The requirements for Coastal Engineers in Integrated Coastal Zone Management

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Abstract

Worldwide there is a need for training of engineers to work within the framework of Coastal Zone Management. This has effects on the education of engineers. Moreover, the requirements for an educational program for coastal engineers from developing countries are quite different from the requirements for the training of engineers from the industrialized world. In a university course for engineers from developing countries more attention has to be paid to the development of capabilities to come to practical solutions given the local constraints and to be able to assess the work done by foreign consultants.

Introduction

Coastal zones are currently experiencing difficulties as a result of rapid population growth, not integrated management and conflicting resource utilization. The problems frequently identified in the coastal zone relate to population safety (from flood-defence to contaminated drinking water), food supplies (from crop selection to harvest failure) and socio-well-being.

In the developed world money, the institutional infrastructure and technical know-how is generally available to tackle the problems, although it will be a tough job. In the developing world solving the problems of the coastal area is much more complicated, because there is generally no money available, a weak institutional infrastructure and a lack of well-trained experts.
It is important to take care of the transfer of knowledge, to train local experts as well as to improve the institutional infrastructure in developing countries.

Because the boundary-conditions for each area are completely different, it is no possible to copy solutions for one area to another area. Besides, solving coastal problems is not only a matter of techniques. The choose solutions need a broad support from local people and local organizations. Otherwise all effort is useless to overcome the problems.

Projects for the 21st century should not and hopefully would not be copies of the past projects.
Two circumstances require a new approach:
- -Environmental compatibility as an planning and design criterium.
- -Introducing recent achievements in hydraulic engineering techniques.

In the same time these techniques have to be adapted to specific local conditions (construction material, labour skills, tradition of water use, etc.)

Coastal Zone Management, Coastline Management and the engineer
The terms coastal zone management, coastal resource management, integrated resources management and coastal area planning and management are often used interchangeably in the international literature. There are two components to this definition -- planning an management. The first component, integrated planning, is a process designed to interrelate and jointly guide the activities of two or more sectors in planning and development. The goal of integrated planning is the preparation of a comprehensive plan

which specifies the means to effectively balance environmental protection, public use and economic development to achieve the optimum benefit for all concerned. The integration of activities usually involves coordination between data gathering and analysis, planning and implementation.
This final point is the essence of the management side of the definition. Coastal management is the process of implementing a plan designed to resolve conflicts among a variety of coastal users, to determine the most appropriate use of coastal resources, and to allocate uses and resources among legitimate stakeholders. Management is the actual control exerted over people, activities and resources. Public participation plays a key role in both planning and management. [HILDEBRAND, 1989]

Sometimes the term "Coastal Zone Management" is used for what is in fact "Coastline Management". But "Coastline Management" is only a part of CZM; in fact it has to be the result of a good CZM-policy for one sector. Coastline Management is managing a coastline in such a way that the CZM-policy can be executed. Thus: maintaining the coastline at those points where it is necessary, but also a (controlled) retreat of the coastline in those places where maintaining the coastline position is not absolutely necessary.
The technical means to maintain a coastline vary considerably. Both soft measures (artificial beach nourishment) or hard measures (beach walls and revetments) can be considered. Education of engineers must therefore be directed both towards Coastal Zone Management as towards Coastline Management.

Hydraulic engineering works are generally big works. Copying solutions from the western, industrial countries for application in developing countries is in general not the best solution for solving the problems of developing countries. The main reason for that is that the available resources in the developing world are different from the resources in western countries. In the industrialised countries there is a strong tendency to solve problems in such a way that the amount of required labour decreases, so a capital-intensive solution is searched for.
In developing countries this difference is much less, but on the contrary it is difficult and expensive to import industrial products from elsewhere. Also it is difficult to have sufficient capital available. For those countries it is more economic to search for solutions which require hardly any investments, but are relatively labour-intensive. These solutions generally require often more maintenance. However, increased maintenance costs are sometimes very pleasant, provided the initial investment is very low. The cost of the solution can be spread over a longer period without borrowing money for a capital intensive solution.

Engineers have to be educated both as designers and decisionmakers. Many engineers, especially those from developing countries, get positions in their government services where they have to prepare or make decisions. Only a few engineers have to be educated as researchers. Engineers trained abroad, once back in their home country, don't have the resources which are available at the institutes where they were educated. It is therefore important to provide them with a good set of basic backup-information for use later-on. This material will be used by the participants themselves, but probably also by their colleagues and subordinates.

