Extra Credit Analysis of Undergraduate Engineering Students

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Abstract

At US universities, a large number of degree-seeking undergraduate students graduate with a higher number of credit hours than is required for graduation, thereby accumulating extra credits. We present a detailed analysis of the extra credit usage pattern of undergraduate engineering students at a large public flagship university using custom analytical tools. Although it is unclear that all extra credits are unwanted or avoidable, they can cause increased time-to-graduation, increased cost of education, delayed entry into the workforce, lower graduation rates, etc., and are thus often believed to be undesirable. However, there is a dearth of studies that seek to explain the credit hour usage pattern of university students. The paucity of studies can be attributed to the use of inflexible and/or opaque commercial degree audit tools at universities, which curtails the possible scope of analytics on degree audit data. Consequently, such studies are generally limited to comparing overall credit numbers such as the total credits earned by the student, the credits required by the student's specific degree program at graduation, etc., and do not consider the usability of individual credits towards the degree program requirements. In this paper, we employ a credit-tree framework for analyzing the extra credit accumulation patterns. A custom-built specialized audit tool was used to (automatically) assign student credits to one of three categories: unusable credits, which do not match any degree requirement; excess credits, which can be removed without changing the requirement satisfaction; and applied credits, which contribute to requirement satisfaction without excess. It is obvious that this facilitates credit analysis at the course and degree-requirement level, which is key to studying the factors affecting credit efficiency. We pursue the following bifold objective: understanding the composition of extra credits in terms of their constituents, i.e., unusable and excess credits, and revealing the factors influencing extra credits. We present an extensive analysis of the widely perceived factors responsible for extra credit accumulation such as transfer credit loss, program (major) change, hidden (prerequisite) requirements, repeated classes, remedial classes, financial incentives (to maintain scholarship), leisure classes, etc. As a conclusion to our analysis, we present a comparison of engineering school results to that of campus-wide results to uncover similarities (or dissimilarities) in extra credit accumulation patterns. The results reveal that although engineering and campus-wide students accumulate a similar number of extra credits, their composition is different. We would like to note that the methods used in this analysis, although applied to the data from a specific university, are generally useful for credit-hour analysis.

1 Introduction

Credit hours are a metric of time spent by a student in the classroom [4]: one credit hour equals one hour in class every week for one semester [21, 11]. As per the requirements of all the regional accrediting agencies in the US, a bachelor's degree is constructed out of a minimum of 120 credit hours [21]. However, a large number of degree-seeking undergraduate students graduate with a

higher number of credit hours than is required for graduation, having accumulated *excess* credits. According to a study done by Complete College America [6] on data provided by 33 states, students accumulated 16.5 credits (a semester of coursework) in addition to the 120-credit-hour requirement. There were five states with students graduating with 24 or more hours of *excess* credits (almost a year of coursework); this demonstrates the severity of the problem. Cullinane's Ph.D. dissertation [8] analyzed 2003-2012 statewide data from Texas and reported that students attempted 135 credit hours, on average, to graduate. Numerous other studies have painted a similar picture of excess credit accumulation [11, 23, 14, 15].

This has attracted attention from university and government administrators alike because credit hours presumably have direct relevance for student success and finances as well as for public finances. Excess credits are accompanied by an increase in time–to-degree [16] [1] [8], and a bachelor's-degree-seeking student can expect to pay $68,153 in cost of attendance and lost wages [7] for an additional year of college. As for the public cost of extra credits, if all bachelor's students pursued just three extra credit hours beyond their degree requirements, it would result in an annual expense of $1.5 billion for Americans [7]. A 2004 study by the Council of State Governments in Florida found that around $720,000$ surplus credit hours cost the state $62 million [17]. The significance of the issue is underscored by the adoption of *Excess Credit Hour (ECH)* policies in numerous states, designed to discourage the accumulation of *excess* credits by imposing additional tuition fees [16]. This discussion assumes further importance when considering STEM students, given the US's demand for them. [12, 3]. Prior research has shown that engineering students are more likely to take longer to graduate [10], and attributed the longer time partly to *excess* credits [14, 11, 10, 15].

