A problem-solving approach in instructional technology for large-sized classes

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Abstract: The most convenient media for learning are printed materials and mobile phones, but these require a sophisticated instructional strategy, a well-defined finite framework and procedure for developing high-quality learning. Different types of knowledge representations and four stages – metaphor, image, model and proposition – implementing instructional technology are introduced in this paper.

Keywords: instructional design; ubiquitous learning; knowledge creation; empirical approach; technology divides.

Reference to this paper should be made as follows: Nishinosono, H., Mochizuki, S. and Miyata, H. (2006) 'A problem-solving approach in instructional technology for large-sized classes', *Int. J. Web Based Communities*, Vol. 2, No. 3, pp.285–301.

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1 Introduction

The remarkable development of Japanese education in the last century now faces new challenges: a drastic demographic decrease in young students, a decline in academic motivation and curiosity, and the bureaucratic rigidity of educational systems. The educational system introduced from Occidental countries about 130 years ago functioned well in the last century but is not effective for our current, rapidly changing and diversifying society. Japan is now struggling to reform its educational system and recover its vitality for enhancing educational potential. A rapidly changing society makes our professional knowledge soon obsolete, requiring us to renew it ceaselessly, while industrial restructuring and organisational change have made employment unstable and professional careers uncertain (Drucker, 2002). The rapid diffusion of Information and Communication Technology (ICT) accelerate the instability of employment and require everyone to be individually responsible for renewing professional knowledge and competence. The present educational system operates efficiently in cultivating manpower for modernising nations in the economic sense, but it is not effective in meeting personal needs in a diversifying society.

A new educational system is needed to accommodate people who cannot keep pace with this changing and diversifying society. Some people working in public education, however, are reluctant or even resistant to reforming the educational system, which was firmly established in the past century. In such circumstances we have to initiate instructional designs based on personal needs and diversified backgrounds and then proceed to national goals that have been agreed upon through democratic consensus. In this sense, there is no substantial difference between developed and developing countries, or industrial and agricultural societies, as all require new knowledge to keep professional competence at a high level in an ever-changing world. It is indispensable that we renew professional competencies to keep our lives more stable and dependable. Lifelong learning for acquiring knowledge is therefore not a special requirement for so-called enlightened people only, but a necessity for every citizen.

Recent developments in ICT enable us to explore an entirely new framework for teaching and learning and to shift from teacher-led to learner-centred instruction. Universal and ubiquitous learning, or u-learning, which can accommodate large audiences seeking professional expertise as well as be incorporated into daily life, needs to be explored urgently (Nishinosono, 2001; 2004). Ubiquitous ICT such as mobile phones, Personal Digital Assistants (PDA) and microchips embedded in our surrounding environments enable everyone to learn at any time and anywhere (Ogata and Yano, 2004a; 2004b).

When we plan to implement ubiquitous ICT in a specific instructional situation, we have to take into account a variety of factors relevant to effective learning for diverse learners. We are expected to apply the abundant scientific findings from past instructional research in designing and implementing instruction, but we often find it difficult to apply previous findings for designing instruction effectively in order to achieve intended goals or realise an expected learning process. We know very little about ubiquitous learning free from teacher-controlled instruction and we face difficulties in designing lessons suitable for diverse student populations, considering their different academic achievements, intelligence, ages, socioeconomic backgrounds and countless other factors. Any designed instruction is unique and requires technological experience (Flechsig, 1997). This means that any technological profession requires ample experience and support from colleagues and superiors. Complex problems are not solved merely by applying scientific findings, but require technological know-how based on experience. From our experience, several preliminary trials while developing a course are required before clarifying intended outcomes. In some cases, revisions must be made ten or more times to achieve satisfactory outcomes. This implies that ubiquitous learning cannot develop from the mere application of scientific findings, but from intuitive trials and systematic revisions for refining the learning itself. This developmental process requires a systematic procedure for enhancing the professional disciplines involved in ubiquitous learning development.

