point afin d'enregistrer et d'analyser les échanges intellectuels enseignant-enseigné pendant les cours. Le POES a été appliqué à l'appréciation de l'attitude d'environ 94 professeurs de biologie, de physique et de chimie dans leur cadre professionnel, ce qui a permis de distinguer différents styles de pédagogie en matière scientifique. Ces styles ont fait l'objet d'une description et d'une discussion du point de vue de leur efficacité pédagogique (déterminée par rapport aux résultats scolaires obtenus) et de l'application du programme d'études dans les établissements modernes.

EUR. J. SCI. EDUC., 1979, VOL. 1, NO. 1, 87–101

Concept Formation in Biology: The Concept 'Growth'

Gerhard Schaefer, Institute for Science Education (IPN), Kiel, FR Germany

1. Introduction

During the past few years, much emphasis has been given to new teaching methods, such as 'process learning', 'situation approach', 'social interaction' etc., because these methods are thought to lead the student to a better qualification for present-day life by enhancing his 'adaptability to changing situations'. Comparatively little attention, however, has been paid to the construction of a coherent pattern of concepts in the student's mind, presumably because of the many complaints about the traditional school system which, being very strongly concept-orientated, was apparently not able to prepare students for the problems of everyday life, like health, sex, environment, working place, leisure etc.

Even if the inefficiency of the traditional concept-orientated education is acknowledged, this does not speak against the usefulness of this kind of education altogether. Investigations with chemistry students carried out by Novak (1977) showed that the kind (extent and depth) of concept training has a clear influence on the behaviour of the students. Novak's observations can easily be confirmed by anybody in his private sphere when examining the relationship between misbehaviour in the areas of technology, traffic, environment, health, sex, nutrition etc., and the concepts underlying it. There cannot be any doubt that the concepts held by people have a strong influence upon their attitudes, decisions, and ways of solving problems. Thus, the mistake of the previous school system certainly was not in that it dealt with concepts, but that it did so in an inadequate way.

Two pedagogical hypotheses characterizing the classical school system may be formulated thus: (1) teaching different subjects at school results in an integration of the subject-bound knowledge within the student; and (2) teaching of concepts and structures of academic disciplines at school leads to their application in one's private and professional life.

These hypotheses have proved to be wrong, i.e. they can no longer be accepted as general truths. If a co-ordination or integration of the different school subjects is not prepared by the teacher in certain phases of teaching (integrated science teaching), then apparently it does not occur in many of the students. Also, if the concepts which are taught at school are not related to everyday problems in some way and thus made practicable, the students apparently fail to use them adequately outside school.

The following report is based upon the hypothesis that *everything that is done at school has to be done in the context of everyday life, if it is to be effective.* This means in respect to concept formation that not only is the *logic core* of a concept alone a significant part of teaching, but also the *associative framework* of the concept which is, mostly, 'illogical' (concerning the term 'illogical' see section 2).

2. The concept of a 'concept'

2.1. The 'Bur' Model

Although some uncertainty exists among educationists and psychologists as regards the precise meaning of the word concept, there is general agreement that a concept has something to do with an abstract structure of properties that is characteristic for a certain class of objects, events or phenomena (Ausubel 1968, Bruner 1960, Oerter 1971, Leinfellner 1965, etc.). It is what may be called the *logic core* of a concept (Schaefer 1978). For example, the concept 'mammal' is characterized by the set containing the elements 'milk glands', 'hairs made of horn-like substance (keratin)', 'secondary jaw joint', 'regulation of blood temperature', 'one aorta on left side', etc. In addition to these characteristics, all individual mammals have further properties by which they differ from each other.

The logic core is normally associated, in our memory, with a certain *name*. Name and logic core together are essential parts of a concept: they are usually regarded as being *the* concept. A mere name without an associated logic core is then regarded as meaningless, the logic core being the meaning. On the other hand, a logic core describing part of reality but without designation by a word, is sometimes regarded as a *non-verbal concept* (cf. 'unbenanntes Denken', Koehler 1956). The interest of psychologists, scientists, philosophers, and mathematicians has up to now been concentrated mainly on the logic core and the name of a concept. This is not surprising since language, as a means of communication has to contain *invariant logic structures* which are independent from the individual cases and the individual persons.

These structures are in themselves certainly not sufficient for an understanding of the full meaning and the full significance of a concept. There are plenty of observations in everyday life which show that although children, students and adults know a particular word *and* its logical meaning, they are not able to use them both in a special situation, in a special context or in a special environment. For example, the concept of energy may be well understood in the sense of physics but may not be applied to actual energy problems in everyday life. Likewise, the chemical structure and the physiological effects of nicotine may be well known to a person; yet this knowledge may be completely blocked out in a special situation (e.g. by social pressure). This demonstrates that there must be something beyond the name and logic core

that makes a concept applicable and memorizable in different contexts. It is what may be called the *associative framework* of the concept (Schaefer 1978). Whether this framework is considered to be something which lies outside the concept, just surrounding it, or whether it is considered to belong to the concept itself (like a frame belongs to a picture), is a matter of definition and not of substance. Important alone is the fact that a concept is never isolated in our memory, but embedded in a network of associations which colour the concept with sensory attributes, emotions, and with other concepts. These other concepts are mostly not linked to the original concept by means of logic relationships (as is the case for subordinate/superordinate terms or part/entity terms—see figure 3) but merely by coincidence in time. Hence, there is no logic between them except the logic that lies in the whole pattern of our world and leads to simultaneous perception of stimuli which seem to have nothing to do with each other (see the reflections about the structure of our memory by Landauer 1978).

