Pedagogical competence for engineering educators:

Re-conceptualizing teaching portfolios

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***Abstract*— The demand for engineering graduates is increasing globally. National governments understand the importance of the sector for economic growth, while students are becoming more aware of the greater life opportunities open to them as a result of an engineering education. The role of effective teaching in the attainment of student outcomes is increasingly recognized and many engineering departments require faculty to meet standards of pedagogical competence. Our aim in this research was to investigate the role of teaching portfolios in the enhancement of engineering educators' pedagogical competence, in particular engineering faculty's changing understanding of key aspects of pedagogical competence over the process of developing teaching portfolios. We found several shifts in participants' understandings and attitudes over a short course intended to support engineering academics in the construction of teaching portfolios for the purposes of tenure, promotion or awards. For example, participants shifted from describing or 'showcasing' their teaching and learning achievements towards a greater appreciation of the role of reflective practice, and from a focus on course content and 'coverage' towards an understanding of concept-building, sequencing and curricular coherence. This paper argues that a short course in the development of teaching portfolios for the purposes of tenure, promotion or teaching awards can contribute to the development of pedagogical competence amongst engineering faculty, but that considerable attention should be given to the complex issue of reflection on practice and that trustworthy assessment of teaching portfolios requires clear criteria for pedagogical competence at different levels of practice.**

Keywords—teaching portfolios; engineering education; pedagogical competence

I. INTRODUCTION

This research arises from the globally recognized need to improve the success of undergraduate engineering students in a context in which the demand for engineering graduates is increasing. While most engineering faculty have learned successfully in a traditional format, they are the exception, not the norm. University teachers globally are increasingly required to meet standards of pedagogical competence, with regard to accurate and up-to-date knowledge within their subject area, as well as knowledge of subject-based teaching and student learning, including online or blended learning modalities. Pedagogical competence presupposes a reflective and critical approach to teaching, engaging in professional learning and increasing pedagogical expertise over time, drawing on pedagogical research in the subject area – and is thus strongly tied to an academic's professional role and identity. The aim of this study is the enhancement of engineering faculty's pedagogical competence through portfolio-building, with the specific research aim of determining how engineering educators' pedagogical competence might develop over a short course in the building of teaching portfolios for purposes of achieving tenure, promotion or teaching excellence awards.

II. A BRIEF OVERVIEW OF THE LITERATURE ON PEDAGOGICAL COMPETENCE

There is general consensus in the international literature that undergraduate engineering programs pose significant challenges to students and that many are marred by high attrition rates, poor student success, and a notable lack of diversity [1]. Students' difficulties when encountering engineering knowledge is well documented in the research literature. In the South African higher education sector, there is concern about the poor retention and throughput rates of undergraduate engineering students; there is also concern that the participation rates in higher education, relative to population demographics, remain racially skewed [2].

There is growing recognition in the research literature that student success in engineering programs is strongly supported when the academics who teach on them are pedagogically competent [3]. Prior research [4] has built a knowledge base of effective undergraduate education pedagogies – such as student engagement in learning [5], the use of authentic real-world environments and examples [6], making engineering discourses more 'visible', particularly with regard to assessment practices [7], the adoption of socially inclusive pedagogies [8], and the 'mainstreaming' of student support mechanisms, such as academic and technical literacies [9]. The effectiveness of these pedagogies for undergraduate engineering student success has been verified through systematic reviews of the research literature.

Significant resources have been invested in engineering education world-wide in an effort to improve the number, quality and diversity of graduates, but these investments have not resulted in widespread adoption or systemic transformation [3]. The lack of uptake of professional learning opportunities amongst academics has been attributed to the need to improve the alignment between engineers' researcher and teacher identities [10], to engineering academics' difficulties with

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educational research and theory [11], and to a serious underestimation of the kind of cultural, institutional and policy change and support is required to change entrenched teaching and learning practices [10]. The teaching portfolio has emerged as an effective approach towards systematic and scholarly teaching by drawing on engineering teachers' reflections on, analyses of and responses to their students' learning. Professional learning toward the development of a teaching portfolio can address a range of issues, from effective classroom teaching, exploring disciplinary modes of inquiry and reflection, enhancing professional and industry connections, linking with wider teaching communities, and making connections with other institutions and groups [12]. Research done in Sweden [13] suggests that teaching portfolios tell 'stories' of teaching that draw on the resources of educational research, and have the potential to carry learning across contextual boundaries and be assessable by colleagues.