2 The teacher's new role: from knowledge delivery to knowledge creation

The present educational system in our schools has effectively contributed to cultivating and disseminating a school-based academic knowledge centred on the traditional styles of lecture, comprehension and memorisation. Higher education follows conventional teaching styles, but it also aims to introduce new disciplines that contribute to strengthening culture, science, technology and economics. Knowledge has been provided through formal institutions, such as schools and universities, but its cost is becoming higher and higher owing to a shortage of expertise and expensive human resources. In spite of such a high cost, people still pursue knowledge acquisition from well-established institutions, competing to enter a limited number of top institutions to acquire prestigious degrees. The teacher-led framework shown in Figure 1 has lasted for a long time and is quite familiar to teachers. The Japanese national government fixes the educational goals and instructional contents, and local governments follow these standards in providing educational facilities and teacher training that seek to achieve these goals equitably in different localities. Teachers make efforts to provide quality teaching and satisfy the demands of their occupation. They accumulate empirical knowledge about teaching in a tacit but rarely explicit form. The presumption of this system is that the educated can efficiently teach the uneducated in these well-established institutions. This framework of instruction has functioned well in a stable or slowly changing society. The situation, however, has changed drastically since ICT was introduced as instructional media in every institution at the elementary, secondary and higher levels. Recent developments in ICT are expected to provide more and better opportunities for learning and to promote general knowledge revitalisation. ICT enables us to provide large audiences with effective instruction while at the same time responding to personal needs, and to cultivate stronger interest in learning and a deeper comprehension of our surroundings. Television programmes introduce us to entirely new worlds, strange and remote from our daily lives. Computer simulations open new horizons in our recognition of the world. These high technologies contribute enlightenment to our world views and enrichment to our lives. We thus also look forward to the development of a vast educational establishment for lifelong learning and educational opportunity to renew a range of professional expertise in a web-based educational society. Nevertheless, we are still concerned about equal access to the knowledge acquisition necessary for renewing our professional competencies, with the intention of overcoming the lack of learning opportunities with distance learning and spanning the technological divide between the haves and the have-nots. The learner-centred instruction shown in Figure 2 requires us to create an entirely new environment to realise autonomous learning among learners. In this type of learning, project methods or a problem-solving approach is effective in keeping learners' interests and involvement at a high level. When we try to initiate new solutions to problems or produce visible outcomes, we start from imagining them, to drawing sketches and making drafts, to actualising them and to constructing the final solutions and/or products. In this process, we utilise paper and pencil, even large sheets of paper for presentations and chalk and blackboard if necessary. Refining new ideas, discussions, critical reviews and consultations with peers and specialists are indispensable means for realising productive and fruitful outcomes. This kind of learning has traditionally been provided in small-group learning environments located only in conventional educational institutions. Thanks to the development of ICT, internet access, e-mail and software such as white boards for collaborative work are available at a reasonable cost and have become very powerful tools to promote such discussions and consultation in our information society. In this working and learning environment, ubiquitous devices such as mobile phones, PDA and mobile computers are effective and efficient technologies to facilitate interactive communication and review. In particular, technological developments in the area of mobile phones have been very rapid, and they now provide access to television programmes and websites. In this context, these devices, available to everyone, can be used to share knowledge for developing universal learning and overcoming educational opportunity divides. This is the rationale for forging a web community among those engaged in universal and ubiquitous learning, or u-learning, for everyone, at any time, and anywhere (Nishinosono, 2005).

Figure 1 Framework for teacher-led instruction

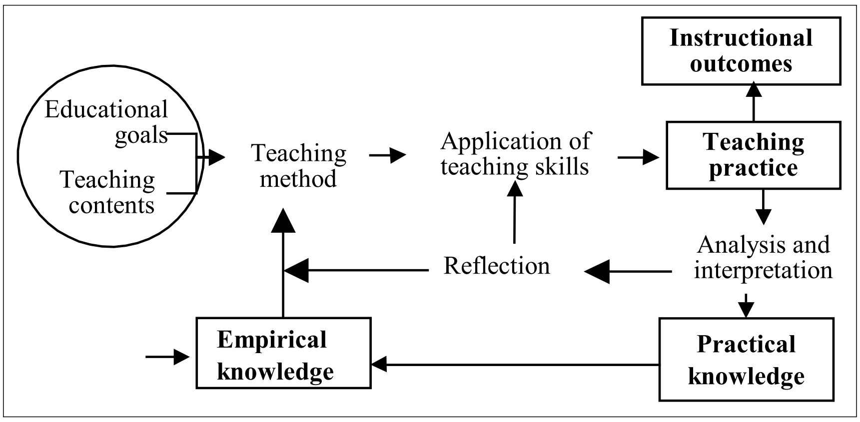
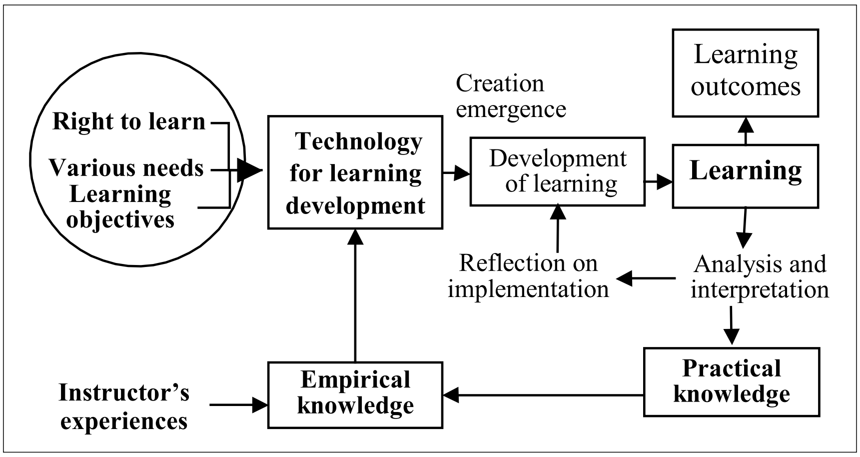


