

ENVISIONING VIRGINIA TECH

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# **BEYOND BOUNDARIES**

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CHARACTERISTICS OF HIGHLY RANKED UNIVERSITIES IN THE TIMES HIGHER  
EDUCATION (THE) WORLD UNIVERISTY RANKINGS

PREPARED BY:

Fatima Sparger Sharif

Office of the Senior Fellow for Resource Development

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## Introduction

The Times Higher Education (THE) World University Rankings include a list of the top world universities based on the indicators of teaching, research, citations, industry income, and international outlook. While an in depth analysis of the methodology THE employs helps universities to better understand the influential university characteristics, it does not point specifically to how other factors, identified in the literature as important to a world class global university, do or do not play a role in the university's rank. This research, therefore, attempts to explore other university characteristics that may be important to a university's THE ranking. It includes the 78 universities from the United States that are ranked in the top 200 of THE.

These characteristics are quantitatively explored in both pairwise regulations as well as a series of regression models. The dependent variables in the regression models are the overall THE score along with each of the subcomponent scores focused on teaching,<sup>1</sup> research,<sup>2</sup> citations,<sup>3</sup> industry income,<sup>4</sup> and international outlook.<sup>5</sup> The

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<sup>1</sup> THE's teaching score includes the findings from an "invitation-only academic reputation survey," "staff-to-student ratio," "the ratio of doctoral to bachelor's degrees awarded," "number of doctorates awarded by an institution, scaled against its size as measured by the number of academic staff it employs," and "institutional income scaled against academic staff numbers" (Retrieved from <http://www.timeshighereducation.co.uk/world-university-rankings/2014-15/world-ranking/methodology>).

<sup>2</sup> THE's research score includes "a university's reputation for research excellence among its peers," "university research income, scaled against staff numbers and normalised for purchasing-power parity," and "research output scaled against staff numbers" (Retrieved from <http://www.timeshighereducation.co.uk/world-university-rankings/2014-15/world-ranking/methodology>).

<sup>3</sup> THE's citation score includes "the number of times a university's published work is cited by scholars globally" "normalised to reflect variations in citation volume between different subject areas" between 2008 and 2012 (Retrieved from <http://www.timeshighereducation.co.uk/world-university-rankings/2014-15/world-ranking/methodology>).

independent variables include institutional control (being a public as compared to private university), land-grant university status, membership in the Association of American Universities (AAU), endowment funding, research funding, median SAT scores, number of members in the National Academies, number of postdoctoral appointees, annual giving by alumni, number of faculty awards, and having a medical school.<sup>6</sup>

### **Independent Variables**

A set of independent variables that are not part of the current THE methodology have been selected for inclusion in this study based on the importance attributed to them in the literature and larger academic context. There are several important variables that are not included as independent variables, because they, in fact, are already included as part of the dependent variable. For instance, federal research expenditures is a variable that is likely to impact the ranking of a university in most ranking system. Since THE already uses this indicator as part of its research subcomponent, it is not included.

*Institutional control* is an important contextual variable that acts as a control variable in the model. It is included because it can be “important in shaping financial outcomes; for example, U.S. News shows that alumni of selective public schools are less

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<sup>4</sup> THE’s industry income score includes “how much research income an institution earns from industry, scaled against the number of academic staff it employs” (Retrieved from <http://www.timeshighereducation.co.uk/world-university-rankings/2014-15/world-ranking/methodology>).

<sup>5</sup> THE’s international outlook score includes “the ratio of international to domestic students,” “ratio of international to domestic staff,” and “the proportion of a university’s total research journal publications that have at least one international co-author” (Retrieved from <http://www.timeshighereducation.co.uk/world-university-rankings/2014-15/world-ranking/methodology>).

<sup>6</sup> These data were collected from The Center for Measuring University Performance which resides at both the University of Massachusetts Amherst and Arizona State University: [http://mup.asu.edu/research\\_data.html](http://mup.asu.edu/research_data.html)

likely to send donations than their private college counterparts” (Bastedo and Bowman, 2011, p. 11). Bastedo and Bowman (2011, p. 16) found that institutional control was negatively associated with alumni giving but positively associated with “all forms of R&D, total alumni donations, and total foundation funding.” In this research, however, we are interested in the relationship of institutional control to THE ranking. *Institutional control* is a dichotomous 0/1 variable in this model.