In a lot of developing countries not enough experience is available to design and build large coastal infrastructural works. The usual procedure is that for such a special case a foreign consulting engineering company is asked to make the final design and to supervise the work. The work itself is tendered and usually built by an (international operating) big contractor. This is a very effective way of working, because the number of these type of works is usually too small to have all the required skills available inside the country permanently.
However, after completion of the work, the structure has to be maintained. In the beginning there is not very much maintenance, but the effort required to for keep the structure in good condition increases in time. In general it is not practical to hire a foreign consultant for planning and supervising the maintenance. Also big contractors are not very interested in doing the maintenance work. So this has to

be done by local engineers. Therefore it is very useful to emphasize maintenance and management of maintenance in educational programmes.

Recent Developments

Coastal Zone Management is by definition multi-disciplinary. A coastal engineer, working in a Coastal Zone Management project, is therefore usually one of the specialists in a team. He has to cooperate with specialist from other disciplines. Because there is a clear tendency that in future most coastal works have to be embedded in a CZM-framework, working in a group is therefore an essential skill for engineers involved in CZM. But apart from the ability to work in a group, it remains necessary that a coastal engineer is a specialist in solving coastal problems.
In this respect the task of a coastal engineer goes beyond that of a coastal scientist, who usually can stop his research after understanding, explaining and describing the problem. As mentioned by CRAWFORD *ET. AL.* [1993] the 346 professionals in 17 US state CZM-agencies consist of 20 different professions, only 15 of them are engineers. Most of the professionals in CZM in the US are Planners, Administrators en Environmentalists (160). In many other countries the contribution of engineers is much larger.

In the past engineers only had to look to the technical aspects. Nowadays, the impact on society and environment, the costs and the sustainability are at least as important. The consequence of this is that the role of coastal engineers has changed considerably in the past few years. Fortunately, also the tools for the engineers have changed considerably. In the past much was done based on experience, engineering judgement and empirical formula. Verification was usually only possible by means of measuring in prototype or by physical modelling.

Worldwide research in coastal sciences and coastal engineering has shown two developments:

- a considerable increase in the domain knowledge (knowledge of coastal processes);
- advanced tools have been developed like mathematical models (in various dimensions) and decision support systems. For design and project development the role of the physical models is nearly completely taken over by the mathematical models.

Types of engineers

Because of this development one may distinguish nowadays three types of coastal engineers:

- the research-engineers, involved in expanding the understanding of the coastal processes; using advanced data-analysis of field data and sophisticated physical models;
- the "toolmakers", engineers involved in translating the newly gained knowledge into mathematical models and encapsulate this knowledge in various knowledge based systems (Hydroinformatics, see ABBOTT [1994]);
- the project engineers (the tool-users), contributing in solving the coastal problems in a multi-disciplinary team.

The first two types of engineers produce products which can be used globally. Results from research done in Australia can easily be used in Iceland. Also (the better) tools can be used anywhere. Tools, developed in the Netherlands can easily be used in Sri Lanka. However applying the tools for solving local problems requires the specific local knowledge of the various parameters of the system.

General requirements for coastal engineers

A difference can be observed in the start of a career in engineering in countries with a strong Coastal Engineering tradition, and in countries without such a tradition. Most of the developing countries belong to the category without a strong CE-tradition.

In the countries with a CE-tradition after graduation a young engineer usually starts his career as junior engineer in a group of more experienced coastal engineers. In university as a student he or she has learned the fundamentals of coastal behaviour. In the first job a young engineer learns how to apply this fundamental knowledge. The starting engineer will first be involved in projects guided by others. In this way an engineer will build up his experience and will especially get a feeling for the relativity of the results of his computations. What does it mean that the CERC-formula tells you that there is a longshore transport of 128,372 m^3/year along the coast ?
In most of the developing countries young engineers do not have the luxury of getting experience in this way. After graduation, they get a position as "expert". Although they will usually work under the guidance of a more senior engineer, this senior engineer is often not an experienced coastal engineer.