In higher-education literature, *excess* credits are often estimated in one of the following two ways: as the credits taken beyond the minimum required by a standard undergraduate degree (generally 120 credit hours), or as the superfluous credits relative to the student's specific degree program at graduation [8, 15]. In this paper, we provide a new definition of *excess* credit hours (introduced by us in [13]) that takes into consideration the *applicability(usability)* of credits towards the degree requirements (refer to Section 3). The more commonly used definition of *excess* credits used so far in this Section will be referred to as *extra* credits from here on in this paper. It is clear that *excess* credits are a subset of *extra* credits. With this in mind, our primary objective in this paper is to explain the extra credit accumulation pattern of undergraduate engineering students. We accomplish this by pursuing the following bifold objective: analyzing the makeup of extra credits by identifying their components and uncovering the elements that affect their accumulation. Following are some of the commonly purported factors responsible for extra credit accumulation in higher education literature: transfer credit loss, unsuccessful course attempts, repeated courses, program (major) change, etc. These factors are perceived to be important contributors for STEM and undergraduate students alike. This leads us to form the following *hypothesis* (assuming engineering is representative of STEM), which we investigate as a secondary objective:

Accumulation Hypothesis: *The extra credit accumulation pattern of undergraduate engineering students is similar to that of campus-wide (all) undergraduate students in terms of the quantity, composition, and factors influencing extra credit accumulation*.

The important contributions of this paper can be summarized thus:

- The quantitative analysis of the composition of extra credits accumulated by engineering students that takes into account the *usability* (explained in Section 3) of individual credits towards the degree program requirements (facilitated by a specialized degree audit tool [13]). Existing works are limited to comparing overall credit numbers or restricted to small populations (such as a department within the engineering school).
- A comparative analysis of the factors influencing the extra credit accumulation of engineering students with respect to campus-wide students. Prior research is limited in comparative assessment, the insights from which can help inform intervention strategies aimed at improving the credit efficiency of STEM students (at institutional and/or government levels).
- A data-driven way to approximate and remove *surplus* credits (explained in Section 3.2) - credits that are not expected to contribute towards the student's degree program and thus can potentially bias the analysis, e.g., Transfer students starting out with more credits than required by their intended degree program contribute to *surplus*.

This work is currently limited to graduated students. Our initial findings, using actual data from a large public (Research 1[2]) university, showed that only 1.5% of the students graduate with 0 extra credits. Moreover, three quarters of the students graduated with at least 15 extra credits, and half of the students graduated with at least 30 extra credits. This is similar to the findings reported at a similar university in [15], where 91% of the students graduated with non-zero extra credits. In contrast, when it comes to engineering students, all but one graduated with non-zero extra credits, and they had a significantly higher number of extra credits (three quarters with 26, and half with 42 extra credits). The remainder of this paper is organized as follows: Section 2 provides a brief summary of background work done in this area. Section 3 gives an overview of the data framework and related tools used to carry out this analysis and also provides a high-level discussion of the methods and definitions used in this analysis. Section 4 presents the various analyses conducted with actual student data, results obtained, and discussion of results. Finally, Section 5 presents concluding remarks and future work.

2 Background and motivation

Administrators know some reasons for more-than-required credit hours (e.g., transfer credits that did not apply towards graduation, courses that could not be applied towards graduation due to insufficient grades, courses that did not satisfy any requirement in the student's degree program, addition of a minor or second major, or a student simply having more courses that can be applied toward the degree program than required), but don't have data to reveal their prevalence or relationships. For example, change of major, large number of transfer credit hours, and working towards a second major/minor were found to be causes for *extra* credit hours in a study analyzing student academic records [14]. Zeidenberg found that among successful degree completers, *extra* credits formed about 12% of total credits at college level (not including developmental or failed courses) [22]. Zeidenberg laid out the following as possible reasons for *extra* credits at community colleges: uncertainty regarding the desired program of study coupled with limited

advising, change of major, course scheduling issues, and transfer courses [22]. *Course transferability* is perhaps the most-studied factor influencing *extra* credits in educational literature [9, 20, 23, 8]. A common pattern seen in these studies is the comparison of *extra* credit accumulation between native (or direct-entry) students and Transfer students. Fink et al. used data mining techniques in their study to find a correlation between the course-taking pattern of a student and accumulation of *extra* credits [9]. An NCES report [18] revealed that 30% of students change program (major) within the first three years, and 10% change it more than once. Kilgore et al. recently conducted a large-scale study [15] that investigated *extra* credit accumulation using frequently used variables in literature (such as demographic, institutional, and financial) and revealed that "...these variables do not contribute much to an understanding of why students have extra credits at graduation." This is one of the few existing studies that address the issue of evaluating factors responsible for extra credit accumulation directly, and it still falls short in providing a conclusive answer underlining the complicated nature of this problem. We note that the use of our specialized audit tool [13] helps us to perform credit analysis at the course and degree-requirement level, which we believe significantly improves the capability to study factors affecting credit efficiency. Moreover, this tool alleviates the constraint of scale imposed by manually analyzing student transcript data, noted in [20, 9]. Kilgore et al. also reported that being a STEM major at graduation was positively correlated with *extra* credit accumulation [15], indicating that STEM students are more likely to graduate with *extra* credits. This result can be extended by a quantitative analysis of the rate, and composition, factors influencing extra credits accumulated by STEM students in comparison to campus-wide (all) students. As mentioned in Section 1, we pursue this direction through investigation of the *accumulation hypothesis*.

