

# Introductory Programming and Educational Performance Indicators – a Mismatch

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## ABSTRACT

Introductory programming courses are known worldwide to pose challenges for both students and educators. A recent meta-review of research in the area has indicated something in the order of a sixty six percent pass rate globally. Yet the New Zealand Government has asked institutions to set high and increasing targets as a goal for student pass rates in its educational performance indicators. Increasingly these metrics are being used to shape the behaviour and educational outcomes sought from educational institutions, with the threat of penalties by way of loss of funding for supposedly “poorly performing courses”. Yet while focused at the institutional level, how do these indicators really meet the needs of all the stakeholders in the tertiary education system? To what extent do they distort and create incentives for perverse behaviours? This review assesses the dilemmas such measurement systems pose to educators using the case of introductory programming as an example.

**Keywords:** introductory programming, CS1, educational performance indicators, performativity, assessment

## 1. INTRODUCTION

The large body of research on introductory programming courses indicates that the subject poses challenges for both students and educators. A recent meta-review of the global literature (Watson & Li, 2014), records that typically some two thirds of students tend to pass the introductory course. Yet the New Zealand Government has embarked on a process of progressively raising the expectations of educational performance asking institutions to set high targets (one example is 85%) of students passing their courses and increasing the target in subsequent years. Under this educational performance indicator (EPI) based regime, institutions that fail to meet these targets run the risk of having their courses defunded. So how are such targets set and how do they impact the stakeholders in tertiary education? Does a solely institutional focus result in better educational performance or does it merely generate perverse incentives and skew outcomes to the detriment of other stakeholder groups such as employers? This paper reviews the dilemmas facing educators in computing in adapting to an EPI driven regime, taking the introductory programming course as an illustrative case.

## 2. EDUCATIONAL PERFORMANCE INDICATORS

### 2.1 What are EPI's?

The Education Performance Indicators: Definition and Methodology document published by the New Zealand Tertiary Education Commission defines educational performance as the:

Activities TEOs undertake that contribute to the Government's vision for the tertiary education system: this requires tertiary education to 'better equip individuals with the skills and qualifications needed to participate effectively in the labour market and in an innovative and successful New Zealand'." (TEC 2014, p.1)

Educational performance is measured by a set of indicators which include:

The standard internationally recognised measures of student achievement are those relating to student retention, progression, and completion of courses and qualifications. In line with these standard measures, we have developed definitions (specifically ‘formulae’) for a core set of performance indicators that measure TEOs’ educational performance through the progression, retention, and completion achievements of their students.” (TEC, 2014, p.2)

The four indicators are as follows:

- Successful course completion is measured by the *EFTS-weighted successful course completion rate*. This is the successfully completed enrolments in courses at a TEO each year, as a proportion of the total enrolments in courses, weighted by the EFTS value of the enrolments.
- Student retention is measured by the *student completion (or continuation) rate*. This is the number of re-enrolments or qualification completions at a TEO each year compared with the number of students present at the TEO in the previous year.
- Qualification completion is measured by the *EFTS-weighted qualification completion rate*. This is the number of qualifications completed at a TEO each year (weighted by the EFTS value of each qualification), as a proportion of the total enrolments in qualifications in that year (weighted by the EFTS value of the enrolments).
- Student progression is measured by the *completion progression rate*. This is a rate of re-enrolment in a higher-level qualification in the following year for students who have completed a qualification.” (TEC, 2014, p.2)

(note: 1 EFTS is an Effective Full-time Student)

### 2.2 The Context

The current government strategy for controlling expenditure in the big spending departments (health, education, corrections, social welfare), has been outlined as setting “some very specific measurable service targets...[e.g.] increase the proportion of 19 year olds with NCEA level 2 or equivalent to 85% by 2017” (Roughan, Weekend Herald,

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This quality assured paper appeared at ITX 2014, incorporating the 5<sup>th</sup> annual conference of Computing and Information Technology Research and Education New Zealand (CITRENZ2014) and the 27<sup>th</sup> Annual Conference of the National Advisory Committee on Computing Qualifications, Auckland, New Zealand, October 8-10, 2014. Mike Lopez and Michael Verhaart, (Eds).