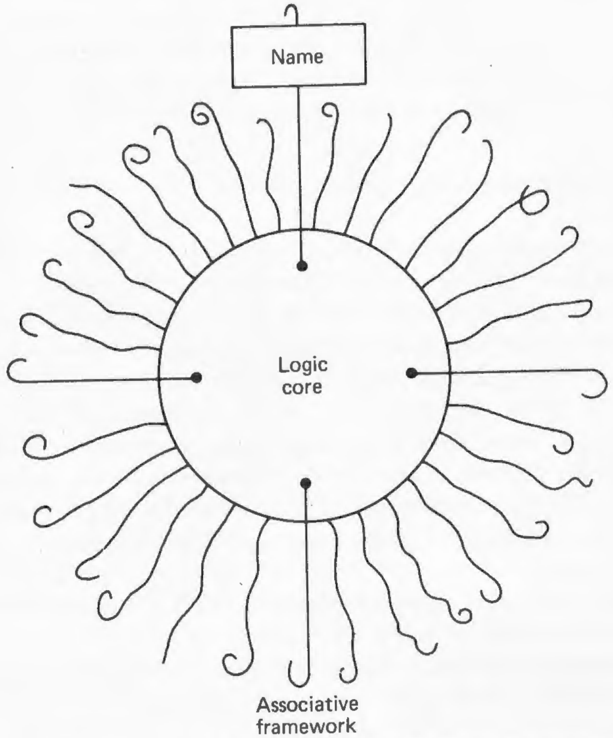

Figure 1. Enlarged concept of a concept, consisting of three essential parts. Bur model with a labelled stalk and with hairs and hooklets as attaching points for life situations

The model of this concept of a 'concept' is shown in figure 1. It consists of three parts:

(1) The *logic core* of the concept, which is the invariant structure representative of a certain class of things or events.

(2) Associated with the logic core there is a *name*. The name serves both as a vehicle for communication between individuals and as a label for effective memorization within the individual.

(3) Surrounding the logic core and additional to the associated name, there exists a tight network of further associations, the *associative framework*.

The associative framework seems to be the first point of attraction for most people, including students and pupils. It covers, so to speak, the logic core with hairs and hooklets which serve as attaching points for certain situations of life so that the concept can be remembered and applied adequately. Of course, all three parts of a concept may serve as attaching points for using the concept in certain life situations: the name, as well as parts of the logic core, as well as the rest of the associations. For example, just the name growth may lead us to remember and to use the concept, as may some phenomenon involving positive feedback (which belongs to the logic core of growth), or even the association police (which has been used during a demonstration against atomic power stations which have to do with energy crisis and this, in turn, with industrial growth). In the following, some general explanations will be given for both the associative framework and the logic core of a concept, before the empirical studies are reported in sections 3 and 4.

2.2. *The associative framework*

Investigations into free associations, which have been carried out at the Institute for Science Education (IPN) during the last eight years, have shown that in spite of the high influence of randomness on single associations (television, books, weather, family events; see also reflections by Deese 1965), there is a marked regularity concerning the categories of associations. All associations given by test persons can be grouped in the following two different ways: (1) in *sections* according to the scientific disciplines (physics, biology, psychology, politics etc.); and (2) in three circular *zones* representing (*a*) the zone of colloquial language, (*b*) the zone of scientific languages, (*c*) the zone of transdisciplinary, formal language (mathematics, systems theory, philosophy of science).

The whole pattern is shown in figure 2. The figure also gives a survey of the whole testing situation using a black box. It points out the still unknown internal structure of the black-box test person, which is stimulated by a key word as input and produces different kinds of output: free associations (verbal), definitions (verbal), other (non-verbal) actions. The internal structure may be roughly divided into affective structure (emotions, attitudes, interests, needs); psychomotor structure (reflexes, habits, techniques, skills); and cognitive structure, which, according to Doerner (1974), may be further divided into the epistemic structure (knowledge, hierarchy of concepts) and the heuristic structure (procedures, algorithms for achieving and improving knowledge). All these structures are linked together by interactions; hence, their separation is somewhat artificial.

