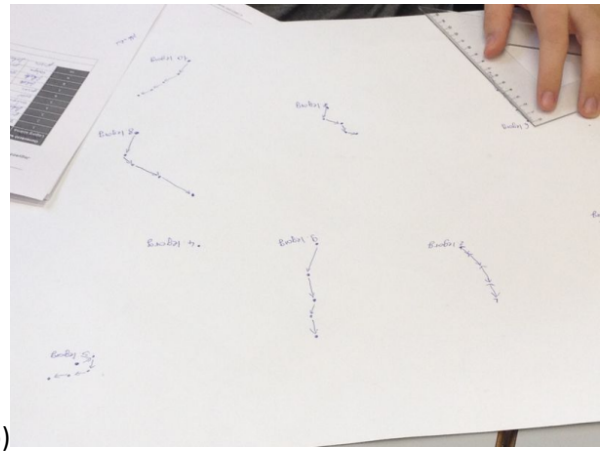
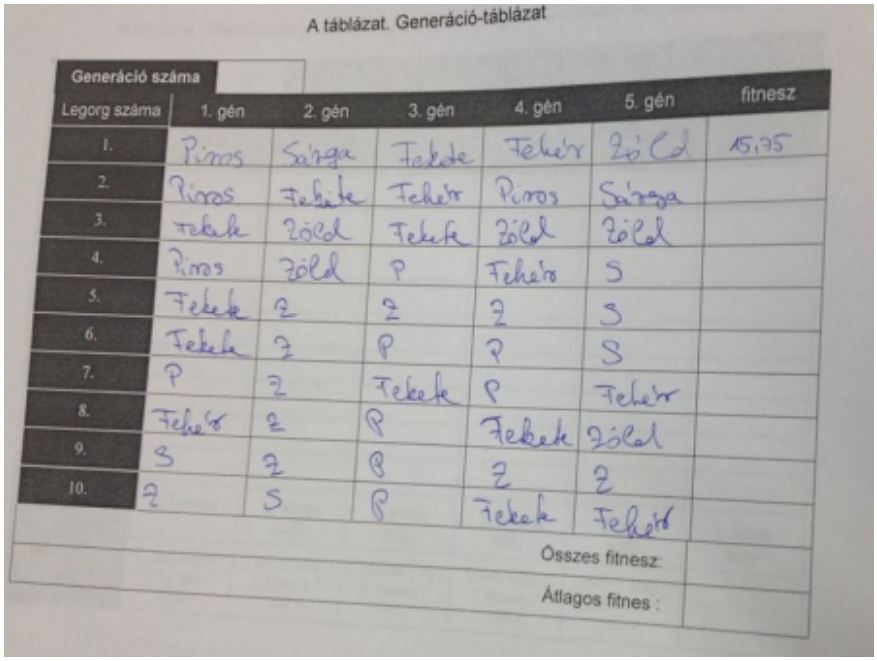
(a)  (b) 

Figure 2: Measuring fitness

Unfortunately we could not have an observer in class because of timetabling problems but a colleague of mine did the activity with a 13th grade class at the same time and we regularly shared our thoughts and experiences.

Sample student artefacts



A táblázat. Generáció-táblázat

Generáció száma / Legorg száma	1. gén	2. gén	3. gén	4. gén	5. gén	fitnesz
1.	Piros	Sárga	Fekete	Fehér	Zöld	15,75
2.	Piros	Fekete	Fehér	Piros	Sárga	
3.	Fekete	Zöld	Fekete	Zöld	Zöld	
4.	Piros	Zöld	P	Fehér	S	
5.	Fekete	Z	Z	Z	S	
6.	Fekete	Z	P	P	S	
7.	P	Z	Fekete	P	Fehér	
8.	Fehér	Z	P	Fekete	Zöld	
9.	S	Z	P	Z	Z	
10.	Z	S	P	Fekete	Fehér	
				Összes fitnesz:		
				Átlagos fitnes :		