July12, p. A23). This approach would also appeal to the business led council of the Tertiary Education Commission (TEC) as akin to the business approach of adopting Key Performance Indicators or KPIs to measure business performance. It is worthy of note that of the seven TEC commissioners only one has any tertiary education sector experience<sup>1</sup>. One could form the view that in the absence of knowledge of how tertiary education actually works, borrowing some simplistic business management and measurement approaches might have appeal to the commissioners.

However, ensuring that the measures adopted do not have the counter effect of reducing the desired performance is a more complex task. Note for instance in the school system the commentary by Holt (2001) observing that there are pitfalls in:

...Conventional programmes designed for students who are identified as 'at risk' [described as]...less challenging and more repetitive, with the teacher breaking down each task into small pieces, working through procedures step by step and leaving little opportunity for higher order thinking...

This culture of managerial oversight is problematic as Pritchard (2012, p. 19) has observed

...the dominant managerialist culture within tertiary education runs counter to the traditional culture of teaching. *Managerialism with its emphasis on efficiency and external accountability treats teachers as functionists rather than professionals and thereby diminishes their autonomy and commitment to the values and principles of education* (Codd, 2005, xv)

He suggests that this situation leads to a culture of performativity in which *ends are separate from means and people are valued by what they produce* (Codd, p. xv).

Pritchard (2012, p. 22) cites Baldwin & James (2002) in identifying the complexity of tertiary learning and teaching, and its "tangible non observable qualities":

The outcomes of tertiary courses are much harder to assess and compare than say the holding properties of two forms of glue. They are complex and long term and many are hard to measure precisely

So in the absence of the ability to actually measure learning we end up with flawed proxies that are easy to measure.

### 2.3 How are the EPI targets set?

The New Zealand Tertiary Education Strategy (TES) 2014 - 2019 sets out the Government's long-term strategic direction for tertiary education; and its current and medium-term priorities for tertiary education. The TEC use this strategy to set performance indicators for the sector. Tertiary institutions are required to complete a three yearly investment plan for approval, where they set the performance indicators for the three year period. These are set by the institution and negotiated with the TEC. The tertiary institutions would appear to set these EPI's either as an increase on previous years achievements or take the median in their sector as the indicator. Thus the measures have a normative effect across sectors.

The tertiary institutions are required to report on all four education performance indicators in their Annual Reports measuring them against previous years and some have

measured the performance against other similar institutions in the sector.

Institutions course completion targets have been increasing over the past five years, for example in the Institute of Technology and Polytechnic sector, one institution's overall course completion targets were reported as:

2009	2010	2011	2012	2013
67%	75%	77%	79%	79%

While a similar institution reported targets as:

2007	2010	2011
74%	81%	85%

The university sector report similar actual results and evidence of increasing targets, including all students, student achievement component (SAC) or publicly funded and international full fee paying.

2010 Actual	2011 Actual	2012 Forecast	2013 Target	2014 Target	2015 Target
78%	79%	81%	81-82%	81-83%	82-84%

#### Massey University Investment Plan 2013 – 2015 (2012)

This reporting then begs the question: are these targets really of value as the course completions are averaged out over all disciplines at all levels. Will students really choose their place of study based on such ambiguous and homogenised information. Yet this is one of the main reasons TEC required institutions to report this annually (TEC, 2014). Without all the other factors this information is extremely misleading.

### 2.4 DO EPI'S MEASURE QUALITY?

The TEC assert that:

TEC's funding is linked to educational performance, and information on the educational performance of all TEOs is published annually. Making information such as completion and retention rates public strengthens the accountability of TEOs and better informs students and employers when they are making choices about tertiary education. (TEC, 2014. p.1)

These goals then demonstrate the prevalent ideological 'consumerist' perspective on education.

In the discourse of enterprise humans are defined in a wholly economic frame, with individual lives as an enterprise of the self, like individual businesses engaged in developing their own human capital. The language of the market takes over, and civic culture becomes consumer culture. The citizen is reconceptualized as the sovereign consumer/customer. This discourse, for some time popular with western governments, has now permeated into the areas of social service provision. Patients, parents, passengers and pupils are re-imagined as customers. (Du Gay & Salaman, 1992)

So the notion of quality espoused here seems to be quality of the information made available to assist the 'student as consumer' choice? Whether the needs of the 'employer as consumer' are met by these EPIs is a moot point, especially if institutions' aims become distorted to reach EPI target completions rather than educational outcomes.