Figure 2 Framework for learner-centred instruction



3 Scientific versus technological approach to universal and ubiquitous learning

The scientific and technological approach for producing modern machinery has resulted in the mass production of cheap and convenient goods for daily life as well as large-scale complex undertakings such as aircraft, tankers, high-rise buildings and even space stations. Computers, the internet and ubiquitous ICT are also modern technological products resulting from the development of information and communication science and technology. In the case of ICT itself, there is no discrepancy between a scientific and a technological approach. Thanks to high-technology-based machinery and facilities, we benefit from the convenience of intercity and international travel, the rapid transference of information on a worldwide scale and the rise of transnational communities. This contrasts strongly with labour-intensive inefficient traditional manufacture, which often requires costly and time-consuming efforts to produce very simple outcomes. Yet with the proliferation of convenient, mass-produced daily necessities, we are losing traditional, high-quality craftworks rich in character.

The same ICT is now being applied to education. Teaching is still a labour-intensive profession, but it is now entering a more innovative stage in our profession towards more learner-driven learning to cope with the great demands of lifelong learning, especially in higher education and at the professional level. This requires the urgent development of autonomous learning technology that can accommodate a huge number of learners at low rates of tuition or fees and high-quality materials to guarantee effective learning outcomes. In this context new instructional technology should maintain the quality and best features of the conventional instruction, while incorporating the innovative features of mobile or ubiquitous learning.

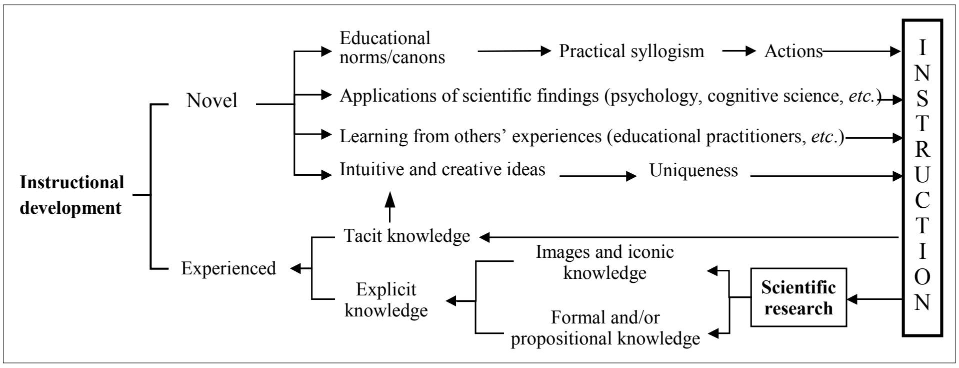
The theory and practice of introducing ICT in education is entirely different from those of ICT itself. While information and communication science has developed efficiently to accelerate the development of ICT, the present state of educational science and technology is not sufficiently developed enough to accommodate such new technologies as ubiquitous ICT in the educational settings rationally and effectively. Ubiquitous ICT can enhance autonomous learning in today's completely teacher-led classrooms as well as independent learning away from educational establishments.

The technological approach is often confused with the scientific approach owing to its objective and generalised features when considered by outsiders, but the approaches are entirely different from the insiders' perspective of implementing procedures to achieve final distinct goals. A scientific approach is adopted in order to clarify one's recognition and to result in new knowledge, while a technological approach emphasises the importance of subjective prescriptions and prospects, actions to realise them and resulting outcomes. In the latter approach, outcomes should be clarified before or during their adoption, described in visible or tangible form and described in statements of instructional objectives or learning objectives in conventional instructional technology. On the other hand, ubiquitous learning aims to realise a learning process and/or outcomes free from teachers' control and intervention.