*Land-grant* institutions differ from other universities due to their unique mission of, “linking new knowledge and understanding to its practical application for the collective good” (The Global Land-grant University, 2013). This variable is especially important due Virginia Tech’s status as a land-grant institution. This variable is included in the model to see if such a designation is significantly associated with a university’s THE ranking.

Membership in the *AAU* is by invitation and it recognizes “that a university is outstanding by reason of the excellence of its research and education programs” (AAU Membership, 2014). Given this description, AAU membership is expected to be associated with a high THE ranking.

*Endowment funding* is recognized as important to the establishment of a world-class university (Salmi, 2009, p. 52), because it can be used to further important institutional goals. Therefore, this research explores the relationship between university endowment figures from 2014 and THE ranking. Similar to *endowment funding*, *alumni giving* is an important part of an institution’s funding stream and, therefore, potentially able to influence THE rankings. In addition, Clotfelter (2001) and others consider *alumni giving* to be an indicator of alumni satisfaction and a reflection of the quality of their a

graduate's educational experience. It is, therefore, of interest to see if these indicators are linked to THE rankings.

The quality of students and faculty is another important characteristic of world-class research institutions. As such, ranking systems include indicators to convey the eminence of the faculty, staff, and students in a university. Systems of ranking in the United States, to include US News and World Report's College Rankings, use SAT scores as an indicator of the quality of the incoming freshman class. Since THE is a global ranking, this measure is not included. Therefore, this study aims to see if this relationship of quality posited by US based ranking systems is also reflected in THE. Faculty has a number of awards that convey excellence from a variety of prominent programs.<sup>7</sup> In addition, membership in the *National Academies* is a premier signifier of achievement in research. Again, these are US based awards and memberships so this study is trying to see how are related to THE rankings.

The final independent variable is whether a university has a *medical school*. Many scholars believe that a medical school is positively associated with a higher ranking because of the wealth of research that takes place in the *medical school*. "The presence or

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<sup>7</sup> Faculty awards from the following programs are included, American Council of Learned Societies (ACLS) Fellows, Beckman Young Investigators, Burroughs Wellcome Fund Career Awards, Cottrell Scholars, Fulbright American Scholars, Getty Scholars in Residence, Guggenheim Fellows, Howard Hughes Medical Institute Investigators, Lasker Medical Research Awards, MacArthur Foundation Fellows, Andrew W. Mellon Foundation Distinguished Achievement Awards, National Endowment for the Humanities (NEH) Fellows, National Humanities Center Fellows, National Institutes of Health (NIH) MERIT (R37), National Medal of Science and National Medal of Technology, NSF CAREER awards (excluding those who are also PECASE winners), Newberry Library Long-term Fellows, Pew Scholars in Biomedicine, Presidential Early Career Awards for Scientists and Engineers (PECASE), Robert Wood Johnson Policy Fellows, Searle Scholars, Sloan Research Fellows, US Secretary of Agriculture Honor Awards, and Woodrow Wilson Fellows.

absence of a medical school has a significant impact on the research productivity of a university, especially in the United States with its strong tradition of funding biomedical research preferentially in comparison to other fields of study” (Capaldi et al., 2010, p. 5). For the purposes of this research, the medical school’s research intense environment and it’s generous funding for health research are expected to improve the research component of the overall THE ranking. Therefore, having a medical school is another institutional characteristic that is expected to be positively associated with THE’s ranking.

## **Results**

When exploring the data, an important concern is where Virginia Tech falls in regard to each of these variables as well as the descriptive statistics associated with the variables themselves. Table 1 provides the descriptive statistics for the top 200 US research universities included in THE as well as Virginia Tech’s value in each category. Since Virginia Tech falls outside the 200<sup>th</sup> rank for THE, it’s values are not included in the descriptive statistics of all top 200 universities. There are a total of 78 US universities that are in the 200.