III. A Methodology to Identify Pedagogical Competence

The research design for this study comprised interviews with engineering faculty from four different universities, all of whom participated in a short course on teaching portfolio development. The Cape Higher Education Consortium, a body that coordinates the work of the four Western Cape-based universities in South Africa, offered a regional short course to engineering educators from different institutions on the development of teaching portfolios for purposes of tenure, promotion, or teaching awards. The participants came from very different engineering and institutional contexts (e.g., research-intensive, teaching-intensive) and were teaching different student groups, some of whom were well-prepared for their programs of study, and others less prepared for university education. The diversity of the contexts in which the study occurred supports the transferability of the research findings across contexts, while the adaption and implementation of an international model of pedagogical competence contributes to the study's generalizability.

Thirty participants initially enrolled for the course, with 20 attending regularly and completing (or completing a first draft of) their teaching portfolios. Participants were self-selected, that is, they elected to attend the portfolio building short course, although their applications had to be approved by their heads of department. Table 1 shows the participants, their engineering fields and their reasons for attending the course. The course took place over four weeks and comprised four full day face-to-face workshops as well as online support, including formative feedback on the developing portfolios, between workshops.

All participants were required to develop eportfolios, and could choose their own online tools with which to create their eportfolios. This variety was allowed because it was felt that the introduction of a new tool or platform might distract from the content of the portfolio. In addition the different institutions had different tenure, promotion and award processes (some of which required an uploaded pdf file and others that used a dedicated eportfolio platform). The facilitators wanted the task of building a teaching portfolio to be as authentic as possible.

A. Data collection

The participants were interviewed during the construction of their portfolios and after their completion, with a view to establishing their changing understandings of pedagogical competence over the portfolio-building short course. The interviews were conducted by an independent consultant (a retired academic with experience in portfolio development and assessment). The participants were interviewed on their portfolios-in-progress using a 'fish bowl' discussion after each of the four full-day workshops. The 'fish bowl' interviews are referred to as 'formative interviews' (FI). These interviews were audio-recorded and transcribed. The course took place over a four week period, during which time a number of tasks were undertaken leading to the completion (or semi-completion) of the teaching portfolios. These tasks including explaining the educational context, writing a 'teaching philosophy statement' that linked that to evidence of the practices described, eliciting and addressing student feedback, and reflecting on the portfolio and the practices described.

TABLE I. Participants, Fields and Reasons for Attendance

Participant	*Engineering Field*	*Reasons for attending the portfolio short course*
1	Biomedical	Teaching award
2	Biomedical	*Ad hominem* promotion (senior lecturer)
3	Chemical	Teaching award
4	Chemical	Tenure
5	Chemical	Tenure
6	Civil	*Ad hominem* promotion (senior lecturer)
7	Computer	*Ad hominem* promotion (senior lecturer)
8	Computer	*Ad hominem* promotion (associate professor)
9	Electrical	*Ad hominem* promotion (associate professor)
10	Electrical	*Ad hominem* promotion (full professor)
11	Electrical	*Ad hominem* promotion (senior lecturer)
12	Environmental	Teaching award
13	Food Technology	Teaching award
14	Mechanical	Ad hominem promotion (senior lecturer)
15	Information Systems	*Ad hominem* promotion (senior lecturer)
16	Information Systems	*Ad hominem* promotion (senior lecturer)
17	Information Systems	Teaching award
18	Information Systems	Ad hominem promotion (senior lecturer)
19	Statistics	*Ad hominem* promotion (associate professor)
20	Transport Systems	*Ad hominem* promotion (associate professor)

The portfolios were assessed online approximately 3 weeks after the final workshop; each participant received feedback from at least two facilitators. Summative interviews (SI) were conducted individually with the candidates in their offices after the facilitators had assessed the teaching portfolios and participants had received their feedback (but before they were submitted to their universities or other bodies for consideration

for tenure, promotion or teaching excellence awards). All interviews were audio-recorded, transcribed and checked before being given to the authors for analysis.