3 Methodology

The audit tool solves an optimization problem that matches classes to degree requirements in a way that maximizes the number of applied credits, subject to the constraints that a) each class is matched to at most one requirement and b) no excess credits are attributed to any requirement. The specialized audit tool produces a decomposition of student credits as follows: *applied*, *unusable*, and *excess*, where *applied* credits count towards the student's degree requirements, *unusable* credits do not count towards any degree requirement, and *excess* credits exceed one or more degree requirement specifications. A credit-tree framework was realized using the credit decomposition produced by the audit tool [13, 19] for the purpose of credit efficiency analysis. We will now provide a brief overview of the credit-tree framework, followed by a concise summary of *surplus* (and *separate*) credits, and then present a concise summary of the methods and definitions used for the extra credit analysis.

3.1 Credit-tree framework

The credit-tree model of categorization [19] is aimed at facilitating the credit efficiency analysis of a student or a cohort of students in navigating their degree at an institution of higher education. Fig. 1 shows the visualization of the credit hour categorization. A brief description of categories is as follows:

- NON-ARTICULATED: Attempted credits from other institutions that do not count at the student's degree-granting institution, e.g., vocational courses [20], remedial courses, etc.

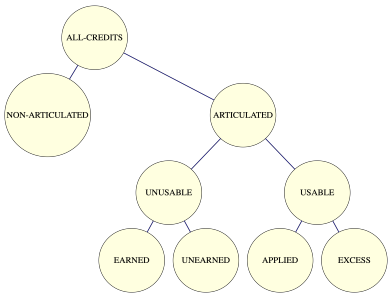


Figure 1: Student tree with the credit hour *categories*.

- ARTICULATED: Attempted credits that count at the student's degree-granting institution for something (includes courses that do not count towards that student's specific degree), e.g., any course at the degree-granting institution, any course successfully transferred to the degree-granting institution, course credits obtained by testing out of a course, etc.
- UNUSABLE: Articulated credits that cannot count towards any requirement in the chosen degree program. Any articulated course can end up in this category.
- UNUSABLE-EARNED (UE): Unusable credits that the student *earned*, i.e., successfully completed by fulfilling the minimum passing requirements of the course.
- UNUSABLE-UNEARNED (UU): Unusable credits that the student attempted but did not earn credit for. Failed courses, remedial courses, repeated courses, etc., are examples of of the types of courses that make up this category.
- USABLE: Articulated credits that can count towards one or more requirements in the degree program. These are all *earned* credits.
- APPLIED: Usable credits that contribute to the completion of the degree program without excess.
- EXCESS (Ex): Usable credits that do not contribute to the completion of the degree program because their contribution to individual requirements exceeds the number of credits required to satisfy these requirements.

Extra credits: Credits not *applicable* towards a student's degree requirements are defined as extra. The extra credit category is composed of unusable-earned, unusable-unearned, excess, and non-articulated credit categories. It was apparent in the early stages of our analysis that around 98.5% of transfer credits get successfully articulated at the university under study, so they are negligible and safe to remove from the analysis.

3.2 Surplus credits

The maximum number of transfer credits applicable at universities can be estimated as the difference between credits required by the degree program and credits owed to a residency requirement [5], which usually turns out to be 90 credits at most universities. Our data shows that about 30% of Transfer students come in with more than 90 transfer credits, which can be observed from the histogram in Fig. 2(a). Regardless of the credit type and intended degree program, not