Table 1. Descriptive statistics for the top 200 THE schools in the United States and Virginia Tech

Descriptive Statistics	Yes	Virginia Tech	Median	Mean
Public	52.6%	Yes	-	-
AAU	74.0%	No	-	-
Land-grant	17.9%	Yes	-	-
Medical school	62.7%	Yes	-	-
Endowment (in thousands)	-	\$796,437	\$2,093,842	\$4,476,029
Alumni giving	-	\$75,120	\$134,011	\$199,874.3
SAT score	-	1210	1340	1305
National Academy Members	-	14	28	53.3
Faculty awards	-	8	19.4	15
Postdoctoral appointees	-	202	455	624.8

The large majority of the universities ranked in the top 200 by THE are members of the AAU and have a medical school whereas only a slight majority are public universities. Less than 20% of the top 200 universities are land-grant institutions. Virginia Tech is lower than the top 200 THE in regard to all of the quantitative variables, with most indicators at around half the value of these elite schools.

### Pairwise Correlation

The initial analysis, presented in Table 2, is a simple pairwise correlation to assess the relationship between each of these independent variables with THE's overall and subcomponent scores. Each of these variables has a relationship at the 0.10 or 0.05 significance level with one or more of the THE component scores. The industry subcomponent score stands out because it has the least number of significant relationships with the independent variables used in this research. This is to be expected given the very different makeup of the industry income variable and academically

oriented nature of the independent variables. The research component has a slightly significant (0.10 level) negative relationship with *public* universities and those with a *medical school*, indicating that those university characteristics are not associated with higher industry income. Additional variables focused solely on industry income need to be sought out to better understand changes in income.

#### *Institutional control and land-grant status*

The public university variable has a significant slightly negative relationship with each of the subscores except for research and international outlook (see Table 2). The teaching subcomponent's correlation coefficient with public universities stands at -0.27 whereas the overall score is -0.22. Although this score is not very high, the significance level indicates that some feature of public universities is having a negative impact on THE scores. It is important to understand the features of public universities that distinguish them from private universities that lead to the lower teaching and overall score. The multiple regression model will allow us to control for some of the differences that may be contributing to this negative relationship. Land-grant university status did not have a significant relationship with any THE scores.

#### *Medical school*

Having a medical school was not significantly related with a higher overall THE score but had a mild positive relationship with the teaching score. Interestingly, it had a mild negative relationship with international outlook and industry income. This is a weak relationship but provides an interesting starting point to consider when analyzing the results of the multiple regression model.

#### *AAU membership*



There was a strong and significant relationship between universities that are members of the AAU and THE scores (see Table 2). The strongest relationship ( $\beta=0.60$ ) was between AAU membership and the research subcomponent. Since membership in the AAU is partly predicated on a strong research record, this relationship is to be expected. In addition, however, AAU membership had strong significant relationships with teaching ( $\beta=0.56$ ), overall (( $\beta=0.56$ ), citations (( $\beta=0.20$ ), and even international outlook ( $\beta=0.20$ ). The requirements for membership in the AAU, therefore, seem to be an important area to study for universities interested in improving THE scores. Therefore, in the multiple regression model employed in this study, instead of using AAU as an independent variable, we will include the indicators that the AAU uses when deciding whether to admit members. These include number of National Academies members, postdoctoral appointees, faculty awards, and a measure of undergraduate education along with research expenditures, state funding, citations, and number of doctorates awarded.

Since THE already takes into account research expenditures, state funding, citations, and number of doctorates awarded, this model will include only National Academies members, postdoctoral appointees, faculty awards, and median SAT score.

#### *Strongly associated variables*

The two individual indicators most strongly associated with the overall THE score are faculty awards and number of National Academy members. These two variables also had strong significant associations with all of the subcomponent scores except industry income. If this relationship holds in the multiple linear regression model, these are two areas to focus on if there is interest in improving in THE rankings. Endowment funding, alumni giving, number of postdoctoral appointees, and median SAT score also have

strong relationships with the overall THE scores and the subcomponent scores. They, similar to the other variables, do not have a strong relationship to industry income.