An other important point is that in the "shortage countries" there is no existing network of experienced engineers. Our young expert cannot go to his former study-mates or to a specialised library. Keeping in touch with the profession is very essential. Nowadays electronic data communication eases the life of the remote engineer. Via the computer libraries can be accessed and contact can be made with colleagues on the other side of the globe.

In the training special attention has to be paid also to these aspects. This fact makes that education for coastal engineers from developing countries has to be organised somewhat different from education for coastal engineers from industrialised countries.
In the industrialised world, there is the luxury that the young engineer can build up experience in a quit protected environment. Therefore in education only focus is needed on information on the basics of coastal engineering and on understanding of processes.
For engineers from developing countries this is not enough. Also attention has to be paid to the application of the knowledge, to the reliability of the results, and especially how to come to workable answers and solutions of engineering problems.

A coastal student from a developing country needs to have a more practical education, because he will usually not have the luxury to develop these skills in the first years of his professional carrier.

Being aware of these points, one may draft a curriculum for engineering students. Listing the items required in the curriculum leads to a long list. Because of the limited time available, it is not possible to teach every item of such a list into depth. Priorities have to be set and choices have to be made.
Given the needs of students from developing countries, these priorities and choices will be different from students from industrialised countries. For each country the basis of good quality coastal engineering and good quality coastal management is the availability of well educated engineers. In most of the developing countries there is still a shortage of coastal engineers, and consequently there is a need for training of engineers.

types of engineering problems

A "resident engineer" in a developing country is usually confronted with three types of problems:
I:Problems which have to be solved by the engineer (or his staff) fully on his own.
II:Problems for which the help of an outside consulting engineer is required.
III:Problems for which the help of a specialist is required.

Type I problems are the everyday problems of the engineer. To solve these problems tools are handbooks and simple P.C.-programs. The engineer should be able to define the problem, analyze the problem, solve the problem, completely without any help from other departments, consultants, etc.

Type II problems are the bigger problems, or special designs to be made. These designs or studies are usually made by outside consultants. The engineer should be able to define the problem, define a commission to a consultant, supervise the study and assess the final report.

Type III problems are the very unusual problems. They cannot be solved by the average consultant. Only a few specialised agencies in the world can do the job. The engineer should know that these advanced techniques exist, which specialistic agency can solve the problem, and how to set-up a supervising structure to supervise this work by a more specialised expert.

A training-course should deliver engineers which have the above mentioned skills. A primary target of such a course should not be the first phase for engineers who have to continue their education in order to solve type II or type III problems. Knowing the fact that most of the engineers will not be type II or type III problem solvers, it is not efficient to focus on these elements; in that case much time is spent to train skills which will never be used.

Practically, the subjects can be divided into four groups:

a: basic subjects:

These subjects are a basis for every coastal engineer, and have to be known to everyone.

b: core engineering:

The real professional items, a participants comes to follow the course for these subjects.

c: supporting subjects:

Related professional items of which some knowledge is necessary; but if you are mainly interested in these items, follow another course

d: specialistic topics:

professional items, but usually not covered by the average coastal engineer; typically the type III problem

Based on our experience in the last 37 years, IHE has developed a curriculum focused on the needs of the developing countries. In this curriculum special attention is paid to the following items:

- good understanding of the basics of the physical processes;
- insight in the effect of reliability of data, used in the design processes;
- develop capabilities to come to practical solutions given the local constraints ;
- develop capabilities to organise the design work in a straightforward way, given the limited resources available;
- develop to ability to cooperate with specialists from other disciplines in a inter-disciplinary coastal zone management project.

Of course this list is also valid for students from industrialised countries, however many accents in this list have to be placed differently. In the following this will be worked out, using examples from coastal engineering practice.

specific requirements and needs from the developing world

For the development of a program for coastal engineering students for developing countries one has to answer the following questions:

- What kind of capabilities are needed in the coming years in the country
- How do we solve the problems at this moment.