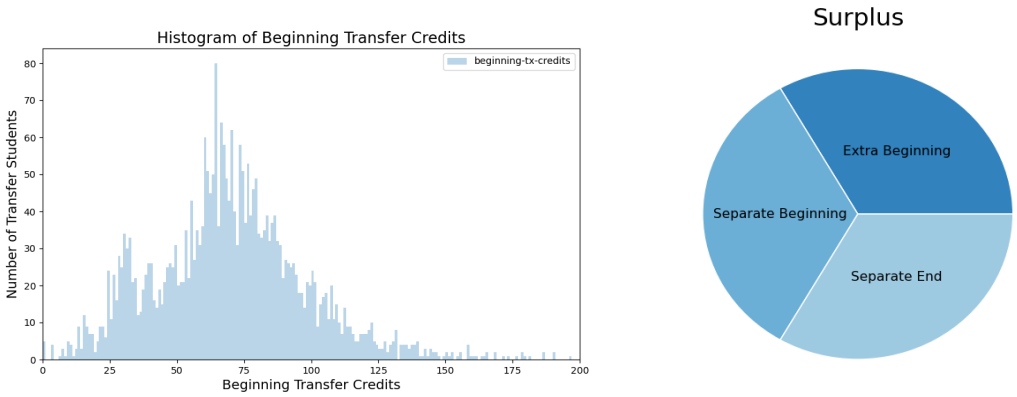


Figure 2: (a) Beginning transfer credits for campus-wide Transfer students (left), and (b) constituents of "surplus" credits (right)[19].

all of these transfer credits can be applied towards a Bachelor's degree, leading us to the concept of "separate" and "surplus" credits [19]. Credits that are accumulated for some other attempted or completed degree and are not reasonably expected to be applied to the current degree are defined as "separate" credits. The separate credits can accrue at the beginning or end. Credits accumulated before starting an undergraduate degree program (e.g., transfer credits exceeding 90) and credits taken towards an advanced degree before officially graduating from an undergraduate degree are examples of beginning- and ending-separate credits, respectively. It is easy to see that separate credits can be a source of bias in extra credit analysis, and thus should be excluded from the analysis. Transfer students are much more likely than Non-Transfer students to have beginning-separate credits.

Ending-separate credits can be approximated as the non-applied ending credits that could be applied to a graduate degree. However, identifying and pulling out beginning-separate credits can be non-trivial. Let us introduce "surplus" credits to help with beginning-separate credits approximation. Surplus credits can be defined as credits that are not expected to contribute to the Bachelor's degree at the time the student enters the university [19]. They can be estimated by running the specialized audit tool [13] against all the courses accumulated by the student prior to joining the university, with the number of applied credits restricted to to a maximum of

$$\begin{aligned} max\ \textit{applied}\ credits = \textit{credits required by the degree program} \\ - \textit{credits owed to residency requirement} \end{aligned}$$

The audit run produces a set of *applied** and *extra** credits. The *extra** credits are an estimate of the beginning-surplus credits (which is composed of beginning-separate and beginning-extra credits), and the total surplus can be estimated as a sum of beginning-surplus and ending-separate credits. Fig. 2(b) illustrates the constituents of surplus credits.

3.3 Analysis overview

Surplus credits were identified and extracted from our dataset using the procedure described in Section 3.2 (with the maximum applied credits set to 90). Then we run the specialized audit tool

against the *filtered class list* (original student class list with all the surplus classes removed) to produce a new set of unusable-earned, unusable-unearned, and excess credits. This will correct the bias caused by separate credits. In fact, this led to a 10% and 17% decrease in the percentage of students with excess and unusable credits, respectively. An initial investigation into the category of credits labeled as unusable-unearned highlighted that courses taken more than once played a significant role in the accumulation of unearned credits. At the university under study, such repeated courses fall into two distinct categories: those where credit is awarded for only one completion of the course, and those where credit is given for each time the course is completed (with ”completion” referring to the finishing of a course within a specific time frame). The first category is referred to as “pre-audit repeated courses,” while the second category is referred to as “in-audit repeated courses.” A notable number of these pre-audit repeated courses were passed successfully. Going forward, these pre-audit repeated courses will be excluded from further analysis and considered separately. As for the in-audit repeated courses, less than 1% of the students in this study had them, and thus we can reasonably conclude them to have negligible contribution towards extra credits.

Following are some definitions important to the procedure and results of the analysis:

- *Extra Credits*: The constituent extra credit categories are: unusable-earned (UE), unusable-unearned (UU), and excess (Ex).
- *Credit Types*: Total, transfer, and non-transfer credit *type* in each credit *category* is utilized in our experimentation,
- *Non-zero statistics (NZStats)*: Aggregate credit hour values for any given cohort of students are represented using the non-zero median simultaneously with the percentage of non-zero credits in this analysis. We refer to this non-zero statistics pairing as NZStats in this paper. NZStats stems from the wider use of non-zero order statistics in our credit hour analysis studies, which we found to be a more representative measure of our credit hour data given the high occurrence of both zeros and large numbers in the various credit hour categories.

