Supplemental Material

CBE—Life Sciences Education

Göransson *et al.*

Appendices

Appendix A. Compulsory modules (with connections to evolution) of three universities that major sets of our participants (65%) attended, with brief synopses of subject matter

University	Students	Bachelor's program 1st year	2nd year	3rd year
Chritian-Albrechts-Universität zu Kiel	biology majors	*Basics of Zoology and Cell Biology (1. Sem.)* (1) Blueprint of representatives of the important large animal groups, (2) functional units of animal organism, (3) basic knowledge of construction and function of the animal cell, and (4) evolution of animal body structures.	*Ecology (3. Sem.)* (1) Influence of environmental factors: radiation, temperature, humidity/water availability, (2) energy balance of animals and plants, (3) resistance and acclimatization, (4) host parasite and predator-prey interactions, competition, and gender conflicts, and (5) mechanisms of evolution in populations *Cell Biology Animal (3. Sem.)* (1) Simple cell biology and molecular biology techniques, (2) experimental handling and phenomenological observation of different cell types and invertebrate organisms under different experimental conditions and under adequate control, and (3) technics: light microscopy, fluorescence microscopy, polymerase chain reaction. *Cell Biology Plant (4. Sem.)* (1) Fluorescence- and electron microscopy of plant cell, (2) protein biochemical methods: electrophoresis, density gradient centrifugation, and (3) in situ hybridization *Genetics and Microbiology (4. Sem.)* (1) Classical genetics, (2) cytogenetics, (3) human genetics, (4) molecular genetics (DNA, RNA, genomes, replication, transcription, translation, gene regulation, epigenetics), (5) recombination, (6) mutation, (7) gene technology, (8) development, (9) basics of microbiological methods (microscopy, enrichment, cultivation), (10) morphological and physiological differentiation of microorganisms (Gram-staining, antibiotics), and (11) genetic exchange between microorganisms.	
	preservice biology teachers	*Basics of Zoology and Cell Biology (1. Sem.)* content see above	*Ecology (3. Sem.)* content see above *Cell Biology Animal or Plant (4. Sem.)* content see above	*Cell Biology Plant or Animal (5. Sem.)* content see above *Genetics and Microbiology (6. Sem.)* content see above

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Appendix A. Continued

University	Students	Bachelor's program 1st year	2nd year	3rd year
Carl von Ossietzky Universität Oldenburg	biology majors	*Microbiology and Cell Biology (2. Sem.)* (1) Molecules of life, (2) energy and enzymes, (3) central metabolism, (4) breathing, (5) photosynthesis, (6) anaerobic metabolism, (7) chemolithotrophy, (8) prokaryotic and eukaryotic cell structures, (9) microbial diversity, (10) importance of microorganisms for human beings, plants, animals, biotechnology and earth system, (11) signal transmission and communication between cells, (12) meiosis, mitosis, Mendelian inheritance, and chromosomal and molecular basis of inheritance, (13) replication, transcription, translation, (14) genomic organization, and (15) mutation and repair.	*Genetics (3. Sem.)* (1) General and molecular genetics, (2) mechanisms of mutation, recombination, DNA repair, and regulation of transcription, (3) quantitative experiments with prokaryotes and eukaryotes, and (4) human genome project and personalized medicine.	-------
	preservice biology teachers	*Microbiology and Cell Biology (2. Sem.)* content see above	-------	-------
Europa-Universität Flensburg	preservice biology teachers	-------	*Evolution and Functional Morphology (3 or 5. Sem.)* (1) Evolutionary theories and mechanisms of evolution, (2) phylogeny of life including theories about genesis of life, and (3) biomechanical knowledge about structure and function of selected bodies of vertebrates. *Ecology (4. Sem.)* (1) Basics of ecology	*Evolution and Functional Morphology (3. or 5. Sem.)* content see left

Appendix B. Coding examples of excerpts (italics indicate relevant text sections for codes)