B. Data analysis

The researchers thematically analyzed the interviews, drawing on the categories of a model of pedagogical competence developed for engineering faculty in Sweden [13]. Figure 1 shows the categories and their relationships. The model explains that promoting and assessing student learning and acquiring a repertoire of teaching practice is underpinned by an understanding of educational theory, by reflection on practice and by classroom-based research. These categories are further explained in the Findings. The literature on pedagogical competence and how this might be developed suggests that teaching portfolios and the processes of teaching portfolio development is a powerful way of enhancing pedagogical competence, particularly in engineering fields [13, 3]. The researchers had access to the portfolios in progress and after completion. In this paper we focus on the interviews about the portfolios, rather than on the achievements of the portfolios themselves.

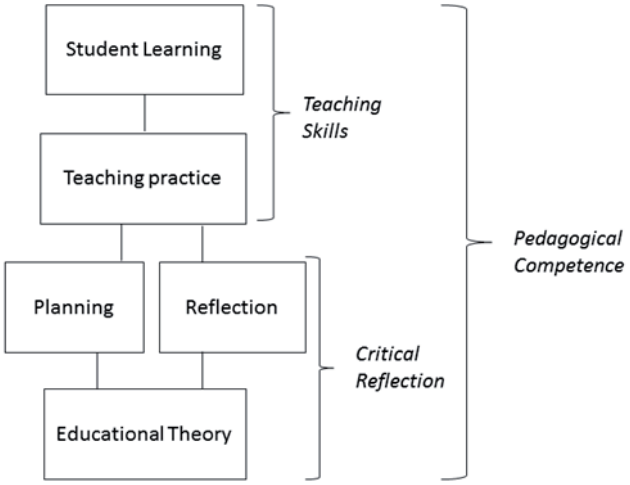

Fig. 1 Model of pedagogical competence adapted from [14]

IV. Findings: Shifts in Pedagogical Competence

The findings are presented in accordance with the categories of pedagogical competence that we adapted from Olsson and Roxå's [13] model, namely: student learning and teaching practice (which comprise 'teaching skills', and planning, reflection on practice, and educational theory (which comprise 'critical reflection). In the interviews these issues were not considered independently but are presented separately for the purposes of analysis.

A. Teaching practice

The first section of the pedagogical competence model, the tip of the iceberg, comprises teaching methods. Engineering faculty who attended the short course were keen to 'showcase' their achievements with regard to innovative methods, and to describe them in their teaching eportfolios. As the portfolio course developed however, they probed more deeply into their own teaching practice and became aware of underpinning issues, such as the difficulty of attaining student outcomes without departmental support as well as the complex role that local contexts play in enabling or constraining teaching and learning.

1) Student Learning

In the formative interviews participants showcased their achievements, such as how they were able to '*support students by bridging the gaps between their secondary school and higher education'* (Participant 4, FI) or how they had taken care to '*support students in relation to English'* (Participant 10, FI). As many South African engineering students speak English as a second or additional language, issues of academic support and academic literacy are pertinent concerns. The course participants were justifiably proud of their teaching skills and the learning outcomes that they had facilitated, however the 'showcasing' and uncritical descriptions of practice that were evident in the formative interviews shifted towards a greater focus on the challenges associated with achieving sustainable student learning outcomes. Participants spoke about the importance of departmental support, and the need for greater '*teaching and learning advocacy'* (Participant 2, SI), as well as how they might '*help departmental colleagues to support student learning'* (Participant 6, SI). In reflecting on his portfolio, one of the participants claimed that he needed: '*to be a change agent to facilitate better student learning in difficult contexts … for example … where one has to counter the effects of rigid mind-sets of traditional staff*' (Participant 11, SI). Another participant claimed that he had learned: '*how to help fellow lecturers in relation to student learning' (Participant 17, SI).*

2) Teaching practice

The short course on portfolio building was largely practical, something that the participants valued in the formative interviews. Positive feedback included that the workshops had been '*informative'*, '*resource rich'*, '*practical'*, with plenty of '*variety'* and '*examples'*. Participants valued the '*helpful links to websites'* containing examples of teaching portfolios in their own disciplines. Some were pleased that participant feedback had been included and addressed as the course progressed.

