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Forms of Research within Strategies for Implementing Undergraduate Research

Abstract

University initiatives for implementing undergraduate research (UR) often falter or become diluted when crossing disciplinary borders that define the internal organization of university institutes and departments. The core defensive argument presented by the disciplines is that of differing research approaches, such that the experience of implementing UR within one discipline is not necessarily transferable to others. This paper introduces a typology of forms of research, which can cross disciplines and support a case for – and inter-departmental cooperation towards – implementing UR. Evidence is provided from universities funded by the German teaching reform initiative (Qualitätspakt Lehre).

Keywords

Forms of Research, Undergraduate Research, Interdisciplinarity, Higher Education, Qualitätspakt Lehre

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1 Introduction: existing strategies

Implementing undergraduate research (UR) in the curricula has been a strategic measure among higher education institutions (HEI) in Germany, the UK, Netherlands, and other European countries in recent years. Experience from the USA shows that UR is associated with reduced dropout rates (e.g. GREGERMAN et al., 1998), and greater interest in studying STEM subjects (science, technology, engineering and mathematics, e.g. RUSSELL et al., 2007). Furthermore, UR seems to support diversity in HEI (e.g. HERNANDEZ et al., 2018). The most important expected external effect, from an EU perspective, can be to foster innovation (EUROPEAN COMMISSION, 2017).

Attempts to implement UR often falter or lose momentum when involving different disciplines, the main argument being that conditions for research differ radically between disciplines. Such an argument has face value but renders disciplines into "black boxes" for university boards. The goal of this paper is to present a means of differentiating between disciplines and forms of research. Forms of research represent alternate ways of producing knowledge. They cross disciplinary boundaries and thus help define more transferable strategies for implementing UR.

1.1 Scientific disciplines

The scientific system has expanded dramatically since the 19th century. As an obvious effect we see a divide between the sciences and humanities. Equally important, but not the focus of discussion, has been the rise of the technical disciplines such as engineering or architecture. The 20th century started with attempts to define the core of scientific knowledge, resulting in works such as POPPER's "Logik der Forschung" (The Logic of Scientific Discovery, 1934). Despite the following pragmatic turn, e.g. by KUHN (1962) who revealed the role of competing scientific paradigms, the idea was to find an explanation of how knowledge functions in the scientific system as a whole, a process resulting in the structuralist view of science (e.g. STEGMÜLLER & WOHLHUETER, 1976).

Disciplines have long formed the core organizational units of science (cf. MIEG & EVETTS, 2018): they define the methodologies, organize peer review, trigger budgets, and channel the careers and self-definitions of scholars. In HEI, scientific disciplines are organized as departments or institutes that define study programs and curricula. With regard to the variety and power of disciplines, two strategies for implementing UR have evolved: a differentiated strategy, and a holistic change.

(A) *Differentiated UR strategy*: This strategy respects differences between disciplines, and operates on the assumption that research is to be viewed within the disciplinary system. This strategy sometimes refers to the conceptual paper by NEUMANN et al. (2002), itself based on studies by BIGLAN (1973a, 1973b) who empirically defined a dimensional structure of scientific disciplines (e.g. hard vs. soft paradigms). This strategy risks reinforcing existing power structures.

(B) *Holistic change UR strategy*: In the 1990s, with the rise of global environmental concerns, a new paradigm of scientific research emerged: mode 2, transdisciplinarity, or coproduction of knowledge, demanding scholars cooperate with citizens and take a future-oriented approach (cf. SCHOLZ, 2013). In this context, some universities, e.g. Leuphana, entirely reorganized themselves (LANG & WIEK, 2013), one secondary effect being the introduction of UR. Other institutions, such as Bremen University, implemented UR in all disciplines in keeping with their profile as a reformist university (cf. KAUFMANN & SCHELHOWE, 2019).

1.2 Research in a system of changing scientific coordinates

If we wish to foster innovation in HEI through UR, as proposed by the EU, we need adequate provision of UR for interested parties (students, faculty), not simply blanket implementation. Innovation is a phenomenon difficult to predict, and requires some supporting conditions, but not everyone is personally able or willing to be innovative. Thus, it may suffice to offer UR in all disciplines as an option for interested students. In this context, the differentiated UR strategy (A) does not seem helpful for two reasons:

(1) It represents an over-generalization on the basis of empirical differences between disciplines of institutionalized science. With reference to NEUMANN et al. (2002), it is often argued that UR is less suitable in hard or pure sciences. However, even if almost all scholars in physics (a hard science) consider UR unfeasible in their discipline, there might be one university teacher who nevertheless supports UR in physics.[2]

(2) It represents a view of the scientific system that is necessarily outdated. There is constant change in that system. The views of BIGLAN (1973a, 1973b) and NEUMANN et al. (2002) are based on conditions prior to the rise of environmental system sciences. Given such radical developments, we might be unable to even imagine future innovations within the scientific system.