Concept	Code description	Example
Threshold Concepts		
Randomness	Mention of relevant stochastic events in evolution. Typically random origin of variation, random death, random mating, etc.	(GT003): There were *random mutations* that made a cheetah run faster than others (GT091): The seeing salamanders died over time due to *random gene drift*, until only blind salamanders remained.
Probability	Outcome of several stochastic events. The system / population does not behave in a deterministic way. Mention of probability in relevant context e.g. chances of survival, probability of a mutation etc.	(GT009): In the reproducing surviving bacteria mutations appear that cause a *higher chance of survival* in spite of the antibiotics. (GT017): There were occasional cheetahs that could run faster and thus could provide for their offspring better since they caught more prey these had *higher chances of survival.*
Temporal scale	Expression of time as a factor.	(GT080): Since bacteria have *short generation times*, more mutations appear *in a relatively short time*. (GI018): This genetic basis was given to their offspring. This *process continues over several generations*.
Spatial scale	Link between cause and effect on different levels of organization or spatial scale.	(GT008): The slow cheetahs reproduce and *by mutation and recombination changes in genes appear,* that for example *cause* the offspring to *build more muscle mass* etc. (GT024): Bacteria can change their genetic structure by mutation (*submicro level*). Because of this, bacteria (*micro level*) can develop antibiotic resistance. When the entire bacteria culture (*macro level*) is killed by an antibiotic, only mutated bacteria survive. These can reproduce without competition and even more antibiotic resistant bacteria appear.

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Appendix B. Continued

Concept	Code description	Example
Key concepts		
Origin of variation	Mention of genetic process underlying change in a trait.	(GT004): Randomly, it can happen that *mutant bacteria (genetic changes) appear*, which are resistant to the antibiotics. (GT064): The cheetahs *possessing a mutation enabling them to run faster*…
Individual variation	Any indication that individuals vary in their traits.	(GT025): *The cheetahs that could run faster* were better hunters. (GT034): Thereby there was a *genetically diverse population*.
Differential survival	Individuals vary in their survival chance due to variation in their traits.	(GT129): Animals, who could run faster captured more prey, so *they had higher chances of survival* and more offspring.
Selection pressure	Abiotic or biotic factors affecting survival and/or reproduction.	(GT008): If bacteria are *treated with antibiotics* … (GT073): Randomly, a blind individual (mutated) is born
Change in population	Change in proportion of individuals with certain traits and / or genes in a population	(S45): Bacteria that are resistant to antibiotics survive and reproduce. Therefore, there will be fewer of the [antibiotics] sensitive bacteria and more of the resistant ones.
Inheritance of traits	Traits are inherited from parent to progeny.	(S37): These bacteria *can reproduce and transfer the gene* which codes for antibiotic resistance.
Reproductive success	Differences in reproductive success between individuals due to traits and/or genes.	(S33): The individuals who could run faster got more food and therefore survived better, *which enabled them to reproduce the most.*

Appendix C. Complete list of variables and their reliabilities (Guilfords' G)

	Swedish sample		German sample	
	Agreement	*Reliability (G)*	*Agreement*	*Reliability (G)*
Bacteria				
Randomness	100%	1.00	92%	0.84
Probability	100%	1.00	90%	0.80
Temporal scale	93%	0.86	88%	0.76
Spatial scale	98%	0.95	100%	1.00
Origin of variation	95%	0.91	94%	0.88
Individual variation	95%	0.91	86%	0.72
Differential survival	93%	0.86	86%	0.72
Selection pressure	95%	0.91	92%	0.84
Change in population	93%	0.86	92%	0.84
Inheritance of traits	89%	0.77	94%	0.88
Reproductive success	100%	1.00	94%	0.88
Cheetah				
Randomness	100%	1.00	100%	1.00
Probability	93%	0.86	94%	0.88
Temporal scale	93%	0.86	90%	0.80
Spatial scale	86%	0.73	82%	0.64
Origin of variation	98%	0.95	88%	0.76
Individual variation	86%	0.73	96%	0.92
Differential survival	86%	0.73	88%	0.76
Selection pressure	91%	0.82	86%	0.72
Change in population	98%	0.95	92%	0.84
Inheritance of traits	91%	0.82	92%	0.84
Reproductive success	89%	0.77	90%	0.80
Salamander				
Randomness	98%	0.95	98%	0.96
Probability	98%	0.95	94%	0.88
Temporal scale	98%	0.95	90%	0.80
Spatial scale	93%	0.86	86%	0.72
Origin of variation	89%	0.77	94%	0.88
Individual variation	93%	0.86	90%	0.80
Differential survival	86%	0.73	86%	0.72
Selection pressure	82%	0.64	100%	1.00
Change in population	100%	1.00	92%	0.84
Inheritance of traits	100%	1.00	100%	1.00
Reproductive success	100%	1.00	94%	0.88

Appendix D. Lexical statistics for collected responses (http://countwordsworth.com/sentences)

	Average word count per answer	*Average sentence count per answer*	*Average sentence length*
Swedish sample			
Bacteria	25	1.5	17
Cheetah	27	1.6	17
Salamander	23	1.3	18
German sample			
Bacteria	41	2.7	15
Cheetah	50	2.8	18
Salamander	46	2.8	17

References

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