Other models of quality could be considered, e.g. educational quality as 'production' in delivery of the curriculum; education quality as delivering a 'service' to the student; and educational quality as 'development' of the student (Pears,

<sup>1</sup> <http://www.tec.govt.nz/About-us/Who-we-are/Board-of-Commissioners/>

2010). The model of educational quality that we prefer reflects the latter conception, and is that advocated by Corder, Horsburgh and Melrose, (1999) in which ‘*transformation of the student*’ through the educational experience is the goal.

The EPI approach relies solely on the education as *consumer service* model, and so marginalises other and truer, or at the very least complementary, measures of educational quality.

## 2.5 University reaction

In comment from the University of Auckland and Massey University the crude nature of the EPI’s as a measure of quality has been critiqued. Vice Chancellor McCutcheon of the University of Auckland questions the validity of the data:

The fundamental problem is that the TEC uses unadjusted institutional average performance measures in its presentation. In reality, the performance measures are influenced by a great many factors, including the socio-economic backgrounds of the institution’s students, student ethnicity, part-time versus full-time status, subject area and whether the students are internal or extramural. (University of Auckland, 2014)

He goes on to comment on the interpretation of the results

A second issue is that, even if they were robust, the data would be difficult to interpret. For example, is a high course completion rate a good thing because it reflects an institution that has excellent teaching and a high level of student support, or a bad thing because it reflects an institution that has low standards and makes it easy for students to pass? (ibid)

Massey University Assistant Vice-Chancellor Cas Carter says the measures do not take into account the student profile of a university such as Massey.

While we understand the Tertiary Education Commission’s requirements for performance data, neither the data set, nor the method of measurement, provides any indicator of quality. (Massey University, 2010)

## 3. INTRODUCTORY PROGRAMMING

Taking the introductory programming course as an illustrative case for our argument, how do we set valid and pedagogically legitimate expectations for our students? For a variety of reasons introductory programming is known as a challenging course and there is a global literature associated with these challenges, as observed in the quote below:

Learning to program can be an incredibly difficult task, to the point where the phrases “failure rate” and “programming course” are almost synonymous (Watson & Li, 2014)

To put this challenge for computing educators in the global context, a tabulation of failure rates in introductory programming by country, based on studies in the literature, reports a range from 60+ percent to 5% (Watson & Li, 2014 figure 1 below). Why is this variation so great and what methodology might be suitable for developing an appropriate indicator for success? (Even assuming that any form of EPI were warranted).

Watson & Li (2014) concluded that a 66% pass rate for introductory programming, was the mean in their selection of globally published studies. So would there be any logic in setting that figure as a target? For instance how representative of typical courses and institutions were these studies? Did they perhaps over-represent the typical pass rates as other studies may have been too embarrassed to report results? Watson & Li’s results left unclear the “individual breakdowns on the failure and withdraw rates of courses” (2014), so the

comparability of these figures with TEC’s EPI’s for course completions (which do include withdrawals and non-completions) is not clear. It is possible that this could account for a further 10% of students, which would then result in equivalent mean pass rates of 56% applying the TEC formula. (A figure which it should be noted is below TEC’s latest threshold level of 60% at which a course is relegated into the category of “low performing provision”). Yet, this despite its consistency with what appears to be a global subject norm?

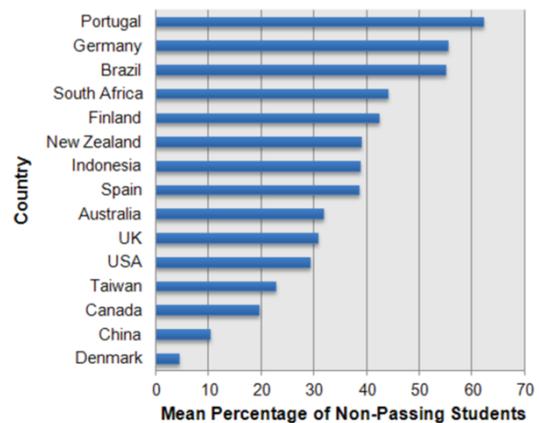


Figure 4: Non-passing students by country.