In order to determine the structure of a concept (in terms of the three

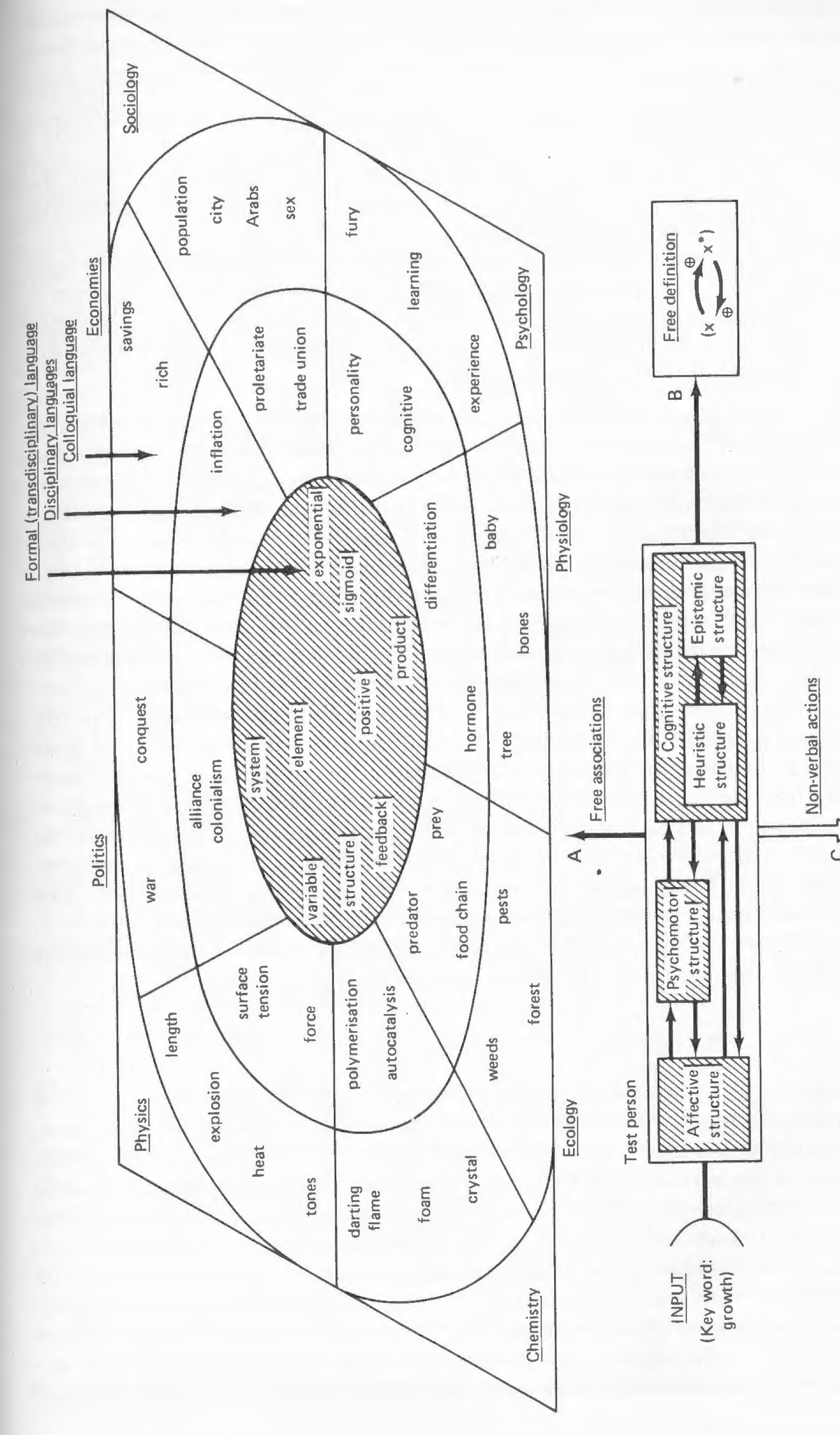

Figure 2. Reactions of a test person to a key-word, and arrangement of free associations in sectors and zones

parts shown in figure 1), investigations are needed in relation to the association level, the definition level and the action level. It may be expected that:

(i) measurements of free associations give sufficient insight into the associative framework of a concept and also provide *some* evidence of the affective structure of the test person;
(ii) measurements of free definitions give sufficient insight into the logic core of the concept, which is part of the whole epistemic structure of the test person;
(iii) measurements of non-verbal actions give *some* insight into the logic core of the concept. These actions are related to the associative framework, but at the same time give information about the psychomotor and affective structure of the test person. The actions are expected to be rather complex.

It is the aim of this kind of research to establish, by comparing (i) with (ii), (i) with (iii) and (ii) with (iii), basic information about concept formation in general, and also to yield specific knowledge about the influence of particular biological concepts like growth, biological equilibrium, health, individuality, etc., upon the behaviour of students in everyday life.

Our investigations so far have been concerned with measurements (i) and (ii). They were not simply restricted to the collection of data about the aspects mentioned, but were focused upon the pedagogical aim of improving concept formation in biology, with respect to both *preciseness* and *transferability*, by application of superordinate terms from systems theory (cybernetics). The philosophy underlying this kind of biology teaching is to 'lift' the student up to the terminology of transdisciplinary thinking (central zone of figure 2) in order to help him to overcome the widely criticized 'range-specific thinking' on a higher level of understanding, i.e. without risking just a fall-back to the lower concept level of colloquial language. It is expected that concepts of the central zone have considerable effect as 'advance organizers' (Ausubel 1968) for structuring new experiences in any field of life. The empirical evidence so far collected supports this expectation (see section 3, and also Schaefer 1972a, Eulefeld and Schaefer 1974, Kattmann and Schaefer 1976, Bayrhuber and Schaefer 1978).