Despite such characteristics, ubiquitous learning should be designed to achieve quality learning outcomes and a high level of learning. How can we describe such high-quality learning without alluding to instructional objectives? Figure 3 shows four different approaches to design instruction:

1. a traditional and teacher-led instruction approach based on educational norms/canons, or practical syllogistic derivation from educational norms to actions
2. the application of a scientific-findings approach based on psychology, cognitive science and other social sciences
3. learning from others' experiences by relying on colleagues and elders
4. an approach featuring intuitive and creative ideas based on our own experiences and tacit knowledge.

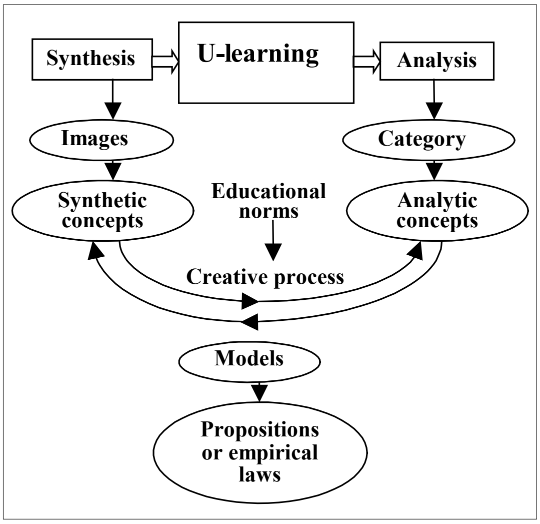
Figure 3 Empirical approaches for learning development



The major concern in this paper is to develop a research method for formulating explicit knowledge in the forms of figurative and/or iconic representations, as well as statements and/or propositions so that this accumulated experience will be easily communicable, systematically revisable and sharable with other experts. Even though four approaches are distinguished here, a comprehensive approach based on creative ideas and genuine procedures is always essential to design appropriate learning suitable to local requirements and personal needs. We must initiate new ideas or breakthroughs and develop them for instruction entirely suitable for a unique learning environment and content. Figure 4 shows two possible procedures, one of which derives from synthesis and the other from analysis, to extract concrete knowledge of models and propositions from analysing actual learning situations, mainly depending on an empirical approach rather than a science-application approach. In this procedure, we must observe the learning behaviour, record and analyse it and evaluate the design process to interpret the effectiveness of learning. Novice teachers prefer to start by making images and then refining them into figurative and/or iconic models. In this process, discussion and critiques are essential to improve their initial ideas and clarify feasible plans. On the other hand, experienced teachers are strongly advised to start by analysing their own teaching. They may be accustomed to teaching via unilateral lecturing and may find it difficult to transform their teaching style from being teacher-dominant to learner-centred instruction. The knowledge that emerges from analysis should relate closely to the synthetic aspects of instructional design or it will be useless. After several trials, however, these teachers will begin to express recognition about the lessons and describe their empirical laws in the form of statements and judgemental propositions, sometimes after having conducted lessons by themselves. The authors make a greater effort to develop instructional design technology sharable in expertise than to identify information technology applications in education, believing strongly in the potential for fruitful and creative outcomes from collaborative teamwork.

In this framework, a definite presumption is not a required prerequisite regarding instructional design in the initial stage. Instead, a back-and-forth process between synthesis and analysis focuses on learning during its implementation. It starts from intuitive ideas, proceeds to relying on empirical knowledge and repeats systematic revisions, from which ideas emerge, from our previous experiences and tacit knowledge.

Figure 4 Empirical research on u-learning



4 Cases of problem solving for instruction in large-sized classes

Before we come to the theoretical framework for implementing u-learning in higher education, we should introduce our trials at Bukkyo University, located in Kyoto, Japan. Present instructional technology starts designing instruction from the standpoint of instructional goals which reflect national policies and an emphasis on nationwide economic prosperity and success in science and technology. Teachers as well as student teachers tend to adhere to such goals without referring to students' individual needs and requirements. This approach raises complicated issues in our ever-changing and diversifying society. Current Japanese students and youngsters are often presumed to be less interested than previous generations in political and international affairs and unable to express their thoughts in logical and critical ways.