### Figure 1. Intro. Programming Non Passing Students by Country (ex. Watson & Li, 2014)

To compound matters, predicting success in studying computing at tertiary level has long been problematic. For instance while Engler (2010) found that “academic achievement at school...has the strongest association with first-year university performance” (p. 35), he also “found no association in performance in information technology studies and taking mathematics with calculus at school, after controlling for school achievement” (p. 36). So sifting out the likely successes then is a challenge and some inevitable level of failure in introductory programming can be predicted both from our experience and from the international literature.

As a result of the challenge in producing capable developers, shortages of software developers have been noted locally (Robertson, CITRENZ June 2014 newsletter) to inhibit the growth of software and web based development companies, and global shortages have been noted in many other countries (Watson & Li, 2014).

Given that software development skills are in demand because they require advanced capability, and that it is always easy to pass a student (if short term commercial considerations take precedence), does a watered down set of programming courses to meet EPIs address these needs? Should the institutions that set rigorous and demanding course expectations be defunded if some students fail, when these successful students are the very ones sought by industry? It is well known that the first year has a “sorting and certifying” effect (Myers & Rowan, 1986) and in our experience students that do succeed and persist past that point tend to subsequently do well.

In that case, what form of assessment should Institutions adopt in the face of an EPI driven funding regime. The implicit model for EPI’s appears to be “norm referenced” (Tan & Prosser, 2004), (i.e. that for a given population of students x% should be expected to pass, where x% is well in excess of half the student body, and with that performance

target also expected to progressively increase over time for instance cf. below

The Minister for Tertiary Education, Skills and Employment has decided to maintain the upper thresholds and increase the lower thresholds for measuring 2014 performance, which will impact on 2015 funding. This reflects the improvement in TEOs' educational performance and the expectation that TEOs will continue to improve their performance, particularly those with poorer performance.

(source: <http://www.tec.govt.nz/Funding/Policies-and-processes/Performance-linked-funding/Details-for-TEOs/>)

How does this model fit with an approach built upon a "standards based" assessment regime (Barker, 1995), such as that in operation at Auckland University of Technology, where students are deemed to have passed a course once they have demonstrated achievement of the course learning outcomes? Does the government want us to end up with a society like Lake Woebegon where "everyone is above average" (Trusted Advisor, 2012).

#### 4. . DISCUSSION

Funding models are powerful drivers of behaviour in governmental organisations. So the funding linked EPI model has significant potential for steering the education system. However there appears to be some tension here between the Government's stated objectives. The New Zealand Government desires greater participation in tertiary education at higher qualification levels by Maori & Pasifika students, greater provision of STEM education and ever improving success rates for students. (TEC, 2014)

However, in the case of the *course completion* EPIs, does achieving an arbitrarily imposed hurdle for passing students at the individual course level actually realise those outcomes? Without acknowledging that students new to tertiary study and taking challenging subjects to which they have had little

prior exposure, may decide that this is not the course for them, these measures become merely arbitrary and punitive instruments. Failure which drives a more appropriate student degree or subject choice in such a circumstance may indeed be a warranted outcome? How many accountants do we need who can't add, doctors who can't diagnose, lawyers who can't draft a contract, software developers who can't communicate over requirements or produce robustly designed and bug free code?

How does society adequately weigh the best interests of all stakeholders - students, educators, employers, educational institutions, professional bodies, parents and the wider community? Instruments such as EPIs that place responsibility on institutions for factors outside their control and treat the student as sovereign consumers have serious shortcomings. Where do family, financial and social pressures not to mention personal responsibility on the part of the individual student fit? For instance in the model of student persistence in a subject, Fig 2, presented below, there are only a few areas in which an institution may productively intervene, respectively in academic and social integration.

So why then is the institution the primary site of the performance measurement regime?

#### 4.1 Dilemmas facing educators

In the face of these pressures how should educators respond, especially as they may often be acting in an institution offloading its own imposed burdens on to the individual teachers?

It is a given that the educators applying their professional judgement are not expected to lower the standards of the learning outcomes of a course, yet they are now being asked to pass a higher percentage of students each year. On one hand the institution wants to receive the student income to stay viable, yet the students really may lack the desire or not have a chance of successful course completion.