Table 2. Pairwise correlations between independent variables and THE scores (overall and subcomponent)

	Overall	Teaching	Research	Citations	Industry	International
Public	-0.22*	-0.27**	-0.05	-0.33**	-0.08*	-0.21
AAU	0.56**	0.56**	0.60**	0.20*	-0.12	0.25**
Land-grant	-0.02	-0.02	0.06	-0.15	-0.03	0.05
Medical school	0.06	0.25**	0.07	-0.20	-0.24*	-0.30**
Endowment	0.58**	0.61**	0.54**	0.29**	0.10	0.33**
Alumni giving	0.70**	0.74**	0.67**	0.35**	0.07	0.35**
SAT score	0.44**	0.44**	0.39**	0.28**	0.09	0.41**
National Academy Members	0.78**	0.76**	0.74**	0.47**	0.20	0.53**
Faculty awards	0.73**	0.74**	0.73**	0.36**	0.01	0.29**
Postdoctoral appointees	0.57**	0.58**	0.55**	0.32**	0.03	0.30**

\*\*p<0.05 \*p<0.10

### Regression Results

The multiple linear regression allows analysis of the independent variables in one model so as to control for contextual variables such as institutional control, land-grant status, and having a medical school. Six regressions were carried out with overall, teaching, research, citations, industry, and international outlook THE scores acting as the dependent variable in each model (see Table 3). The overall (adjusted  $R^2 = 0.68$ ), research (adjusted  $R^2 = 0.64$ ), and teaching (adjusted  $R^2 = 0.71$ ) regression models had very strong adjusted  $R^2$  values indicating that the independent variables are explaining a majority of the variance in the model. The citations (adjusted  $R^2 = 0.31$ ) and international outlook (adjusted  $R^2 = 0.41$ ) models were still quite strong with the independent variables accounting for over a third of the variance in the model. The industry income (adjusted  $R^2 = 0.04$ ) model had a very low adjusted  $R^2$  so it will not provide much insight into the factors that need to be considered when attempting to improve the industry income score.

Table 3. THE score regression results

Variable	Overall	Teaching	Research	Citations	Industry	International
Public	-4.79 (0.20)	-3.73 (0.25)	4.06 (0.37)	<b>-4.85</b> <b>(0.08)</b>	2.94 (0.72)	-3.41 (0.26)
Land-grant	-2.97 (0.49)	4.50 (0.31)	2.29 (0.71)	<b>-6.52</b> <b>(0.08)</b>	-14.77 (0.17)	1.18 (0.77)
Medical school	0.90 (0.77)	<b>8.94</b> <b>(0.02)</b>	1.09 (0.83)	<b>-5.85</b> <b>(0.06)</b>	-6.70 (0.46)	<b>-7.89</b> <b>(0.02)</b>
Endowment	0.00 (0.76)	0.00 (0.50)	0.00 (0.94)	0.00 (0.59)	0.00 (0.75)	0.00 (0.99)
Alumni giving	0.00 (0.52)	0.00 (0.78)	0.00 (0.83)	0.00 (0.89)	0.00 (0.82)	0.00 (0.85)
SAT score	<b>0.01</b> <b>(0.04)</b>	<b>0.02</b> <b>(0.03)</b>	<b>0.02</b> <b>(0.05)</b>	0.00 (0.58)	0.00 (0.89)	<b>0.01</b> <b>(0.06)</b>
National Academy Members	<b>0.15</b> <b>(0.00)</b>	<b>0.19</b> <b>(0.00)</b>	<b>0.21</b> <b>(0.00)</b>	0.06 (0.13)	<b>0.23</b> <b>(0.06)</b>	<b>0.12</b> <b>(0.01)</b>
Faculty awards	0.45 (0.12)	<b>0.82</b> <b>(0.00)</b>	<b>1.26</b> <b>(0.00)</b>	0.31 (0.15)	-0.70 (0.27)	-0.22 (0.34)
Postdoctoral appointees	<b>-0.01</b> <b>(0.03)</b>	<b>-0.02</b> <b>(0.00)</b>	<b>-0.02</b> <b>(0.00)</b>	0.00 (0.41)	0.00 (0.77)	0.00 (0.96)
Adjusted R <sup>2</sup>	0.68	0.71	0.64	0.31	0.04	0.41

For the overall score, the three indicators that were statistically significant were number of National Academies members, number of postdoctoral appointees, and median SAT score. Whereas median SAT score has a slight positive association with the overall score and number of postdoctoral appointees has a slight negative association, the number of National Academies members has a strong positive association. The positive association of the National Academies members holds true across all of the subcomponent scores.