Figure 3: Student artefact: First generation table.
(*piros (P)* = red, *sárga (S)* = yellow, *zöld (Z)* = green, *fekete* = black, *fehér* = white, *fitnez* = fitness)

B táblázat. Génállomány-táblázat (génenként és generációnként egy táblázat)

Generáció száma	1.	Allélok				
Gén száma	1. gén					
Legorg száma	Fitnesz	Sárga	Piros	Fekete	Zöld	Fehér
1.	4				4	
2.	14	14				
3.	0				0	
4.	11			11		
5.	10					10
6.	6				6	
7.	9					9
8.	0			0		
9.	15	15				
10.	4			4		
	Σ fitnesz 73	Σ sárga súly 29	Σ piros súly 0	Σ fekete súly 15	Σ kék súly 10	Σ fehér súly 19
Relatív fitnesz (kerekítve)	Σ sárga súly / Σ fitnesz * 100 = 40	Σ piros súly / Σ fitnesz * 100 = 0	Σ fekete súly / Σ fitnesz * 100 = 21	Σ kék súly / Σ fitnesz * 100 = 14	Σ fehér súly / Σ fitnesz * 100 = 25	

Figure 4: Example of gene pool table for first generation (gene 1).
(*fitnez* = fitness, *sárga* = yellow, *piros* = red, *fekete* = black, *zöld* = green, *fehér* = white)

B táblázat. Génállomány-táblázat (génenként és generációnként egy táblázat)

Generáció száma	1.	Allélok				
Gén száma	5. gén					
Legorg száma	Fitnesz	Sárga	Piros	Fekete	Zöld	Fehér
1.	4					4
2.	14			14		
3.	0	0				
4.	11			11		
5.	10				10	
6.	6	6				
7.	9			9		
8.	0		0			
9.	15				15	
10.	4					4
	Σ fitnesz 73	Σ sárga súly 6	Σ piros súly 0	Σ fekete súly 14	Σ kék súly 25	Σ fehér súly 8
Relatív fitnesz (kerekítve)	Σ sárga súly / Σ fitnesz * 100 = 8	Σ piros súly / Σ fitnesz * 100 = 0	Σ fekete súly / Σ fitnesz * 100 = 33	Σ kék súly / Σ fitnesz * 100 = 30	Σ fehér súly / Σ fitnesz * 100 = 12	

Figure 5: Examples of gene pool table for first generation (gene 5).
(*fitnez* = fitness, *sárga* = yellow, *piros* = red, *fekete* = black, *zöld* = green, *fehér* = white)

B táblázat. Génállomány-táblázat (génenként és generációnként egy táblázat)

Generáció száma	2.	Allélok				
Gén száma	1.					
Legorg száma	Fitnesz	Sárga	Piros	Fekete	Zöld	Fehér
1.	3	3				
2.	0	0				
3.	5	5				
4.	6					6
5.	4	4				
6.	4	4				
7.	7					7
8.	4				4	
9.	0				0	
10.	19			19		
	Σ fitnesz 52	Σ sárga súly 16	Σ piros súly 0	Σ fekete súly 19	Σ zöld súly 4	Σ fehér súly 13
Relatív fitnesz (kerekítve)		Σ sárga súly / Σ fitnesz * 100 = 30	Σ piros súly / Σ fitnesz * 100 = 0	Σ fekete súly / Σ fitnesz * 100 = 37	Σ zöld súly / Σ fitnesz * 100 = 8	Σ fehér súly / Σ fitnesz * 100 = 25

Figure 6: Example of gene pool table for generation 2 (gene 1).
***fitnez* = fitness, *sárga* = yellow, *piros* = red, *fekete* = black, *zöld* = green, *fehér* = white**