While some positive comments were made with regard to the group work activities and discussions that were included on all four days of the short course, there were participants who did not enjoy participating in group work on discussions, as a participant explained: *'I don't know if it's because I'm a control freak … I just feel a bit uncomfortable with this whole scenario … it's not that I don't trust people, but I mean, I don't know these people. So it just made me uncomfortable' (Participant 4, FI).*

Participant 4's comment might be related to concerns about sharing personal information online more generally, in particular the perceived risks of sharing too much personal information. However, portfolios (whether online or not) can create discomfort because they make teaching practices visible. Several other participants felt uncomfortable about sharing their portfolios, explaining that they would prefer '*to be taught the skills* [without having] *to participate'* (Participant 7, FI).

On the second day of the short course, three guest presenters (engineering faculty members who had completed a similar course on portfolio development the previous year) made presentations on their 'portfolio journeys'. The participants appreciated these presentations; as one of the participants put it: '*here were people who could answer my queries and identify with my concerns'* (Participant 9, FI).

The short course was regionally based and there was initial reluctance amongst participates to engage across different institutions and engineering disciplines. As can been seen from Table 1, we took a broad view of engineering and included participants from a variety of STEM-based disciplines, even if not specific to traditional engineering disciplines. Several participants requested more discipline-specific forms of teaching. One of the participants complained that: '*We did not hear much about discipline-specific teaching… there are only a small amount of lecturers who teach techniques that I could relate to' (Participant 12, FI).* Even when the course information was found to be useful, participants found disciplinary input necessary: '*It was useful, but I also missed someone in my discipline who shares some of the same constraints' (Participant 6, FI).*

By the time of the summative interviews, several participants had developed a greater appreciation of group work; Participant 4 who initially felt '*uncomfortable*' with group work, now stated: '*I feel a bit different about people having access to my stuff. If I get positive criticism that only helps me. So I feel that … allowing that would be more constructive' (Participant 4, SI).* Another participant reported that: '*Group discussions made me feel part of something bigger and contributing to the discussion gave me a purpose for being here … I tried my best to give valuable input' (Participant 8, SI).*

There was a greater valuing of working with colleagues from different engineering disciplines: '*Having a variety of disciplines helped [me to]understand how contexts change … the variety of academic disciplines of my group members was very helpful and provided insightful thoughts'* (Participant 10, SI). One of the participants pointed out that: '*It helps to notice that certain aspects are applicable across all the disciplines, as it was very helpful to draw from experience in other fields'* (Participant 3, SI). Another participant suggested that: '*There are certain principles that cross disciplines and it somewhat helps define the borders … limitations of our specific discipline contexts'* (Participant 1, SI). Participants had thus shifted towards valuing inputs from other contexts and identified similar teaching principles reflected across contexts. Participant 6, who had initially wanted more 'discipline-specific' teaching methods, came to value sharing practices across contexts and disciplines: '*Hearing about other contexts enriches learning … It gave me insight into approaches used in the various other disciplines'* (Participant 6, SI).

B. Critical reflection

The facilitators devoted one of the four workshop days to the concept of 'critical reflection' and its role in improving teaching and learning. They had expected participants to draw on the educational research literature in their disciplines as well as some general higher education theory to critically reflect on their own practice; they were also expected to provide peers with feedback, drawing on educational theory and research – but most participants did not understand how to do this. Facilitators had attempted to model how one provides feedback and critique through the way in which they responded to the participants' portfolios, but more was needed. In retrospect facilitators identified 'critical reflection' as a 'threshold concept' [14] in educational development, linked to additional key concepts such as student-centered learning, provision of 'epistemological access' [15] to engineering knowledge and 'constructive alignment' [16].

1) Planning

'Constructive alignment' was an important part of the portfolio course, and participants were assisted in using this concept to plan their curriculum (or to reflect on an existing curriculum). Planning learning did not feature much in the formative interviews. Participants took for granted that there were topics to be covered and a syllabus to be '*got through*'. In fact, it was a matter of pride amongst many of the participants that they had completed a content-heavy course, often with under-prepared students. By the summative interviews, some participants were critical of their earlier emphasis on content and coverage, and intended to pay more attention to '*the coherence of concepts [in their subject]'* (Participant 10, SI) or criticized the '*disjointed'* sequence in their syllabus (Participant 16, SI) or the '*lack of coherence between [the course] context, the [classroom] tasks and assessment tasks'* (Participant 8, SI). One participant stated: '*I strongly believe that what I have learnt throughout this workshop will be implemented in revising my study guide for the benefit of my students' (Participant 7, SI).*