The conventional educational philosophy suggests that small-sized classes are preferable and face-to-face interactions are indispensable to maintaining quality education and human relationships between teachers and students. Despite such idealistic expectations, however, in practice universities are faced with offering large-sized classes in undergraduate courses owing to the huge demands for higher education and the high cost of expertise. The framework discussed here does not emerge from theoretical considerations, but from empirical trials repeated for practical implementation in one-semester classes twice a year for the last six years.

The experimental instruction started in 1999 for an undergraduate course entitled 'Introduction to Instructional Technology', which accommodated 228 students in a large classroom. According to our preliminary survey of their impressions of teaching, students complained about the one-sided lecture style, boring contents and passive learning nature of conventional instruction. After repeated improvements while teaching twice a year for six years, we have achieved far more satisfactory instruction with active participation for our growing number of students (enrolment numbered 276 for the Spring Semester 2005). At the beginning of the class, we conduct a survey on their self-perceptions of teaching and images of their school experiences and give questionnaires on communication types in order to divide them into small teams of five or six members in the second week. Then they start to play ice-breaking games to become familiar with each other. They proceed to teamwork sessions to create proposals about ideal schools and instructional plans to share with other teams during poster sessions. After the interim presentation session, they start working independently, but continue communicating with each other and collaborating to finalise their personal reports to be submitted at the end of the lesson. An aim of this course is to cultivate the collaborative competencies, communication skills and critical thinking needed to tackle complicated problems in contemporary education (see Figure 5).

Figure 5 Classroom scenes

(a) First week in a large classroom

(b)Second week of beginning team working

(c) Third week of moving out to library and other rooms

(d) Team working independen in a computer room

(e) Using mobile phone for confirming schedule

(f) Textbook in printed form and mobile phone

(g) Presentation of their first draft of a project

Cultivating critical thinking competence and promoting the right to learn among students is a common ground for designing autonomous learning, but it does not necessarily imply any specific method for instructional development. Today is the right time to explore learner-centred instruction for cultivating discussion competence among students and for promoting autonomous learning rather than passive attitudes in the classroom. There already exists extensive literature discussing instructional development, but it has not persuaded us to change our metaphors, mental models and frameworks, which are deeply embedded in the current instruction. One possible way to change such theoretical rigidity is to start from actual problematic situations and develop a persuasive framework for active learning among students even in large-scale classes. Designing is the creative process of imaging learning events and actualising them in reality. The instructional development procedure discussed in the following sections emerged from our successive attempts to make this process more flexible and easier to implement.

5 Knowledge for developing u-learning in large-sized classes

In the coming knowledge society, learners' intentions and autonomous learning capabilities will be key in enhancing the right to learn and to accommodating students' diverse needs. The development of learning technology suitable for autonomous learning at the secondary as well as higher education level is urgently needed to cope with students with diversified academic backgrounds and learning needs. In a web-based and computer-mediated learning project, most developmental trials start from the implementation of ICT, especially multimedia and broadband technologies in the conventional classroom situation. In this case, the designers' attention and interests tend to focus solely on technology, not on learning itself. If we approach universal education purely from a high-technology standpoint, it is almost impossible to overcome the ICT divides faced by economically deprived people. High-technology versus low-technology approaches are not a dichotomy, but two extremes which should be linked seamlessly for disseminating universal education. In this context, we should take into account the potential of ubiquitous, inexpensive information technology as an important means and take a first step from the standpoint of knowledge creation and problem solving to overcome technology divide issues. Adaptation of simple hardware is essential and appropriate for critically effective and inexpensive instruction. In the u-learning project, we started instruction mainly with printed materials and mobile phones and have tried to work out a premise for autonomous learning suitable to distance learning. Textbook-based instruction helps us focus our efforts critically on instructional design technology for students' active and creative involvement in learning. This approach also requires a well-thought-out strategy in order to develop appropriate instructional materials. At the same time, if we start from discussion and communication with peers and fellow instructors in institutions or at remote workplaces, we find that ubiquitous communication devices such as mobile phones, PDA and portable computers are also useful tools for enhancing knowledge creation and refinement inside and outside the classroom, even at students' distant homes. New trials often require entirely new, innovative solutions unfamiliar to our own and others' experiences. Even if we adopt ubiquitous facilities, instructional development should follow a systematic and scientific procedure to make the development more effective and acceptable to other experts in instructional development.