2.3. *The logic core*

The logic core of a concept may be described by an intersection set of properties characteristic for the class of things or events under consideration. In a normal set, such properties are just listed without any specific order. However, if the logic core of a concept is to be regarded as a *system* consisting of structured concept elements, the intersection set is merely a list of these elements and hence does not reveal the structure between the elements, i.e. the logic relationships between the concept, its parts, its special cases, and its epistemic surroundings in the whole. Doerner (1974) has proposed a three-dimensional scheme in order to specify these relationships. The scheme is constructed of two logic relationships: the subordinate/superordinate relationship (dimension of *abstraction*) and the system/element relationship

(dimension of *complexity*). The third axis is used for summing up similar concepts, i.e. concepts which belong to the same superordinate term or which consist of the same elements.

Figure 3 shows the application of this scheme to the concept of growth. It contains, in the vertical direction, the specific cybernetic relationships which will be discussed in a second article in this journal. The scheme is a theoretical picture of a section from the epistemic structure round the concept growth. It points out very clearly the basic difference between a 'horizontal' and a 'vertical' understanding of a concept. The *horizontal understanding* is most commonly aspired to and also achieved in school and university teaching, whereas the *vertical understanding* using abstract superordinate terms from mathematics or systems theory has remained rather underdeveloped because of a general reluctance of biologists to consider formalizations. As Greeno (1977) found in a mathematical context, explicit understanding at a higher level of abstraction and generality improves problem-solving at the lower (implicit) level. Vertical understanding and explicit understanding seem to be synonymous, and the same is true for horizontal and implicit. Whereas in mathematics the vertical understanding goes up to the highest levels of abstraction, in biology it is very much confined to the concrete levels. Therefore, the effects found by Greeno in mathematics cannot simply be transferred to biology teaching. This series of investigations seeks to examine whether in biology education a vertical understanding up to the higher levels of abstraction is possible and how this may be achieved.

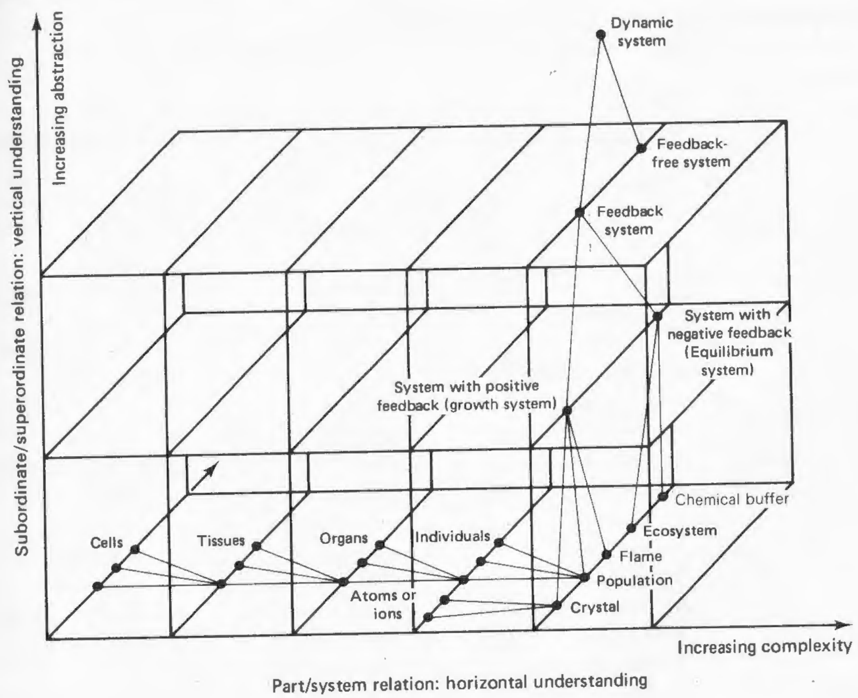

Figure 3. Section from the epistemic structure round the concept growth

3. Empirical investigations on the concept of growth

3.1. Measurements of free associations

These were carried out on students from the middle and upper grades of German secondary schools, on university biology students and on biology teachers at German High Schools (Gymnasium). Subjects were asked to write down quite spontaneously and without deliberation every word that came into their mind in response to a given key-word. On average, subjects produced six words as free associations, although students at the lower education levels (upper level of the elementary school) sometimes produced only two or three associations or even none. An example of a completed test

Table 1. Example of a completed test sheet

Ed. major, female, 31 years old
fourth semester

Test T.B. 1 on concept formation in biology, part I
Several basic biological terms are listed in the following for which the associative framework (the 'spectrum of associations') is to be determined.