The analysis only involves graduated students from the university under study. Although the data from a specific university was used to conduct the analysis in this paper, the analyses can be easily replicated for other higher-education institutions given the general characteristic of the specialized audit tool that served as the facilitator of this analysis. The quality of the analysis is dependent on the input to the audit tool. Furthermore, the analysis results can be representative of other similar higher-education institutions in the US.

4 Experimentation

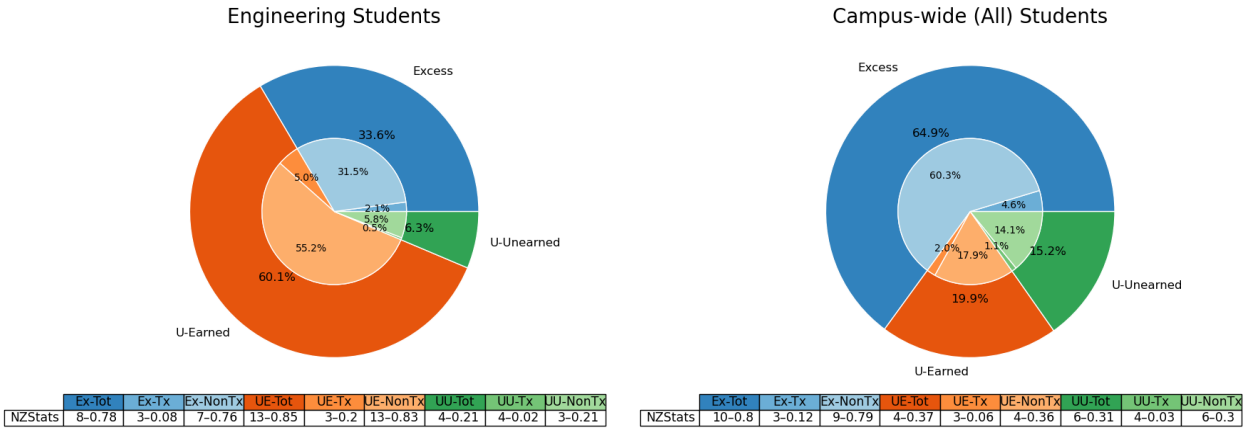
The experimentation and results discussed in this section address the objectives stated in Section 1: to explain the extra credit accumulation pattern of engineering students, and to investigate the *accumulation hypothesis*. To that end, we start with studying the composition of extra credit categories for undergraduate engineering students. Thereafter, we examine the following important factors widely perceived to be responsible for extra credit accumulation for “engineering (engg) students cohort,” and contrast it with that of “campus-wide (all) student

cohort": transfer credit loss, program (major) change, prerequisite (hidden) requirements, repeated credits, and remedial courses. As mentioned in Section 3.3, all the experiments were performed using *filtered* data.

4.1 Dataset

Actual transcript data of Bachelor's-degree graduated students from a large public (R1) university was used for experimentation. The campus-wide dataset includes 11038 students that graduated between Fall 2015 and Summer 2022 from this university, 999 of which were engineering students. The campus-wide (all) student cohort encompassed 114 different degree programs. The number of campus-wide *Transfer* students (students that transferred into the university under study) in the dataset was 3015, out of which 263 were engineering. Following are a few notable raw statistics among the engineering graduates: 971 graduated with greater than 0 extra credits, 778 graduated with greater than 0 excess (Ex) credits, 852 of them graduated with greater than 0 unusable-earned (UE) credits, 211 of them graduated with greater than 0 unusable-unearned (UU) credits, and 688 of them had at least one program (major) change prior to graduation.

4.2 Composition of extra credits



	Ex-Tot	Ex-Tx	Ex-NonTx	UE-Tot	UE-Tx	UE-NonTx	UU-Tot	UU-Tx	UU-NonTx
NZStats	8–0.78	3–0.08	7–0.76	13–0.85	3–0.2	13–0.83	4–0.21	4–0.02	3–0.21

(a)

	Ex-Tot	Ex-Tx	Ex-NonTx	UE-Tot	UE-Tx	UE-NonTx	UU-Tot	UU-Tx	UU-NonTx
NZStats	10–0.8	3–0.12	9–0.79	4–0.37	3–0.06	4–0.36	6–0.31	4–0.03	6–0.3

(b)