Collaborative teamwork is essential in ensuring fruitful and creative outcomes from u-learning. The Japanese educational system continues to feature harsh competition among candidates aiming to go from elementary- to secondary- to higher-education stages. Their learning heavily deviates towards exam preparation and forced competition with their peers. Collaborative teamwork is not fostered and difficult to realise yet, even at the university level. To overcome such a distorted and dissuasive attitude, five principles are emphasised in classes as an example of educational norms: autonomous learning, collaborative work, contributions to teamwork, responsibility to the team and respect for other people. Universal education rather than selective streaming and a smooth articulation between different stages of educational life are urgent issues to be tackled in our rigid schooling system. Ubiquitous ICT and collaborative work are expected to be very effective in solving these problems.

In the conventional procedure of designing instruction, we start with specifying instructional objectives and sequencing them, and then take into account other factors such as teaching materials, teaching environment and teaching tools. In this procedure, instructional objectives are usually derived from the national course of study, developed into a sequence of sub-objectives and actualised in the form of instructional materials. Instructional technologies come on the scene after the selection of instructional objectives and their sequential development. On the other hand, when we start with learners' needs and learning objectives, we cannot anticipate the instructional process and final learning outcomes at the very beginning of the course. We need to appropriate technologies that will allow us to analyse their needs, assess their relevance to instructional contents and develop a learning environment in parallel to evaluation related to educational goals. Saegusa (1964) suggested there are two interpretations regarding technology in education. One interpretation is that educational technology is a branch of educational expertise similar to educational philosophy, educational psychology, educational sociology and so on. Another interpretation is that it is a technological discipline, just like brewing technology, processing technology, medical technology, nursing technology and many other technologies. The latter interpretation gives us a broader view of technology in education. When we approach it from the perspective of learners' personal needs, the factors under consideration for instructional design are numerous and complex. Fortunately, ICT is a powerful tool for dealing with such complex problems and is now applied in almost all disciplines to solve complex problems systematically and to enhance their expertise. We can describe the complexity of learners with a relational database and plan a scheme for future perspectives adapting simulation technology. In this context, we can borrow ideas from other areas of technological expertise.

From the technological perspective, we can conceive four steps – metaphors, images, models and propositions – to create an entirely new instructional process for designing autonomous learning. Creative instructional design proceeds from ambiguous images to concrete procedures, to learning materials and to tangible outcomes. Teamwork requires a framework for creating sharable ideas and common outcomes from diversified participants. Common metaphors provide a framework for generating sharable images, allowing us to proceed to the more concrete process of developing learning activities. In developing the course 'Introduction to Instructional Technology' for a large class comprising more than two hundred students, we chose two metaphors as our framework and followed the MACETO model for instructional design and a set of propositions for learning development. The four-stage framework of transferring instructional knowledge and a logo representing five norms for effective team learning are still at the stage of hypothesis and are to be confirmed by further scientific research.

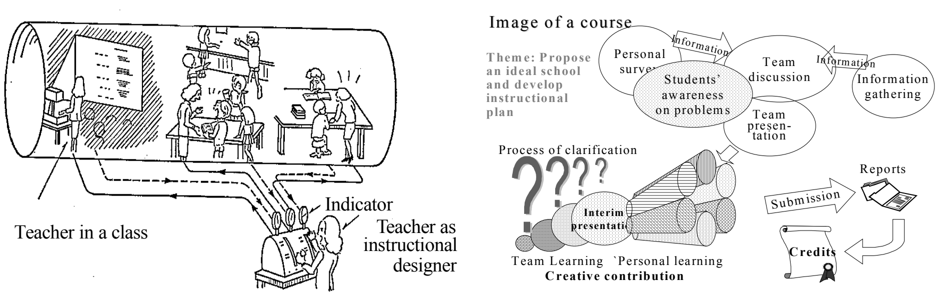
5.1 Metaphors: brewing technology and paragliding technology

Brewing technology depends on biological changes in fermentation and paragliding technology is based on natural laws of aerodynamics and meteorology. These metaphors suggest relatively passive intervention or facilitation in the changing learning process. Despite such passivity, very careful attention to the learning process and scientific knowledge are required to produce effective outcomes.

5.2 Images

Images emerge from the metaphors common to instructional designers. We develop many images as figurative elements for designing flexible instruction: we show only two of them here. Images make it easier to arrive at a consensus among instructional designers, material producers and teachers. The first author adopted this approach in the late 1970s (Nishinosono *et al.*, 1978) and has further developed it since then to clarify internal structures using figurative representation (see Figure 6).