In this part of the test we would like to ask you to write down as spontaneously as possible, i.e. without any consideration, up to six associations each, which occur to you for every term. The associations can stem from the narrower field of biology or from any other sphere of everyday life.

Please list the associations in the order in which they occur to you!

Example :

Blood	1. red	2. flowing	3. warm
	4. haemoglobin	5. iron	6. car accident

Term		*Associations*	
Growth	1. *large*	2. *foodstuff*	3. *cells*
	4. *energy*	5. *disturbance*	6. *period*
Metabolism	1. *sickness*	2. *digestion*	3. *steady state*
	4. *energy*	5. *growth*	6. *change*
Individual	1. *alone*	2. *strong*	3. *object–subject*
	4. *personality*	5. *group*	6. *particular*
Stimulus	1. *reaction*	2. *nerve*	3. *conduction*
	4. *synapse*	5. *overstimulation*	6. *stimulate*
Reproduction	1. *propagation*	2. *hormones*	3. *fallopian tube*
	4. *uterus*	5. *pregnancy*	6. *sperm*
Health	1. *illness*	2. *environment*	3. *nutrition*
	4. *nature*	5. *sports*	6. *medicine*
Behaviour	1. *disturbance*	2. *therapy*	3. *research*
	4. *behaviorism*	5. *observation*	6. *measurement*
Equilibrium	1. *balance*	2. *backflow*	3. *labyrinth*
	4. *steady state*	5. *fall over*	6. *lose*
Learning	1. *psychology*	2. *difficulties*	3. *concentration*
	4. *memory*	5. *training*	6. *memory traces*

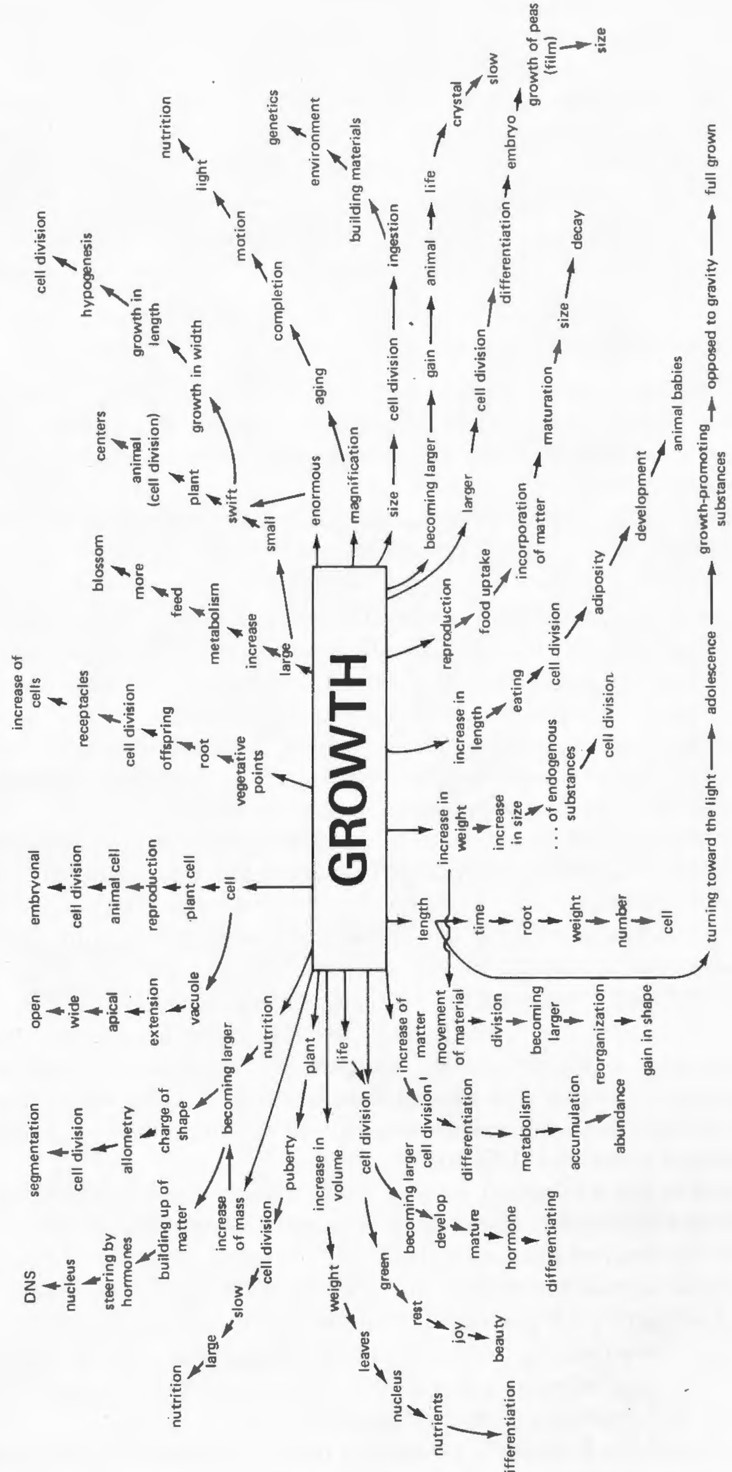

Figure 4. Chains of free associations for the concept growth by 23 biology teachers from different 'Gymnasium' (High Schools)

sheet is given in table 1. This lists some key-words other than growth; these key-words are currently being examined and the results will be reported in due course (Schaefer 1979).