The teaching and research scores have significant associations with SAT scores, number of National Academies members, faculty awards, and number of postdoctoral appointees. Faculty awards were particularly strong when it came to the teaching and research scores, so those universities that have faculty receiving prestigious awards are also ranked highly in terms of teaching and research. As for the overall score, there is a slight positive relationship with median SAT score and slight negative relationship with number of postdoctoral appointees. More research needs to be done to understand why a higher number of postdoctoral appointees would be associated with a lower teaching score. One difference in the results between teaching and research scores was that having a medical school was statistically significant for the teaching score, having a large positive impact.

The citations score was influenced by institutional control, land-grant status, and having a medical school. All three had a negative statistically significant relationship with the citations score so that being a public land-grant with a medical school has a much lower citations score than private non-land-grants without medical schools. The medical school finding is surprising given the intensity of research that medical schools conduct. More research needs to be conducted to understand if the quantity of research at medical schools does not translate in high numbers of citations. The international outlook score was similarly

negatively influenced by having a medical school. The domestically oriented nature of medical schools may contribute to lower levels of collaboration internationally. Although there is evidence of many medically oriented international collaborations. Again, this is an area for further research. The international outlook score also had significant associations with median SAT scores and number of National Academies members. Whereas SAT scores only had a slight influences, the number of National Academies members again was shown to important in this area.

Finally, the industry income score only had a significant association with number of members in the National Academies. Given the low adjusted R2 value for this model, there is need to better understand what contributes to increased industry income by the university.

## Discussion

Overall these findings indicate that the quality of the faculty and students that attend the university is reflected in THE scores. Number of members in the National Academies, faculty awards, and median SAT scores were all significantly associated with multiple subcomponents and the overall THE score. In this section, we will discuss how the literature suggests achieving these goals. Improving the overall THE score involves addressing each of the subcomponent scores. Schools in the top 100 THE have well established faculty members that are conducting the type of research that is awarded by a variety of programs and leads to membership in the National Academies. These findings indicate that it is the quality of the faculty, staff, and students that are particularly important to THE scores.

Quality is a nebulous term that can be measured in a number of ways but THE focuses not on the quantity of research output but instead on those factors that indicate highly

competitive and impactful research. Although Virginia Tech is significantly below highly ranked schools in terms of a number of important indicators, such as endowment, alumni giving, SAT scores, and postdoctoral appointees, those indicators are not necessarily linked with a higher THE score. Whereas endowment and alumni giving are not at all significantly related to the overall THE score, the number of postdoctoral appointees only has a slight negative impact. Therefore, careful analysis is required to really tease out those indicators that may impact THE scores. The prominence of membership in the National Academies in impacting both the overall THE score and all other subcomponent scores except for citation implies that prestige afforded by institutions of power is an important consideration when attempting to improve THE scores. Similarly, membership in the AAU had a significant impact on THE scores. Such a membership takes into consideration a variety of factors, some of which overlap with THEs own scores but it also goes beyond those factors. There is an institutional, reputational component that is quite important. This is reflected in both the importance of AAU membership and faculty membership in AAU. This argument does not build a causal case that AAU membership leads to a higher THE score, but rather that there is an association that includes multiple components, which encompass something greater than the individual components themselves.

A surprising finding is that having a medical school is not necessarily beneficial to THE scores, as indicated by the strong negative relationship between having a medical school and citations score as well as having a medical school and the international outlook score. The medical school, as an institution, has characteristics that are important to improving the university and society. In a global ranking system, however, focused on international collaborations and deeply impactful scientific work, the medical school does

not seem to be necessarily associated with an improved score. This is an area that requires further research.