Figure 6 Two images showing gradual transformation of instructional modes

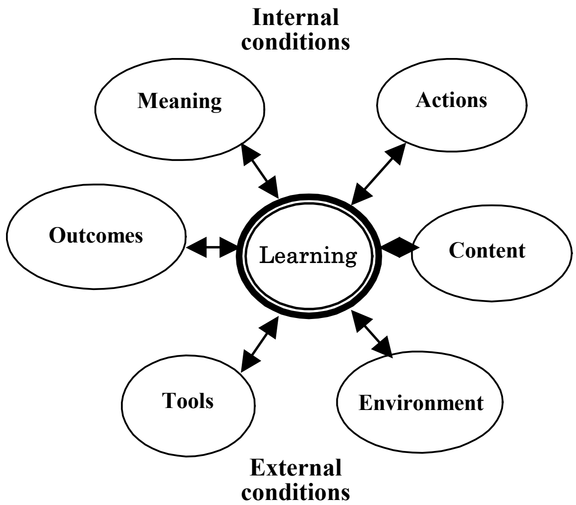


(a) Teacher controlling her actions (Nishinosono, 1981) (b) Designing autonomous learning (Nishinosono, 2002)

5.3 Models

Models represent more tangible relevant aspects of instruction. The most important model for this instructional design is the MACETO model, which represents meaning (M), actions/activities (A), contents (C), environment (E), tools (T) and outcomes (O). This model consists of two parts: internal conditions and external conditions. Instructional design starts from arranging internal conditions to enabling students to learn autonomously. The meaning of learning is of high priority and provides us with an orientation to learning activities as a whole (see Figure 7).

Figure 7 MACETO model for instructional design



Hypothesis *If we succeed in arranging learners' internal conditions meaningfully, they can overcome externally difficult conditions and work hard autonomously.*

5.4 Propositions

Instructional design heavily depends on empirical and tacit knowledge and know-how that is difficult to transmit to other instructors through media. To overcome this difficulty, we must train instructors to express their experience in the form of models and propositions. Only five propositions out of the 65 that emerged from one lesson are listed in Table 2 as examples.

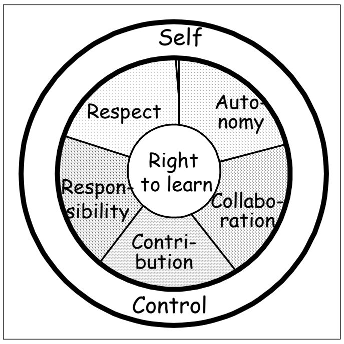
Table 2 Examples of instructional propositions

Transformation from image to key concept, graphic presentation and modelling is indispensable but hard for student teachers to achieve. Modelling is much more difficult than the previous step.
Realisation of autonomous learning requires cultivating students' heightened attitude towards learning. To cultivate such an attitude, it is effective to require that students complete a framework sheet (MACETO format) each time before they can organise learning by themselves.
Alternative strategies of degrees of freedom in learning: 1 When we increase the degree of freedom in learning and give more initiative to students, learning results in a wide range, from excellent to poor, in quality and quantity. 2 When we decrease the degree of freedom in learning and give less initiative to students, learning results in a reliable but mediocre outcome of both less excellent and less poor quality.
To manage a large group of students who learn autonomously, it is effective to form groups and clusters of groups, encourage active participation and let them recognise their responsibility towards autonomous learning.
To make learning meaningful, it is effective to start the lesson from one's earlier experiences relevant to instructional contents.

5.5 Logo and norms

Norms are indispensable for maintaining effective and collaborative teamwork. A logo is suggested to team members, who are requested to discuss their own choice or addition of new norms for creating their team identity symbol. The original figure and norms are shown in Figure 8. Five norms are suggested to participants as an example for further discussion: autonomy, collaboration, contribution, responsibility and respect.

Figure 8 Norms for teamwork



In the conventional procedure of instructional design, we start with identifying educational goals, then specify instructional objectives, develop a teaching process, implement instruction and evaluate outcomes. On the other hand, in the case of starting with identifying learners' needs and motivations, we immediately confront complex problems, so we must proceed to clarifying the meaning of learning, assessing learning outcomes, encouraging learning activities, specifying instructional contents and arranging the learning environment. In this circumstance, teachers are expected to develop their professional expertise, deepen their experience and communicate with colleagues and professionals on the web, even at a distance, in order to enrich their professional competencies. We need to explore a new means of communication to promote effective sharing of their experiences.