Sciences (natural, social, human, life sciences, etc.) are the longtime epistemic project of our societies. If we concede that beyond the science/humanities divide and all disciplinary differences, there is one shared goal – to increase our knowledge – then we should adapt UR strategies more specifically geared to the creation of scientific knowledge, i.e. research. Fortunately, there is a growing body of literature concerning student research. We now have a clearer understanding of the process of research involved (e.g. FISCHER et al., 2014). Furthermore, we see that investigation is only one (although central) of several phases of the research process (PEDASTE et al., 2015).

[2] In practice, UR in physics and chemistry (both hard sciences) plays an important role in the national UR student conferences in the US (cf. www.cur.org).

	Collecting Data	Experi-ment	Hermeneu-tics	Building Concepts & Theories	Structuring Profes-sional Practice	Simulation	Developing Machines	Design
Methods; facilities (examples)	Interviews	Labs	Document analysis	New definitions	Good practice guide	Computer program	Machine prototype	Conceptual design
Research operation	To observe	To observe	To judge	To judge	To model	To model	To construct	To construct
Formaliza-tion		Controlled observation		Towards a consistent system		Program-ming		Meeting esthetic principles
Form of knowledge (Aristotle)	*Episteme*	*Episteme / techne*	*Nous / episteme*	*Sophia / episteme*	*Phronesis / techne*	*Techne*	*Techne*	*Techne / nous*
Typical uses / disciplines	Almost all disciplines	Physics, chemistry, psychology	Theology, cultural an-thropology, sociology	Mathemat-ics, philosophy, almost all disciplines	Manage-ment studies, social work	Macro economics, climate change research	Engineering, biotechnol-ogy	Architecture, the arts
Relevance to UR	Easy start	Elaborate setting	Difficult (?) start	Difficult start	Conditioned start	Easy start	Elaborate setting	Conditioned start

Fig. 1: A typology of research forms (cf. MIEG & DINTER 2017; MIEG in press; WISSENSCHAFTSRAT 2012). Conditioned start: there might be requirements (specific access to the field, talent, professional experience, tools…)

2 A typology for forms of research

MIEG & & DINTER (2017) introduced into the UR discussion a typology of forms of research, which focuses on knowledge creation as the core step within research. The typology is based on a scientific reclassification by the German Council of Science and Humanities (WISSENSCHAFTSRAT, 2012). Figure 1 provides an overview of the revised typology. Following an idea by REINMANN (2018) it includes a reference to basic research operations. In addition, the typology is aligned with considerations about forms of knowledge, leading back to ARISTOTLE (1994/2009) who defined different forms of knowledge.

2.1 Principle research operations

Research – as knowledge creation – consists of one of the following basic operations (which I introduce from a history of science perspective):

(1) To observe: from observing nature (in astronomy and biology) to participatory observation (in ethnomethodology) and the structured collection of big data;
(2) To judge: from the exegesis and interpretation of texts and other symbolic representations to formal theorizing;
(3) To model: from the description of best practice (fundamental in medicine and engineering since their inception) to modern, often computerized, modeling (climate change research or macroeconomics);
(4) To create: from basic engineering to creating in the arts.

In other words: The core of our investigation might be to observe phenomena (e.g. by collecting environmental data), or to judge something (e.g. by interpreting a historical text), to model changes (e.g. by computer-modeling the dynamics of air or water in a turbine), or to create a machine (e.g. a computer working with light rather than electronic chips).

The differentiation of principle research operations helps to define distinct forms of research. In addition, the presentation of the typology in Figure 1 starts with examples of methods (e.g. interviews) and facilities (e.g. labs), to provide a first impression of the differences among the forms of research. It should be noted that:

(a) The typology – in particular the distinction between principle research operations – is pragmatic with regard to the objective of finding forms of research that might explain differences in the research/teaching nexus across disciplines.
(b) The presentation of each form of research attempts to capture a basic understanding within the scientific system, being aware of the varieties of interpretations of a research form that might exist in different disciplines. For instance, I use a narrow notion of "experiment" that reflects its development in physics since the time of Francis Bacon (cf. SAGASTI, 2000).
(c) The paper by WISSENSCHAFTSRAT (2012), from which the typology in Figure 1 is derived, discussed options for the future of scientific data management and, to that end, defined forms of research. One innovation of that article was to understand theorizing (i.e. the building of concepts and theories) as its own form of research. MIEG & DINTER (2017) transferred the proposed classification, expanded, and systematized it.