These findings indicate that Virginia Tech has the capacity to move up the rankings. Although Virginia Tech is below the top 100 and 200 ranked schools, it has some National Academies members, is a powerful research institution that has is on a trajectory of change, and improves upon the academic quality of incoming freshman every year. By focusing on those characteristics that seem to be particularly weak for the university, Virginia Tech can improve its overall THE score (see Table 4). Table 4 presents the THE subcomponent scores for Virginia Tech, overall average of the top 400 ranked universities, as well as the difference between the two from the year 2011 to 2014. Although Virginia Tech is very close to the average in regard to the THE teaching score and the THE research score, it is significantly below the average in terms of the THE citations score and THE international outlook score. Although it had a much lower industry score, it experienced a big jump between 2012-2013 and 2013-14. For this reason, the remainder of this paper will focus on the specific THE subcomponent scores that have been the most problematic for Virginia Tech: THE citations score and THE international outlook score. Citations is a particularly important area where Virginia Tech falls behind in comparison to universities in the top 100 or 200 of THE because it accounts for 30% of the overall score.

Table 4. 2011 - 2014 THE subcomponent scores: Virginia Tech, overall average, and the difference

THE Scores	2011-2012			2012-2013			2013-2014		
	VT	Avg	Δ	VT	Avg	Δ	VT	Avg	Δ
Teaching Score	36.9	37.8	0.9	38.5	41.7	3.2	33.7	37.3	3.6
Research Score	40.4	35.9	-4.5	44.4	40.8	-3.6	40.4	35.6	-4.8
Citations Score	30.3	57.3	27	37.2	65.3	28.1	38.7	66.5	27.8
Industry Score	24.2	46.9	22.7	27.9	50.2	22.3	42	50.8	8.8
International Score	25.1	51.3	26.2	27.8	52.4	24.6	27.5	54.3	26.8



### *Citations and international outlook score*

THE's international outlook score, in addition to including international coauthorship, measures the ratio of international students and staff to domestic students and staff at the university. The United States higher education system may be difficult for students to navigate, so universities have been using a myriad of methods to reach out to international students. Where the 2013 *Report of the Commission on International Student Recruitment* highlights problematic recruitment methods, it also points to the importance of recognizing the cultural context of the students that a university is trying to attract. The role of parents in decision-making in some cultures may mean having recruitment methods that are oriented to more than just the student. "The cultural contexts from which students and their families make their decisions vary significantly from country to country and institutions often lack knowledge of these cultural features in trying to recruit" (NACAC, 2013, p. 11). If Virginia Tech is interested in improving international student recruitment, it can begin to learn from other universities that employ culturally appropriate recruitment methods. Although NACAC warned of the potentially problematic nature of recruitment agencies abroad, it also recognized that mechanisms of recruitment situated within foreign contexts may be more effective for attracting international students because it can be in the language of not only the student but also the family (NACAC, 2013). Like the finding for citations, public awareness is essential for student recruitment. THE itself provides a forum for students to learn about universities. University collaborations and partnerships located in other countries will similarly act to introduce international students and faculty to Virginia Tech. Individuals already acquainted with the university due to their work on other projects are more likely to consider it as a site for study. In this way, including recruitment efforts

when undertaking international partnerships can be an efficient way to recruit student and faculty abroad.

Universities interested in increasing international faculty recruitment need to explicitly focus on this as a strategic goal. Drexel University is interested in attracting international faculty so it has listed it in the guidelines as one of the considerations during a faculty search (Drexel University, 2015). In addition, it has made it easier for international faculty to imagine coming to Drexel by creating resources such as the, *Drexel University Guidebook for International Faculty: A Practical Guide to Working at Drexel and Living in Philadelphia* (Drexel University, 2013).

Virginia Tech's THE citations score is particularly problematic in comparison to those universities in the top 200. Therefore, this is an area where Virginia Tech is in particular need of improvement. There is a combination of broader structural changes that contribute to improved citations as well as efforts that can be taken by individual authors. Intervention across this spectrum of the institution is in order to significantly increase citations for a large university such as Virginia Tech.