Hypothesis *Our experiences with instruction are accumulated tacitly as well as explicitly, of which explicit knowledge can be described in a set of iconic and/or figurative representations and formal propositions to be easily communicated among instructional professionals for enhancing the Right to Learn.*

Effective sharing of experiences in practical instruction requires a common framework to conduct research and report the result and other expertise. Figure 3 shows four possible approaches to designing novel instruction: practical syllogistic derivation from educational norms to actions, application of scientific findings, learning from others' experiences, and intuitive and creative ideas enhanced by tacit knowledge accumulated from our previous experience. We start to generate intuitive and creative ideas by referring to the tacit knowledge emerging from our past experience. The concern in this paper is to develop a framework of instructional design for a research method for formulating explicit knowledge in the forms of figurative and iconic representations, as well as formal statements and propositions (see Table 1).

Table 1 Types of knowledge for developing u-learning*

		Explicit knowledge		
	Tacit knowledge	*Figurative and iconic knowledge*	*Formal knowledge*	*Characteristics of approaches*
Scientific approach (recognition oriented)	intuition, cognition, images	figurative models, figures and tables, symbols, pictures	numerical formulae, recognition statements, explanatory propositions	universal, reliable, deductive, analytic, systematic
Technological approach (action oriented)	hunch, intuition, empirical laws, proficiency, senses	images, models, figures, tables, symbols, pictures	empirical statements, judgemental propositions	individual, unique, physical, inductive, synthetic
Characteristics of knowledge	difficult to express in language; empirical intuitive; subjective personal; emotional and analogical; knowledge at the workplace; specific to locality, objects, person and time; sharable by collaborative work requiring specific experiences; possible to propagate and develop	expressible in figures, symbols, pictures and behaviours; intersubjective; unique; digitised knowledge transferable through network; reusable, sharable and editable	linguistic knowledge; systematised knowledge; knowledge about the past lexicographical structure for understanding methods, procedures and objects; objective, societal, organisational, rational, theoretical, digitised and encoded knowledge transferable through networks; reusable, sharable and editable	

Note: *This table was developed by Nishinosono following the original table by Nonaka and Konno (2003).

6 Conclusions

Considering the diversified backgrounds of learners, team learning is adopted to accommodate such diversity and to allow all those involved in teamwork to display their different talents and capabilities for collaboration. This kind of instruction requires highly developed technology to design complex learning situations. In the process of developing educational courses, there are four possible approaches for applying a rational procedure for instructional development: practical syllogistic derivation from educational norms to actions, application of scientific findings, learning from others' experiences and refinement of intuitive and creative ideas. Actual instruction is too complex to manage from a single concept. It is impossible to cover the whole process according to only one specific scientific approach. Learning from other designers and practitioners is always very fruitful. At the same time, we often face many entirely unfamiliar situations, but nevertheless have to conduct instruction. We cannot wait for knowledge to emerge from scientific associations or for information from others' experiences. In many cases in daily teaching, we start from our intuitive ideas and confirm their validity empirically.

The authors started from intuitive and creative ideas, referring to tacit knowledge that is hard to express verbally but certainly embedded in our own experience and the adopted concept of 'education as technology', and we developed a framework of 'metaphor, image, model and proposition'. In the beginning we may express these ideas in the form of metaphor and iconic representations more easily than in strictly logical statements. It was confirmed in the instructional course that young students were quite familiar with expressing their ideas in non-linguistic ways and started expressing their original ideas, discussing the issues and refining them towards final concrete outcomes or products of instructional materials, models representing the instructional situation, and logical statements and propositions convenient to revise later or to communicate with their peers in written form. In this process, continuing communication and critiques among students through the web were indispensable in encouraging their active involvement. The authors collected their experiences from the abovementioned courses in the form of statements, judgemental propositions or empirical laws.

Education has become too difficult to tackle by teachers working alone. They need to help each other, obtain public support and communicate personally with students, colleagues and the local community. ICTs, including ubiquitous equipment, are very powerful tools for facilitating mutual communication and, in this sense, for contributing to a truly universal education. Nevertheless, it requires us to become more imaginative and creative and to develop scientific procedures in pursuit of a rationale for instructional development in our professional discipline. Thanks to recent technological developments in qualitative and quantitative analysis, we can easily investigate the validity and relevance of empirical knowledge during real classroom instruction. For this purpose, we need to develop a scientific procedure to clarify our experiences and refine them to be able to communicate with each other through international networking.

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