Often one observes that university programs in coastal engineering are set-up from a scientific point of view. Usually the start of a coastal program begins with the need to develop capabilities to study the coastal engineering environment. In order to gain status of the university, this research has to be on adequate (international) level. Because the funds (and consequently the size of the scientific staff) are

limited, an adequate research level can be reached in perhaps only one very specialised field. For the *scientific* development of the profession in a developing country this can be a good step.
For the *training of engineers*, this is usually not a good approach. For engineers in developing countries it is not useful to be specialist in a very limited field of coastal engineering. An engineer in a developing country has to be more a generalist, because he has to solve all problems by himself (If he is only a specialist in topic X and he has to solve a problem in topic Y, he cannot go to a specialist in topic Y, because that specialist does not exist. He is the only engineer).

reliability of data an the generation of alternatives

In coastal engineering there are many non-accurate descriptions of the physical processes. Waves are often described using only an H_s, the quality of sediment transport formulae is usually quite doubtful, etc. In many cases, various levels of accuracy of the description of the physical processes exist. Sediment transport formulations exist in many gradations, for longshore transport one may use the simple CERC formula. It is also possible to use a much more detailed approach: First determine the radiation stresses in a two dimensional grid, undertow, etc. in front of the coast. Then by calculate of the sediment transport in each gridpoint, using a more advanced sediment transport formula, which includes eddy viscosity, etc. However, if one has to use bathymetric data from a nautical chart and wave data from Global Wave Statistics, it is of no use to apply a detailed computational technique to determine the longshore transport. The quality of the formulae used in the design process has to be in line with the quality of the available input data.
Especially engineers from developing countries have to be very aware of this. Also they should carefully examine which part of their input causes the highest unreliability in the final answer. In order to investigate the effect of unreliability, probabilistic computation techniques are extremely relevant. Therefore training in probabilistic computation has to be an essential part of a course in coastal engineering for students from developing countries.
Designs have to be made in such a way that they are not very sensitive to those (mostly unreliable) data. Therefore it is necessary to train students in the generation of alternative solutions. All alternatives have to be evaluated in order to find out which solution is the less sensitive one.
In engineering courses often not enough attention is paid to the generation of alternatives. Usually students only learn how to use design rules to come to (one single) solution. Especially for developing countries this should be avoided.

practical solutions

Often various designs are possible. In the industrialised countries, usually solutions are chosen which require as less labour as possible. The consequence is that many extremely good quality shoreline protection methods are no longer applied in the industrialised world (like the brushwood bottom protection mattresses and the pitched stone revetments). In the industrialised world we cannot effort these structures any more, they are too costly. Because of the different ratio between labour costs and capital costs in developing countries, one may come up with completely different, but extremely good quality solutions. In engineering textbooks (usually from the industrialised countries) implicitly the capital intensive approach is used. For developing countries this is usually a wrong approach. This aspects needs special attention in a course for engineers from a developing country. See also VERHAGEN AND YAP [1992].

collection of field data

Usually the availability of data in developing countries is much less then in the industrialised world. Part of this shortage of data can be overcome by using remote sensing techniques. Unfortunately in coastal

engineering often long time series are needed. And even with the most sophisticated satellites one gets only time series covering a short periods.
Often the engineer has to define how to set up a survey-system in order to collect data for coastal projects. It is important that in such a case the limited amount of money available for such surveys is spend in an optimal way. For coastal projects long time series covering a wide area with limited data, are always better than sophisticated measurements at one moment and one place. The survey-plan has to be in line with that. In developing countries with manual measuring techniques many very useful data can be collected at extremely low cost. Although the quality of each individual observation may be somewhat lower that individual observations with advanced measuring devices, the fact that many data are available results in a much higher quality of the final data set.
Therefore engineers have to be trained in setting up such manual observation schemes, combined with advanced statistical data processing.

Educational material

In university programs, often extensive use is made from reference books, to be purchased by the participants or by using books from the library. For the training of engineers from developing countries this has some disadvantages. Most of the students have to study with very limited financial support. Usually the fellowships do not have large book-allowances, and professional specialized textbooks are quite expensive (a standard reference book costs at least some hundreds of US $). And library books one cannot take home for reference; Also these books are mainly written for readers based in industrialized countries.
Therefore custom-made lecture notes are in most cases the best solution. In our course in Delft, the total package of lecture notes consist of approximately 7500 pages.