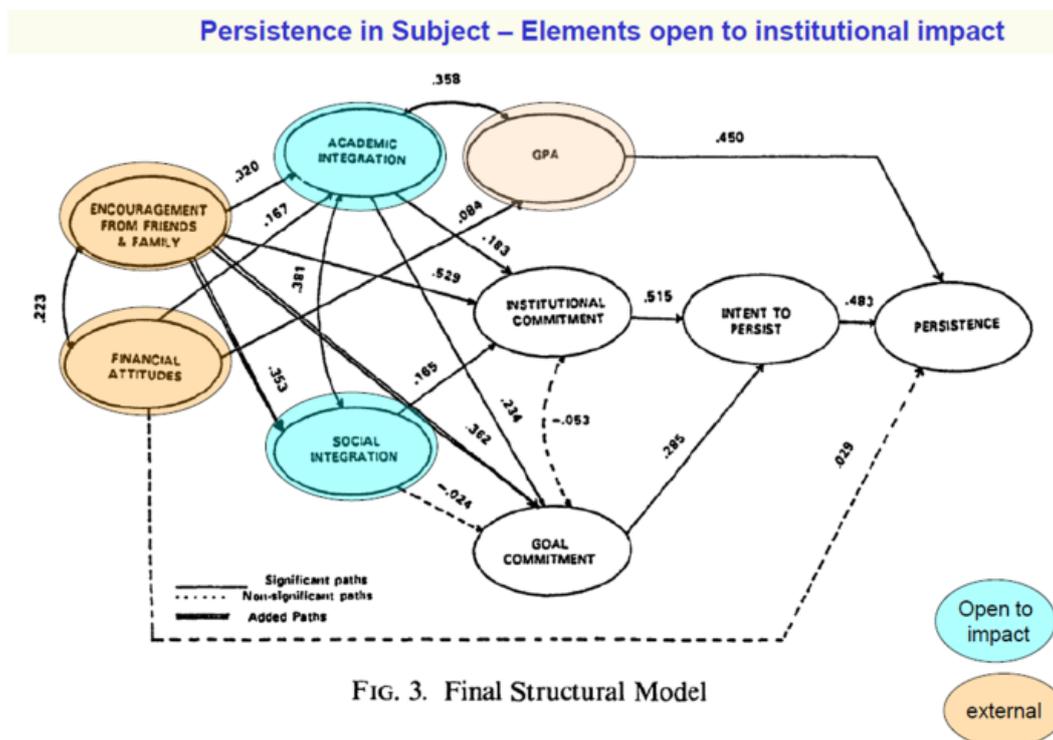


FIG. 3. Final Structural Model

Figure 2. Persistence in Subject – Elements open to Institutional Impact (adapted from Cabera et al 1993)

That leaves the responsibility with the educator who now faces pressure from their managers to meet targets that have been set to satisfy internal and external factors over which they have no control.

One area of weakness with an EPI driven regime is that there appears to be no set criteria for dealing with student withdrawals from a course which could significantly change the course completion results of a course. If students withdraw before the 10% mark of a course are they included in the course completion results as a failure in that course? Victoria University of Wellington state in their 2013 – 2015 Investment Plan in discussing low provision: “Most of the remainder are courses with initial small enrolments that were affected by late withdrawals” (Victoria University of Wellington, 2012).

Students, (such as IT practitioners) who take a course just to acquire the knowledge rather than complete the assessments, would again alter the course completion results for a course. In such cases the educator has little control over the course completion results which could very well exceed the required performance indicator target, if withdrawals had not been counted and everyone sat the assessments, yet for these reasons it would be reported as well below the required performance indicator.

#### 4.2 Exemption to the target?

For courses such as introductory programming where there is overwhelming international evidence of pass rates significantly lower than those being globally set by institutions there needs to be an opportunity to be exempted from these targets. However the way the targets are set, as a blanket overall target, any course which was not meeting the target would be seen to lower the result of an institution and would not be looked on favourably and possibly classed pejoratively as *low performing provision*. Taking this further, will institutions retain courses with low course completion rates even if they are integral to the qualification, and especially in an environment where TEC imposes financial penalties for such course outcomes?

#### 4.3 When to teach introductory programming

There is overwhelming evidence to demonstrate that the introductory programming course is a “gate-keeper” to success in computing/computer science qualifications. (Selby et al, 1998). In the regime of attempting to meet arbitrarily set course completion targets institutions it would be shrewd to not offer introductory programming in the first semester of a qualification. However the information technology industry advice and our own experience in curriculum development indicates that to be a capable software developer it takes six semesters of study to cover a sequence of courses progressing from ‘programming in the small’, through software design, software process and team work experiences, to completing a significant piece of software at the ‘programming in the large’ level. The dilemma then is that Introductory Programming does need to be included early regardless of the course completion rates.