Figure 4 shows several chains of associations relating to the concept growth which were derived from the population of biology teachers. The diagram reveals that there apparently is no special order in the sequence of associations (first biological, then non-biological, or vice versa). Instead, the sequence seems to be rather irregular. However, when classifying the associations in certain categories, a marked regularity appears in regard to the *frequency* of associations within the categories. This is shown clearly by table 2.

Table 2 gives the following results:

(1) For all age groups and at all levels of education, the percentage of *geometrical* associations (high, narrow, large, small, volume, etc.) was very large. Growth is thus subliminally associated with the notion of becoming larger.
(2) A large percentage of associations falls to the *general formal* category (thriving, disturbance, structure, swift, process etc.). Apparently, this percentage does not change with age groups or levels of training.
(3) Surprisingly, almost no associations for the *physical* category mass or weight come to light in all populations. This is particularly striking because growth is normally connected with an increase of substance, i.e. weight. The subliminal reaction to the key-word growth tends more toward the formal, external (visible) aspect of growth rather than to the content or substantial (ponderable) aspect. This is also supported by observation 2.
(4) The percentage of associations in *sociological* categories (sociology, economy) is surprisingly low. Concepts such as economic growth, capital, over-population, seldom come up; the frequency of such designations is highest for 'Oberstufenschüler' (pupils in higher grades) and students.
(5) Associations from the field of *psychology* (knowledge, education, becoming smarter, learning etc.) are also quite rare. They are most frequent for 'Hauptschüler' (pupils of the upper division of elementary schools) and decrease noticeably with level of training. This coincides with earlier assessments of associations using other concepts (Schaefer 1972b).
(6) Whereas the biological associations in the area of *Man and animals* decrease noticeably (from approximately 24 per cent to 7·5 per cent) with the level of training in biology, associations in the area of *plants* increase noticeably within the same time period (from 0 per cent to approximately 16 per cent). This is surely a result of the study of biology in which 'growth of plants' (elongation growth, secondary thickening, plasmatic growth) is a theme which increases in importance with increasing education level.
(7) Results in the biological categories *differentiation* and *physiology* are relatively constant: the percentage for differentiation is 17 ± 3 per

Table 2. Free associations of pupils, biology students and biology teachers for the concept growth and their distribution in different categories. Because some categories overlap, the sum of the percentages in one line is sometimes larger than 100 per cent

	Geometric measures	Weight	Differentiation, development	Physiology, biochemistry	Cell division, reproduction	Man and animals	Plants	Psychology	Sociology	Economies	General and formal aspects	Other
Hauptschüler (9th grade) n = 63	54% large, fat, narrow, thin	1% become heavier	17% glands, mature	7% vitamins, fresh air	0%	20% puberty, body	0%	5% becoming smarter, language	0%	0%	18% disturbance, slow	0%
Realschüler (9th + 10th grades) n = 89	30.3% large, fat, etc.	0.39%	20.4% cell, bone, brain	14.8% eating, hormones, nutrition	2.5% nucleus, equatorial plane	24.3% children, baby, adolescent	3.7% chestnut, blossom, tree	2.3% play, knowledge, education	0.2%	0.58% factories, money	16% structure, life, becoming	0.4% April, run
Gymnasiasten (11th/13th grades) n = 92	20% large, fat, etc.	1%	14.3% change, embryo	14.5% warmth, hormones, sun	4.1% nucleus, division	25.4% child, man, fauna	8.6% flora, blossom, green	1.9% status, symbol, growing pains	1% state, population	3.3% national product, prices	17.4% strength, process, expansion	1% snowball crystal,
Students (of biology) n = 112	21% large, fat, etc.	0%	17% deformed organs, habitus	12.8% water, DNS, climate, pill	8.5% division, mitosis, bacterial culture	18% cripple, youth, fish, age	13.3% annual ring, cambium, mushrooms	2.5% learning, impression, intellect, complexes	2.8% skyscraper, mortality rate	1.4% industrial, capital	20% swift, increase, evolution	0.3% basketball, wardrobe
Biology teachers at Gymnasien (high schools) n = 67	13.4% dwarf, increase of volume, large, etc.	2.8% increase of mass	9.3% order, specialization	14% metabolism, chlorophyll	15.9% mitosis, DNS, nuclear-division	7.5% child, animal, chicken,	15.9% internodes, meristem, buds, leaf	0.9% learning	1.9% increase in population	0.9% factory, turnover	18.7% temperature, structure, irreversible	1.9% styrofoam, colour
	Geometric category	Physical category	General biological categories			Special biological examples		Sociological, psychological category			Formal category	