Tools

In mathematical modelling of coastal processes there is in general a tendency to make programs more sophisticated and more advanced. The consequence of this modelling is that models become usually more specialised, and also more difficult to handle.
Although much effort is paid to the user-friendliness of systems, general systems require much input, which has to be defined in some way. Most programs nowadays can be handled relatively easy only if one is familiar with the program.
On the other hand, 90 % of the problems in engineering are rather standard problems. These problems require only the application of very few formulae. Continuous research is going on to improve the quality of such formulae, although also here is a tendency to concentrate on the more exotic cases. This is very understandable, because for a researcher the challenge of such problems is much more attractive. For the design-engineer, this development is not so attractive, because for his daily work he is therefore often condemned to use out-of-date reference material. Especially engineers working in smaller companies or agencies have difficulties is accessing the latest developments. The Shore Protection Manual is still their major source of reference information.
Because application of a dedicated program requires familiarity with the input structure, many designers having a minor problem, will not use such dedicated programs. The time they have to invest in learning how to handle the program is too much in comparison with the importance of the problem. So in such cases designers often go back to graphs and design-manuals.
To overcome this problem, IHE has developed a very simple package, called CRESS (Coastal and River Engineering Support System). In fact CRESS is a collection of small routines, each containing a formula, or group of formulae, important in coastal and river engineering. The input and output is highly standardized, and is both available in numerical and graphical form. Working with CRESS is fast and simple, the package is designed in such a way that is works on all types of machines, even on the slow ones, and that it does not require a lot of memory. Uncompressed it still fits on a 720 Kb diskette.

For a design several steps have to be taken. CRESS does not automatically transfer data from one step to the next one. In this case the user is forced to think about the input and all the intermediate results. CRESS does not prevent the user to apply a formula outside its range of application. Often in engineering it is useful to do so, however it has to be done with great care. Tendencies and sensitivities are very important. The graphical routines of CRESS are made in such a way, that the sensitivity of a given parameter can be shown easily in the diagram.
The available Help-routines allow the user to find some background-information on applied formula, but also lists of constants, which can be entered (example: the Manning-coefficients).

Being an educational institute, our first aim in developing CRESS was not to provide a handy tool for designers, but to develop an instrument for the training of our students. In our view a design engineer has to be able to understand the physical background of the formulae used, and has to know the sensitivity of the various input parameters. In most cases it is not necessary that a designer can derive all formulae used, neither it is necessary to know the formulae by heart. However, for training in real design, one has to apply formulae quite often, especially in order to develop a feeling for the ranges of validity and for the sensitivity. Doing this with a (programmable) pocket-calculator takes a lot of time (with the risk of many data-entry errors) which is in our opinion not well spent time.
In CRESS all these formulae have been placed. Applying CRESS goes very fast, and therefore all the available time can be used for evaluation of the given output. Because of the fast and flexible graphical output, students get develop a feeling for ranges in a relative short time.

Outline of the IHE coastal M.Sc.-course

In the scheme an overview of the whole course is given. The value between brackets in the following overview is the number of credits for each specialization (coastal, estuaries, ports). The sum of all Credits per branch is more than the required 75; this is because some of the subjects are elective.

•**Refresher** (7/7/7)

In the refresher some undergraduate subjects are repeated, like basic statistics, basic hydraulics, soil mechanics and informatics and computer-programming.

•**Basic Subject and general tools** (9/9/9)

In this block the basic subjects for coastal and port engineers are discussed, like sediment transport, tides, wind waves and density currents. Also much attention is paid to modelling techniques, both physical and mathematical. Risk-analysis and probabilistic design methods are also included.

•**Coastal projects and the environment** (4/4/4)

All coastal projects have a great influence on the social and ecological environment. The engineer should include that in his design. Also the process of decision making is very relevant for engineers, especially for them working as government officials. Attention is paid to pollution in harbours, environmental impact assessment, oil spills and integrated coastal zone management. A two week workshop in Coastal Zone Management is included in the course.

•**Coastal Engineering** (9/5/2)

This block starts with a general introduction to the various aspects of coastal engineering, followed by specific topics relevant for a coastal engineer, like the design of access channels, coastal sediment transport and coastline management. Sea defence structures and revetments are a very important part of this block. The morphology of estuaries is discussed in detail. Exercises in design of coastal protection structures are included.

•**Geotechnique in coastal areas** (2/5/2)

The interaction between soil and water is studied in this block. Major exercises are scheduled in slope stability and sheetpile design. New foundation techniques are discussed, as well as an overview (with lab work) of soil investigation techniques (both on land as at sea).