At the institutional level, evidence suggests that collaborative coauthored papers, especially those involving international coauthors have higher citation rates when compared to single authored papers or papers with authors originating in a single country (Aksnes, 2003). Virginia Tech's goal of becoming a global land-grant university that fosters interdisciplinary work, therefore, is well aligned with the goal of increased citations. Through greater collaboration, especially with parties from other countries, researchers will have a higher likelihood of increasing citation rates. An increase in internationally coauthored work will also improve Virginia Tech's international outlook score since the

number of internationally coauthored publication is one of the indicators used to calculate the score. As the university builds relationships with institutions abroad and focuses its resources on simplifying access to international partners, global collaboration is more likely to occur. These broader, structural changes will ease the way for individual faculty and departments to initiate the type of collaboration that leads to multinational coauthored work.

Similarly, papers with coauthors have more citations than papers without coauthors (Aksnes, 2003). While the number of coauthors differs by field, coauthorship is also a reflection of the degree of collaboration taking place within an institution, department, or school. Virginia Tech is already moving in the direction of encouraging collaboration because of its focus on interdisciplinarity. Federal funding agencies have also been encouraging interdisciplinary research and often have grant requirements for team members across disciplines. While a greater level of collaboration across disciplines is a goal that the university has been pursuing for many years, the outputs of this goal need to include coauthored publications in order to influence the citation score. Collaboration is important to the university for many reasons and can have a variety of outputs, but in order to influence Virginia Tech's THE ranking, there is a need to place an emphasis on generating coauthored publications.

Scholars have found that exposing academic publications to a wider audience is also associated with an increase in citations (Ebrahim et al., 2013). This is an action that can take place at both the individual author level as well as at the institutional level. At the institutional level, communication with the broader public can focus on highlighting work done by scholars. Likewise, general access publications and websites focused on the innovative work of a department, school, or college can increase awareness of the work.

While Virginia Tech currently has a multitude of venues for communicating the work of researchers, strategically focusing on those areas where citations are particularly low may have an outsized influence. The university can create an open repository of publications so that individuals have access to the articles for free. Harnad (2006) finds that free access to articles increases citations by more than 50%. If not an open repository, the institution can incentivize faculty members to create personal websites that have links to their publications. If ease of access to articles is important to citations, then personal websites provide a forum for researchers to better understand the research profile of a given scholar which may increase their use of the scholar's work in their own research. Similar to increasing access to the article itself, Piwowar et al. (2007) have found that making the research data itself available is associated with increased citations. Overall, these findings indicate that accessible research that transparently shares the data, an understanding of the research profile of the scholar, and the research output are positively associated with citations.

Scholars need to take the next step with their research, after it is published, by sharing it with those outside of their discipline.

At the individual level, there are specific ways of improving citation frequency, as summarized by Ebrahim et al. (2013), to include a "unique name," using the article's keywords in the text for the abstract, and the author posting the articles online so they are accessible and free. Like the university would do as an institution, scholars themselves can place publications in existing open access repositories, personal websites, and other online sources that will expose it to a wider audience. Also at the individual level, Corbyn's (2010) analysis of 50,000 papers found that the greater the number of references the higher the citation record for a given paper. She does not yet have evidence for a causal pattern

between referencing and citations but partly attributes this finding to “reciprocal altruism.” For the scholar trying to increase citations, including additional references might be a useful and simple way to do so. A combination of concrete steps by the university and individual scholars as well as a capacity to generate deeply impactful research will likely lead to increased citations.

This discussion of methods of improving specific THE subcomponent scores as well as the specific characteristics of highly ranked THE universities provides a starting point for Virginia Tech to consider how it can improve its THE ranking. Virginia Tech’s drastic improvement on the THE industry score is evidence that the university can improve its score. By focusing on improving the citations and international outlook scores, it can begin to move up on the subcomponents in which it is especially weak. In addition, the importance of faculty membership in the National Academies, faculty awards from prestigious programs, AAU membership, and the quality of incoming students provides a sense of the characteristics of highly ranked universities that Virginia Tech needs to consider.

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