Table 3. Example of completed test sheet

Test T.B.1 on concept formation in biology, part II

Try to define the terms used in part I. The definition should be brief, but as accurate as possible:

Growth is *the reproduction and enlargement of cells.*
Metabolism is *the restructuring of food into substances for energy gain and growth.*
An individual is *a simple being in a population.*
A stimulus is *an impulse which sets off a reaction.*
Reproduction is *a numerical increase of a population.*
Health is *when the psyche and physis are not disturbed.*
Behaviour is *an observable reaction of a living thing to environment.*
Equilibrium is *when both sides are in balance with each other.*
Learning is *a change of behaviour.*

Table 4. Free concept definitions given by 'Oberstufenschüler' (high school pupils), biology students and biology teachers of the concept growth analysed by frequency and various response categories. Due to the overlap of categories, the sum of the percentages is sometimes greater than 100

	Geo-metric measures %	Metabo-lism, mass, weight %	Differen-tiation, de-velopment %	Cell divi-sion, re-production %	Organ-isms %	Other systems %
High School Pupils	67	15	34·5	33·4	90	25
Biology Students (University)	62	9	41	42	84	30
Biology teachers (at High Schools)	55	55	37	73	91	9
	Geometric category	Biological categories			Reference systems	

cent and that for physiology is 14 ± 1 per cent. The relatively low percentage of associations in the direction of differentiation for biology teachers is probably due to the conceptual separation of growth and differentiation in some textbooks.

(8) A clear-cut effect of biology education through the school and university is discernible in the biological category cell division, reproduction: the percentage of associations increases continuously from 0 per cent to approximately 16 per cent. One can see in this a sign for the development of a greatly changed conception of growth which includes the increase of a *number of particles* (cells, individuals).

This interpretation is supported by the findings in table 4 (free definition of concepts).

3.2. Definition of concepts: the logic core

From the study of the definitions of concepts given by the subjects participating in the investigation, we attempted to determine what knowledge aspect the concept growth has for individual people. Independent of the linguistic ability to formulate definition which—as was expected—was very different for the different populations, it was easy to discern from the free concept definitions the concept elements which the test persons themselves applied to the word growth and, hence, the place which they give to the term growth within a knowledge structure (see figure 3).

The concept elements were analysed and classified into categories. The categories, and the frequency of responses in each category are presented in table 4. The investigation encompassed only 'Oberstufenschüler' (pupils of the upper level of High Schools), students and teachers, because the formulation of concept definitions causes too great difficulties for younger pupils. One test sheet which was completed is presented in Table 3.

As can be seen from table 4, a large percentage of the definitions given falls into the geometric category of concept definitions ('becoming larger of a living thing'). The percentage decreases slightly with an advancing level of biology education. At the same time, the percentage of formulations involving the notions of 'cell division' and 'reproduction' increases to a large extent; this is in line with the results from the assessment of associations (see table 2). Formulations such as 'there is an increase in the number of body cells so that the body increases in width and size' also become more frequent.

On the other hand, the percentage of concept formulations involving the notion of 'differentiation' is fairly constant at approximately 38 ± 3 per cent. A typical example of this category could be the interpretation of growth as the 'constant change of body and mind'. The frequency with which the concept definitions were applied to living things is striking (about 90 per cent). Growth is thus considered by the examined populations as being a mainly biological phenomenon. It will be shown in a following article that it is possible to facilitate the transfer of the logic core of the concept growth to other systems by means of cybernetic instruction. At this stage, i.e. without any cybernetic training, only 9 per cent of the concept formulations given by biology teachers do not expressly refer to organisms. Examples of these 'non-biological' definitions are:

'Enlargement or increase of the available mass.'
'Enlargement of, for instance, populations, cities, industrial buildings, etc., i.e. the enlargement of things and processes.'
'In general, the increase or enlargement of individual elements of a system.'
'The increase or enlargement of objects, processes, facts.'
'An increase or accumulation—which occurs according to certain laws—of things.'

These formulations, which already concern more the formal (systems theoretical) aspect of growth, made it worthwhile to investigate the influence of purposeful systems theoretical trains of thought on the concept of growth. These investigations will be reported in a subsequent article in this journal. They will show that a clear shift in the definitions, as well as in associations, occurs as the result of cybernetic training. The shift shows the possible change in concept formation by formalization, which seems to concern the logic core (growth as a subcategory of positive feedback reaction) as well as the associative framework which facilitates the transfer of the logic core to other, non-biological areas.

References

AUSUBEL, D. P. 1968, *Educational Psychology. A cognitive view.* (Holt, Rinehard and Winston: New York.)

BAYRHUBER, H. and SCHAEFER, G. 1978, *Kybernetische Biologie.* Unterrichtseinheit für die Klassenstufe 11 bis 13 (S II); Grundkurs/Leistungskurs. (Aulis: Köln). (In German.)

BRUNER, J. S. 1960, *The process of education* (Vintage Books, Random House: New York).