Figure 1 introduces pairs of research forms for each principle research operation; in each pair the second form represents a more formalized version (cf. MIEG et al., 2013); in detail:

(1) <u>Principle research operation: to observe. Pair of research forms: Collecting data; Experimentation</u>. Collecting data represents a general way of conducting and documenting observation, and has always been common in astronomy, zoology, and botany. The experiment represents a *formalized* observation: effects are studied under defined and controlled conditions in order to detect regularities that allow for explanation (cf. VON WRIGHT, 1971).
(2) <u>Principle research operation: to judge. Pair of research forms: Hermeneutics; Building concepts and theories</u>. The origin of hermeneutics is the interpretation of texts, e.g. of the bible or legal texts. In a broader sense,

hermeneutics refers to the understanding and interpretation of socio-cultural contexts. Beyond this, the building of concepts and theories strives for a consistent system of propositions (cf. e.g. BUNGE, 1967).

(3) Principle research operation: to model. Pair of research forms: Structuring professional practice; Simulation. The structuring of professional practice refers to models of professional practice as it is or should be (e.g. guidelines on dealing with a vulnerable homeless person in a social care context). This form of research is common in all disciplines that have a professional branch (e.g. medical therapies). Simulation represents a more formalized version of modeling, as it presupposes programmability. Any simulation, no matter how complex it might appear, is a reduced view of the world (cf. e.g. MIEG, 1993).

(4) Principle research operation: to create. Pair of research forms: Developing machines; Design. Developing machines refers to functional creation with regard to a problem to be solved or a function to be executed (e.g. in engineering). In contrast, design is creation with regard to esthetic-functional principles (e.g. in architecture, cf. ALEXANDER, 1964).

2.2 Forms of knowledge

Research (investigate, inquire, test, probe, examine…) makes use of the entire variety of knowledge. Aristotle already distinguished between science in a narrow sense (providing theories) versus the multiple forms and ways of knowledge (or cognition) which are effective even in practical work. ARISTOTLE proposed five forms of theoretical and practical knowledge, “states by virtue of which the soul possesses truth by way of affirmation or denial” (Nicomachean Ethics VI, 3; see ARISTOTLE, 1994/2009). I introduce these forms of knowledge with reference to the typology of forms of research:[3]

[3] For our context of UR implementation in HEI, I changed the order of the forms of knowledge and re-interpreted them. In my opinion, this remains closer to Aristotle’s con-

1) *episteme* (scientific knowledge): Genuine scientific research is based on empirical observation (form of research: Collecting data).
2) *sophia* (philosophical wisdom): The highest form of knowledge, in a narrow sense, is theory (Building concepts & theory).
3) *techne* (art): To make something work is also knowledge; it is cognition of functional relations (e.g. Developing machines).
4) *phronesis* (practical wisdom): To define options for how to proceed in value-laden settings – such as in politics or in the workplace – is a specific form of knowledge (Developing professional practice).
5) *nous* (intuitive reason): This refers to understanding as a specific form of knowledge (cf. VON WRIGHT, 1971), such as in hermeneutics.

Forms of research and forms of knowledge do not directly correlate. The first four forms of research in Figure 1 could, in a broad sense, also be classified as scientific knowledge (*episteme*); in the case of experimentation, art also comes into play (*techne*). The last four forms of research all involve art (*techne*) in some sense. Therefore, we could distinguish between a realm of *episteme* (ranging from Collecting data to Building concepts & theories) and a realm of *techne* (ranging from Structuring professional practice to Design). In today's sciences, e.g. in biotechnology, the two realms often overlap.

3 Forms of research in undergraduate research: first evidence

What roles do the forms of research play in academic teaching and learning? Are all forms equally applicable for undergraduate research? The Qualitätspakt Lehre, a German federal program to improve teaching at institutions of higher education in Germany (see www.qualitaetspakt-lehre.de), also provided support for fostering

cept of science than, for instance, FLYVBJERG (2001) who characterizes social sciences as phronesis.

undergraduate research. As part of a national research project, we studied the implementation of inquiry-based learning, e.g. for UR purposes. The project involved constructing a network of academics from about 50 German universities. This network published a series of books on multidisciplinary experiences in inquiry-based learning, particularly in undergraduate research. MIEG (in press) reassessed the contributions of three of these books (KAUFMANN et al., 2018; LEHMANN & MIEG, 2018; MIEG & LEHMANN, 2017) with regard to the practical value of various forms of research for undergraduate research.