2) Reflection on practice

The concept of 'critical reflection' or 'reflection on practice' was unfamiliar to most course participants, and in the formative interviews many were skeptical that reflecting on one's practice was necessary for developing and improving as a university teacher. Comments such as: '*… it's a waste of my time…' (Participant 14, FI)* were fairly common. Some participants were prepared (albeit reluctantly) to suspend their disbelief and try to reflect on their practice: '*Considering that [reflection on practice] will be applicable in certain fields and not in others … but it is worth trying what is likely to succeed in my field' (Participant 20, FI).*

On completion of the portfolio course at the summative interviews several faculty had shifted their positions. One participant claimed that reflection on practice was: '*Probably one of the most important things I have learnt at the workshop' (Participant 17, SI)* Another participant felt that reflection was a useful 'tool' for improving teaching: '*I fully agree that one must consider all tools used in determining one's teaching philosophy' (Participant 5, SI).* While another regretted that she had not found out about the power of reflection on practice earlier: '*I wish I reflected more on my teaching practice prior to this course' (Participant 6, SI).*

3) Educational Theory

There was considerable reference to *'confusion' (Participant 7, FI)* and *'content overload' (Participant 20, FI)* with regard to educational theory and research in the formative

interviews. Participants were resistant to learning about educational theory, or engaging with education as a discipline: *'I am not sure what to make of disciplines that are different from my own'* (Participant 10, SI) or '*I have a limited perspective on teaching and learning in that way…*' (Participant 19, FI). One of the participants explained: *'I'm not into social sciences at all. So not only do I have to learn a whole new way and new terminology and a new way of thinking, but a new way of making sense of my teaching…'* (Participant 6, FI). Participants complained about: '*the new context and language terms that also had to be mastered [which] made the process [of portfolio development] a little more demanding'* (Participant 15, FI). One participant claimed to have tried his best, despite the difficulty of encountering a new discipline, saying: '*I tried my best though I had little knowledge of education as a discipline'* (Participant 11, FI).

Although the process of acquiring educational knowledge was challenging, by the time the summative interviews took place, many (although not all) participants had come to understand why educational theory and research might be beneficial to one's development as a university teacher, despite severe time constraints:

> *I've become more interested in it. But I just don't have time to explore the depth. I only finished my first draft last night … today's deadline was the last in a series of deadlines for me, and it just had to wait its turn ... So I haven't been able to go into the kind of depth that you need to go into, that kind of depth, the kind of stakes that you're aiming for… (Participant 9, SI).*

Interestingly, participants used what they were learning about educational theory to reflect on their own learning, as one participant explained:

> *I've learnt now partially through this course that I'm a reflective learner … I need to sit with something for a long time and chew it over before I understand it' (Participant 16, SI).* For some participants, their portfolio journeys were memorable: '*I remember feeling … the elation of insight into the education field … coupled with the stress of a massive steep learning curve …(Participant 7, SI).*

TABLE II. SUMMARY OF RESEARCH FINDINGS

Categories	*Formative Interviews*	*Summative Interviews*
Student Learning	Focus on teaching and learning achievements	Emerging focus on the support and advocacy work needed to achieve student outcomes.
Teaching Practice	Valued practical input, but wanted more 'discipline-specific' teaching methods.	Greater appreciation of context in teaching, as well as interdisciplinary collaboration.
Planning	Focus on course content and coverage	Great focus on coherence, sequencing and 'Constructive Alignment'.
Reflection	Sceptical about the value of reflection on practice.	More open to the potential of reflection on practice for enhancing teaching and learning.
Educational Theory	Resistance to educational theory and education as a discipline.	Greater appreciation of education as a discipline and educational theory (even if difficulties persist)

The findings of the research study in terms of the shifts in understanding and attitude between the formative and summative interviews are summarized in Table 2. The trends shown in Table 2 were identified through the process of coding the formative and summative interviews. While the trends did not apply to all participants, there was evidence that some participants had developed deeper levels of understanding of what pedagogical competence entails.