To not only teach the students the joy of programming but move closer to meeting these performance indicators, strategies that educators could adopt are to look at ways to motivate students and intervene when students are struggling. This should happen as a matter of good teaching not just to meet an arbitrarily set EPI. Academic staff in tertiary institutions who value teaching and learning, will always strive to improve their teaching and learning regardless of any EPI’s that are imposed upon them. Steele (2010) argues that as introductory programming is such a difficult subject to

teach with “varying rates of motivation” that introducing a competition is one method of retaining motivation and retention. Another approach such as the interviewing interventions discussed in Sarkar et (2013) may help to encourage students to complete the course and therefore help institutions to approach the arbitrarily set target.

#### 4.4 Possible reactions

There are a number of possible reactions to these EPI targets that have been set. The content of the courses could very easily be watered down to be made much simpler than the original course. Providing no one is going to check on this, an increased successful completion rate would be achievable. The question then arises as to the success rate students in subsequent courses and the view of the industry stakeholders who are employing these graduates. By “watering down” the course content and the learning outcomes educators could certainly keep managers and funding bodies happy. Students might then be able to decide on an institution for their study based on these advertised results, yet not be able to perform in the workplace.

The dilemma facing the educators would then be that of lowering their standards, and passing students who in their professional opinion should not achieve a passing grade. Once an institution had a reputation for producing graduates who were not capable, even though students were flocking to enrol based on the institutions high EPI’s, stakeholders would surely shy away from employing those graduates. [An anecdotal report to the authors by an industry colleague, suggests that employers are currently relegating to the rubbish bin applications by graduates from some institutions]. In this case the graduate outcomes reputation would be a much better measure to guide a student’s choice of institution.

#### 4.5 Impacts

The pressure on institutions and particularly educators and departments with the introduction of the EPI’s is increasingly intensifying. Arbitrarily setting EPI’s and reporting on them institutionally may also see some dubious behaviour among senior management staff. If an educator reports a ‘below target’ course completion result and it is changed by the higher levels of institutional management for whatever reason, what sort of impact will that have on the credibility and integrity of that institution?

As earlier noted, there are so many factors that contribute to success: domestic students vs international students, part-time student vs full-time students, school leavers vs mature students, distance students vs internal students. The dilemmas posed in response to these managerially imposed targets, has a corrosive effect which potentially destroys the collegiality and professionalism of academic staff.

Moreover this measurement regime is essentially in violation of the education act under which “academic freedom and the autonomy of institutions are to be preserved and enhanced”, including:

(d) The freedom of the institution and its staff to teach and assess students in the manner they consider best promotes learning (Education Act, 1989, s161).

A normatively based evaluation regime which really only reproduces the 80/20 success/failure split of any pareto law at the aggregate level really measures nothing.

To misapply this from of measurement at individual course levels by punitively withdrawing funding for failure to meet a target set at the aggregate level, is wholly flawed. It has the potential to: punish institutions taking risks by trying to promote access for students; to weaken standards for challenging disciplines such as the STEM subjects; and to

distort degree curricula by forcing the removal of essential but difficult core courses.

## 5. CONCLUSION

The New Zealand Government's policy settings of an educational 'performance based' planning, target setting and measurement regime are shaping institutional behaviours, with local adoption of broad targets to meet externally imposed demands and metrics. At a discrete discipline and course level these indicators have considerable distortionary potential.

As one example explored here, introductory programming is a difficult subject to understand when it is first introduced and trying to meet the wider targets set by TEC through the institution is counter to the purpose of learning this subject. It would be irresponsible to the many stakeholders of computing education programmes to pass students who really aren't capable of meeting the learning outcomes of these courses.

The setting of Educational Performance Indicators without regard to the discipline areas or the students involved is ill advised and ill judged. One of the published driving factors in setting and reporting on these is to furnish students with information to choose their institution of study. Publishing these as a single result is irresponsible and in no way should influence a student's choice of place to study. There are many other factors that should be considered before making such a choice.

Does the TEC truly believe that they are promoting quality by asking institutions to set and report on arbitrary EPI's that are really meaningless out of context? We believe in this critique, that we have made the case against the misguided and damaging performativity underlying this policy.

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