The last row of Figure 1 shows the assessment by MIEG (in press) based on more than 60 contributions (single book chapters), with case descriptions from more than 30 disciplines ranging from architecture to theology. The main findings are:

(1) Two forms of research are suitable for an easy introduction to undergraduate research: data collection and simulation. Collecting data, for instance by interviews, can be taught and conducted at several levels of complexity and with different degrees of preparation. Interviews are even used for UR in disciplines such as theology, which require intensive training for their core methodologies (e.g. exegesis).[4] In a similar way, computer simulations become ever less demanding for students and can be used in disciplines where UR appears difficult due to theoretical or practical reasons (e.g. mathematics, archeology).

(2) One form of research seems to be very difficult at the undergraduate level: Building concepts & theory. Therefore, the seminal work on inquiry-based learning in higher education in Germany (BAK, 1970), which dates back to 1970, proposed that, within conceptually complex disciplinary fields such as legal studies or sociology, students should only be permitted to work on

[4] One example of many: The Catholic University of Applied Sciences Freiburg issued a revised study guide for the bachelor program in theology, which now includes UR, explicitly mentioning interview techniques: https://www.kh-freiburg.de/kh-freiburg/pdf-de/studium/studiengaenge/bachelor/modulhandbuch_ba_angewandte-theologie_2018_01_24.pdf (winter term 2018/19, retrieved October 23, 2018)

suitable subsystems. The proposed restriction still holds today. In a similar way, hermeneutics does not provide an easy entry into research. Consequently, within the academic network mentioned above, a case book with a specific focus on hermeneutics was published (KAUFMANN et al., 2018), in addition to the more general practical and conceptual volumes on UR.

(3) Even in engineering, we find universities providing for UR (e.g. TU Dortmund, cf. JUNGMANN, 2019). The 1970 publication on inquiry-based learning (BAK 1970) forecasted that undergraduate research would not be possible in disciplines where a multi-layered academic education with inputs from basic sciences such mathematics and physics is indispensable. As MIEG & DINTER (2017) noted: in recent years, a paradigm shift occurred in engineering education, towards the idea: just let the students decide for themselves whether to initiate a project as an early entry to research. UR in engineering turned out to be more a question of organization and mentoring than a fundamental problem within a complex subject.

However, there are also some caveats.

1) Does any project-based study qualify as research? In several disciplines such as product- or communication design, it is quite common to organize the study program as a series of projects. Scholars and students in those fields sometimes consider that conducting a project is per se research. HEIDMANN et al. (2011) demand that, to become a *research* project, the design project should be organized as a research process.
2) Basic skills: For two forms of research, namely Structuring professional practice and Design, it is helpful and sometimes necessary to bring in sufficient skills or professional experience (e.g. in social work) in order to be able to conduct and really learn from research. These forms of research cannot so easily be carried out by all disciplines.

4 Conclusion: new strategies

The underlying idea of the proposed typology of forms of research is to define research independent of – or across – disciplines. Different disciplines may share some of the same forms of research. Furthermore, any scientific discipline may employ multiple forms of research. Hence, a HEI strategy for implementing UR must offer disciplines ways of probing UR through forms of research that might not be addressed by that discipline's methodological canon: such as interviews in theology, or computer simulation in mathematics.

If we view UR in the context of fostering innovation in Europe, such a nudging strategy (cf. TAYLOR & SUNSTEIN, 2008) might be more appropriate than the differentiated strategy, which risks ruling out UR for some disciplines. The nudging strategy might also be more appropriate than a holistic strategy for university transformation. Europe has many very old universities, some of which (depending on the national context) are very large, serving more than 50,000 students. In Europe, these could equate to medium-sized towns. In such organizations, it can take a decade or more to diffuse and implement an innovative strategy. University boards might fear that, by the time innovation is implemented throughout the institution, the chosen "holistic strategy" could already be outdated. In contrast to a holistic strategy, the proposed nudging strategy aims to find a point – (course, teacher…) at which to initiate UR within a discipline – that might ultimately become part of an encompassing implementation strategy such as the connected curriculum (FUNG, 2017).

Among the innovative features of the proposed typology are, firstly, the understanding of building concepts & theories as a specific form of research (already proposed in WISSENSCHAFTSRAT, 2012) and, secondly, to introduce the structuring of professional practice as a research form of its own. Building concepts & theories requires sufficient academic training, as it is a strength of research universities. Here, for instance, master's and doctoral students can supervise UR, with the supervising students being concerned, for instance, with conceptual research, and bachelor students with aligned empirical studies. Structuring professional practice is a strength of universities of applied sciences, and allows for a practice-based research/teaching nexus. Hence we see: The ways in which we may choose to effectively implement UR are influenced not only by the differences in how students and disciplines can approach forms of research, but also the ways in which HEIs understand research.

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