V. CONCLUSION

Initially, more superficial approaches to teaching and learning were identified, namely a tendency to describe or to 'showcase' achievements, rather than reflect on practice towards improvement. There was also a tendency to conflate pedagogical competence with teaching 'skills', rather than understanding pedagogical competence as an engagement with the research literature and educational theory on effective teaching and learning in engineering as a basis for reflective practice. However, over the course of a four week short course comprising four full-day workshops on portfolio development and considerable online support between the face-to-face workshops, these negative tendencies (while not completely absent) shifted towards a greater awareness of the impact of departmental cultures on teaching and learning, the importance of the local context and of interdisciplinary collaboration in the enhancement of teaching and learning, a greater awareness of the need for coherence, alignment and sequencing in planning learning, a greater appreciation of the role of reflective practice and a growing appreciation of the application of educational theory in developing as a university teacher.

We conclude that engineering faculty need more support for the difficult (perhaps 'threshold') concept of 'reflection on practice' and its role in enhancing engineering teaching practice, as well as the need for clear criteria for pedagogical competence, which should include the teacher's use the research literature for the purposes of reflection on practice. Engineering faculty require clear definitions of pedagogical competence, that explain how their portfolios will be assessed for purposes of tenure, promotion or the attainment of teaching excellence awards. In this regard we would recommend a modification of Olsson and Roxå's [13] model of pedagogical competence to address different levels of practice for tenure, promotion (at different levels), and teaching awards. Cameron and Woods [17] propose a 'Ladder of Learning' – a structured framework that can inform appropriate criteria of pedagogical competence for university teachers at different levels along a continuum from novice to expert.

For readers wanting to repeat this experience in their universities, the model would need to be contextualized. While we have tried to ensure transferability by including different types of engineering disciplines and drew participants from different institutions, each engineering faculty and institutions would have specific concerns to be addressed. Thus while the broad parameters of 'Student Learning', 'Teaching Practice', 'Planning', Reflection' and 'Educational Theory' are fundamental to the model, the detail of what would be valued under these categories would be contingent on different universities' missions, the specific intentions of engineering faculties (e.g., whether the faculty has a focus on graduate

employability, or on introducing problem-based learning), the demographics of their student body, the existing pedagogical capacity of the faculty, and so on.

There are many challenges involving in enabling engineering educators to recognize the difference between a straightforward teaching methods course with practical 'how to teach' guidelines for teaching a specific subject (which many might expect) and a course intended to develop pedagogical competence. Offering a teaching methods course would be costly and impractical, given the diversity of subjects, disciplines, levels and contexts in most engineering faculties. Pedagogical competence training, on the other hand, encourages teaching academics to reflect continuously and improve upon their practice in line with developing theoretical understandings. Not only is pedagogical competence a more collaborative and interdisciplinary model (and more cost-effective) it has greater potential for the continuing professional development of engineering faculty in their roles as universities teachers. As one participant put it:

> *I've been able to put words to how I have been doing things. So there's now terminology to what I've been doing and exposing me to other things that I can use and have an opportunity to. But also I think the main thing is opening up the door to more reflection and thinking outside the box as to what options there are that are out there that you might not have thought about... (Participant 17, SI).*

Teaching portfolios, because they are associated with 'high stakes' university practices (tenure, promotion and awards) are a potentially 'high impact practice' in professional learning. Portfolios are meaningful to engineering faculty because they enable a focus on the faculty member's specific subject area and practice (rather than on generic themes in teaching and learning). Teaching portfolios have been used to demonstrate evidence of growth, competency, and the attainment of excellence, as well as a means towards linking theory (or research) and practice in professional education, but little research has been undertaken with regard to teaching portfolios in the professional development of engineering faculty. Teaching portfolios have the dual function of both showcasing teaching accomplishments as well as creating an opportunity for further growth and development through reflecting on practice. While much is known about the role of reflective practice in professional development towards enhancing teaching, less is known about the difficulties of attaining such reflective practice in engineering contexts.

The study proposes a framework for re-conceptualizing teaching portfolios for engineering faculty and offers suggestions to assist educational developers in enhancing pedagogical competence in engineering education. Insights gained from the findings could potentially strengthen the quality of teaching in engineering faculties beyond the Swedish context in which the model was developed, and the South African context in which it was adapted and implemented.

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