•**Dredging, reclamation and project planning** (5/5/5)

An overview is given of dredging equipment, dredging technology and execution of works. In workshop the participants are trained in the preparation of tender documents for a major earthmoving job. This workshop is given in close cooperation with the International Association of Dredging Companies.

•**Design of coastal structures** (6/2/6)

The major part of this block is the design of breakwaters (3 Credits). In an exercise the participants have to design a breakwater according to the latest scientific results. Other subjects in this block are the design of quay-walls, building pits, barriers, locks and offshore berthing structures (jetties).

•**Port planning and management** (-/3/9)

This block gives detailed training for port engineers. Merchant shipping is discussed, as well as port planning and port management. A full week workshop in port planning is included in the course. Modern port simulation models are presented and used in exercises.

•**Related subjects** (2/2/2)

For coastal engineers it is important to have some knowledge in related fields. Therefore some related topics are included, like hydrographic surveys, remote sensing and ocean engineering. Also every year some special lectures are given on topics of current interest.

•**Groupwork** (7/7/7)

In a small group (6-8 persons) a real-life problem has to worked out and solved in detail. The groupwork involves an integrated approach to working out a design under the guidance of experts. In the groupwork the important aspects are integration of knowledge from various subjects, how to handle the problem of insufficient or inadequate data and the problem of organising the work in a group of experts.

•**Fieldtrips, study tours** (6/6/6)

During the course several one-day field trips are made to several places in the Netherlands to see coastal engineering works under construction, or in function. We will also visit some design offices, laboratories, consultants and harbour authorities. A longer field trip (one trip of 3 weeks or two trips of 1 + 2 weeks) to other European countries is included in the curriculum.

•**Individual thesis work** (25/25/25)

It is our intention to keep CRESS on the level of the state-of-the-art in coastal and river engineering. When research results in new approaches to design problems, and in practical application this leads to acceptable results in the design process, such new developments will be implemented as soon as possible in CRESS.
Examples of new developments in CRESS are the Breakwater armour unit formula of Van der Meer (as alternative of Hudson), the longshore transport formula of Queens (as alternative of Cerc), the new Delft run-up formula (as alternative of the 8Htan(alpha) formula).

It is not our intention to build out CRESS as a sophisticated tool able to solve all major problems in coastal and river engineering. For example, a very simple routine is available to compute the flow in a tidal inlet, using the storage-area approach. This routine is fast, and also the input can be generated very fast. However, this routine is not able to compute flow in longer inlets, or in inlets with more than one opening towards the sea. For such problems, one has to use a package, specially designed to solve that kind of problems, e.g. a one-dimensional flow program.

Engineers have to be trained is the use of such simple programs, but also in the use of more advanced programs. Attention has to be paid to the interpretation of the results from computer programmes. Also an engineer has to be able to decide which package is relevant to use in order to solve the given problem. An engineer should be able to decide when a on-dimensional flow program is sufficient and in which cases a three-dimensional program is absolutely needed.
Especially engineers from developing countries have to be trained in this aspect. Often the computation will be done by foreign consultants. And of course they like to apply their most sophisticated, and consequently most costly programs. A local engineer, representing the client has to be able to verify what is really needed and what is overdone.
Therefore in training programmes interpretation of results from computer programs, selection of programs, and evaluation of reliability is more important than training in the development of new software.

Non-technical aspects

Many of the participants will receive, after returning to their home countries, responsible functions. Therefore also attention is paid to the organization of group-work, project planning and project supervision. Participants will be trained in the management of design-groups. Also a short introduction will be given to the psychology of group behaviour, an essential item for future managers.
Training will be provided in the assessment of the environmental aspects of coastal works, using recently developed analysis methods.

As a part of the curriculum students have to solve a coastal management problem in group. The problem itself is ill-defined and only a limited set of data (sometimes even contradictory) is given. During this period students have to spend a lot of time on problem definition and on how to organise themselves. Long term evaluation of the IHE curriculum shows that students from developing countries in retrospect see (after being back in their country for some years) this as one of the most valuable parts of the course.

pure science

A last important point to mention is the worldwide focus on the "pure science" in coastal engineering. Much research in coastal engineering leads to longer formulas, not to better applicable formulas, as is proclaimed by SMITH [1994]. Especially for Coastal Engineers, working in a CZM-team, it is vital to know the physical processes instead of only knowing the mathematical approximation of these processes. In education this point is often underexposed.

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