DEESE, J. 1965, *The structure of associations in language and thought* (John Hopkins Press: Baltimore).

DOERNER, D. 1974, Kognitive Struktur und Information. Paper presented to the workshop: *Struktur und Information als Determinanten von Lehr- und Lernprozessen*, organized by the German Society for Cybernetcs (DGK), Bad Homburg. (In German.)

EULEFELD, G. and SCHAEFER, G. 1974, *Biologisches Gleichgewicht.* Unterrichtseinhei für die Klassenstufe 6 bis 8. (Aulis. Köln). (In German.)

GREENO, J. G. 1977, Processes for comprehension and for production in problem solving. Paper presented to the workshop: *Developmental Models of Thinking* (IPN, Kiel).

KATTMANN, U. and SCHAEFER, G. 1976, New Approaches to Restructuring School Biology. *Journal of Biology Education*, Vol. 10, No. 3, pp. 139–47.

KOEHLER, O. 1956, Zählversuche bei Dohlen. *Zeitschrift für experimentelle Tierpsychologie.* (In German.)

LANDAUER, T. K. 1978, Quantity and Quality in Knowledge. Report during the ASI-Conference: *Structural/Process Theories of Complex Human Behavior* held in 1977 in Banff (Canada).

LEINFELLNER, W. 1965, *Struktur und Aufbau wissenschaftlicher Theorien* (Physica-Verlag: Wien/Würzburg). (In German.)

NOVAK, J. D. 1977, *A Theory of education* (Cornell University Press: Ithaca and London).

OERTER, R. 1971, *Psychologie des Denkens* (Ludwig Auer: Donauwörth). (In German.)

SCHAEFER, G. 1972a, *Kybernetic und Biologie* (Metzler: Stuttgart).

SCHAEFER, G. 1972b, *Kybernetische Konzepte als Instrumente für die Begriffsbildung in der Biologie.* (Polykopierte Fassung. IPN: Kiel). (In German.)

SCHAEFER, G. 1978, Kybernetik im Biologieunterricht. *Unterricht Biologie,* Heft 2, pp. 2–21. (In German.)

SCHAEFER, G. 1979, *Begriffsbildung in der Biologie. Beiträge zur Didaktik der Naturwissenschaften.* (Aulis: Köln). In preparation (publication probably 1979). (In German.)

Summaries

English

A concept is understood here as a *logic core*, which is surrounded by an *associative framework*, to which also the *name* of the concept belongs. The logic core is a pattern of properties of a class of things, which is invariant to individual objects of the class as well as to the observer. The pattern is determined by logic relations, which are constituents of the epistemic structure of the learner.

In this article an analysis of the situation concerning the concept 'growth' is carried out. The logic core of the concept is theoretically investigated by means of systems theory and is empirically tested by means of free definitions. The associative framework, however, is determined by means of free association tests.

It is shown that in the course of school education a marked shift takes place in the logic core as well as in the associative framework from a 'growth in terms of geometric dimension' towards a 'growth in terms of particle numbers'.

Deutsch

Ein Begriff wird hier verstanden als ein *logischer* Kern, der von einem *assoziativen Umfeld* umgeben ist, zu dem auch der *Name* des Begriffs gehört. Der logische Kern ist ein Merkmalsmuster einer Klasse von Gegenständen, das invariant bzgl. der Einzelgegenstände und auch bzgl. des Beobachters ist. Das Muster wird durch logische Relationen bestimmt, die Bestandteil der epistemischen Struktur des Lernenden sind.

In dieser Arbeit wird eine Bestandsaufnahme zum Begriff 'Wachstum' durchgeführt. Der logische Kern des Begriffes wird theoretisch mit Hilfe einer systemtheoretischen Analyse und empirisch mit Hilfe von freien Begriffsbestimmungen durchgeführt. Das assoziative Umfeld dagegen wird mit Hilfe freier Assoziationsmessungen erfaßt.

Es zeigt sich, daß im Verlaufe der Schulausbildung sowohl der logische Kern als auch das assoziative Umfeld eine Verschiebung vom 'Wachstum einer Größendimension' in Richtung auf 'Wachstum einer Teilchenzahl' hin erfahren.

Français

Un concept est compris ici dans le sens d'un *noyau logique*, entouré d'un *champ associatif*, auquel correspond encore le *nom* du concept. Le noyau logique est l'indice d'une classe d'objets, qui est invariant par rapport à chaque objet, et par rapport l'observateur. Cet indice est défini par des relations logiques, qui sont des éléments de la structure épistémique de l'etudient.

Dans ce travail se trouve l'inventaire du concept 'croissance'. Le noyau logique de ce concept est construit à l'aide d'une analyse théorique des systèmes et, empiriquement, à l'aide de définitions de concepts libres. Par contre, le champ associatif es conçu à l'aide de mesures d'associations libres. Tout au long de la formation scolaire, se dessine la tendance d'un déplacement de la 'croissance de la dimension d'une grandeur' vers la 'croissance d'un nombre de particules', ceci aussi bien pour le noyau logique, que pour le champ associatif.