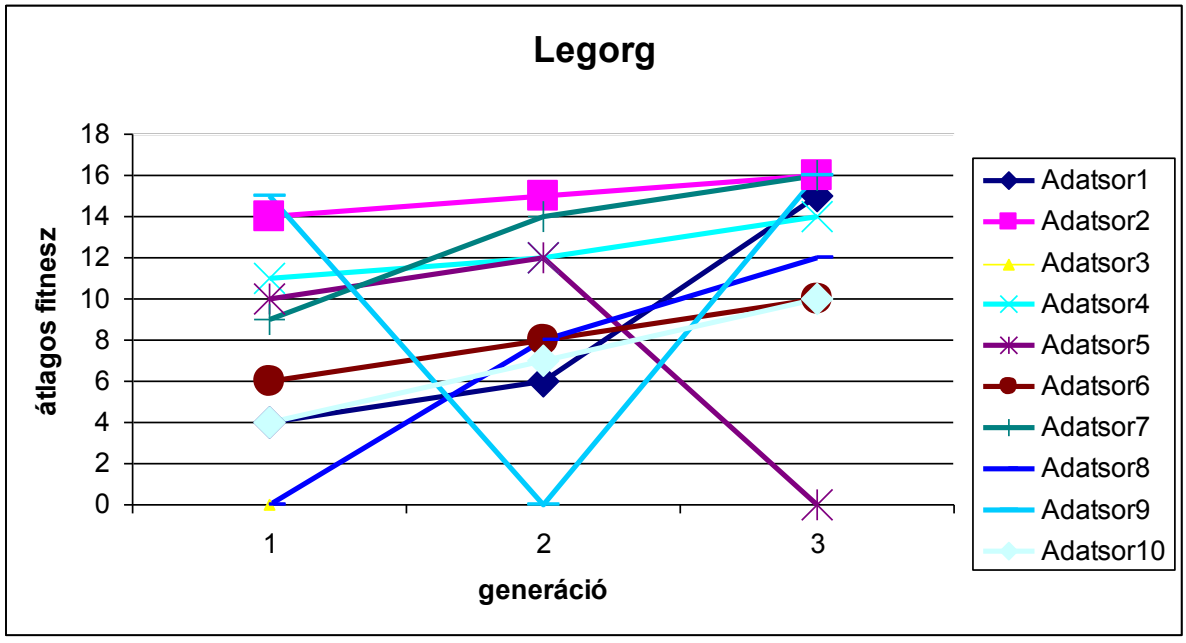


Figure 7: Average fitness (y axis) over three generations (x axis). *Adatsor* = series

2) What do the results show?
The fitness level continuously rises by generation. It shows difference in two cases, probably because of the effect of mutation.

3) What type of selection is shown by the simulation?
Natural selection

4) What type of simulation are the most realistic biologically?
The growth of the fitness level by generations.

5) Please describe some biological adaptation!
Peppered moth (Biston betularia) – darker coloured individuals – industrial revolution
Mimicry – adaptation to the environment or other species
Galapagos finch – beak for the nutrition
Camel – kidney, water excretion

6) How can the natural selection influence a population's genetic diversity? When does the genetic diversity benefit against the "optimized" genetic diversity?
Stabilizing selection: the selection affects on the individuals with extreme phenotype, the allele frequency of the population is relatively stable. This is the most frequent form of the selection.
Diversifying selection: it affects on the individuals with average properties, if it persists, then more groups will form and it can raise the genetic variability.
Directional selection: only an extreme individual phenotype is favored

7) How would the general fitness level change, if we would raise the possibility of mutation?
It would increase by beneficial mutation, and would decrease by lethal mutation.

Figure 8: Sample questions and answers at the end of implementation

(v) Use of assessment data

The students were given oral feedback on their work. The experience was useful for me, just one year before the final examinations. I must make sure that the students have further practice in organising and implementing an experiment, and in forming and communicating coherent arguments.

(vi) Advice for teachers implementing the unit

In my opinion, the structured nature of the activity should be of help to a teacher with little experience in inquiry learning. The activity requires a lot of discipline and perseverance from the students, however.

It is definitely worthwhile for a teacher to build a generation of legorgs, so that they have experience of the difficulties and the opportunities offered by the task.