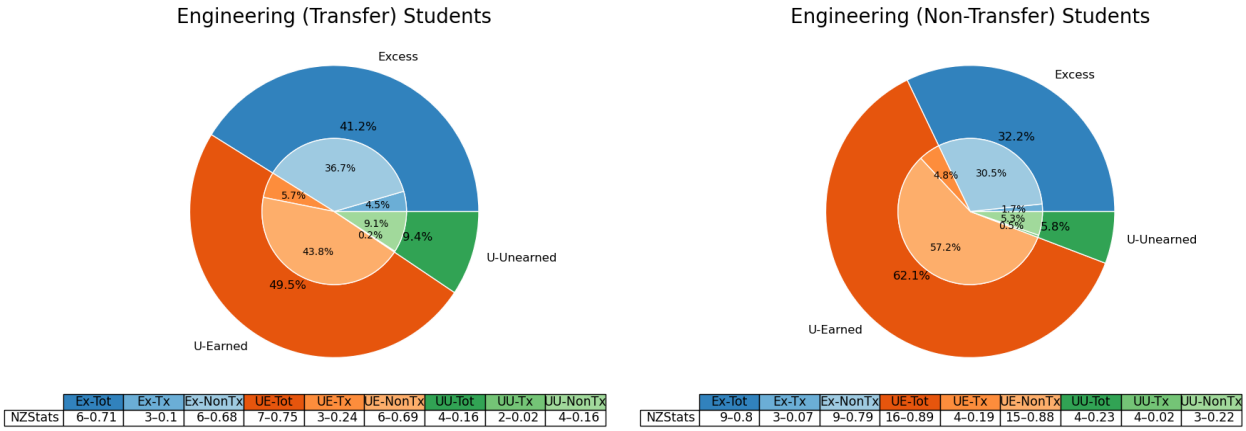
Figure 3: A breakdown of extra credits into their constituent categories for (a) engineering students (left), and (b) campus-wide (all) students (right). The outer ring in the charts represents the *total* credits, whereas the inner pie breaks down the *total* credits into *transfer* and *non-transfer* credits. The data table displays NZStats with each cell formatted as "$x - y$," where y is the fraction of students with non-zero credit value and x is the median of these non-zero credit values.

Ninety-seven percent of engineering students graduate with some extra credits, and about half of them graduate with at least 20 extra credits. In terms of the makeup of extra credits, a quick glance at Fig. 3(a) shows that UE is the dominant extra credit category in engineering, and that too by a considerable margin. Around 85% of engineering students graduate with UE credits, and about half of them accumulate about 13 UE credits – almost a semester's worth of coursework that the students earn credits for, but is not *usable* towards their degree program. Furthermore, the *non-transfer* credits seem to dominate the UE credit category, with 83% of the students having

non-zero UE *non-transfer* credits, accumulated with a non-zero median of 13 credits. Ex follows behind UE as the second dominant category, with its NZStats at $(8, 78\%)$, i.e., 78% of engineering students accumulated Ex credits with a non-zero median of 8. UU is the smallest extra credit contributor for engineering students.

In contrast, 88% of campus-wide students graduate with 15 non-zero median extra credits, indicating that engineering students accumulate almost 2 more courses worth of extra credits compared to the whole university population taken together. Composition of extra credits is another striking dissimilarity between campus-wide and engineering students. Ex credit category, with NZStat of $(10, 80\%)$, is the dominant extra category for campus-wide students, followed by UE, and then UU. The results in this section do not seem to agree with the *accumulation hypothesis* – engineering and campus-wide results differ both in terms of the quantity and composition of extra credits. Let us now explore factors influencing extra credit accumulation.

4.3 Transfer credit loss



	Ex-Tot	Ex-Tx	Ex-NonTx	UE-Tot	UE-Tx	UE-NonTx	UU-Tot	UU-Tx	UU-NonTx
NZStats	6–0.71	3–0.1	6–0.68	7–0.75	3–0.24	6–0.69	4–0.16	2–0.02	4–0.16

(a)

	Ex-Tot	Ex-Tx	Ex-NonTx	UE-Tot	UE-Tx	UE-NonTx	UU-Tot	UU-Tx	UU-NonTx
NZStats	9–0.8	3–0.07	9–0.79	16–0.89	4–0.19	15–0.88	4–0.23	4–0.02	3–0.22

(b)

Figure 4: A breakdown of extra credits into their constituent categories for (a) Transfer engineering students (left), and (b) Non-Transfer engineering students (right). The outer ring in the charts represents the *total* credits, whereas the inner pie breaks down the *total* credits into *transfer* and *non-transfer* credits. The data table displays NZStats with each cell formatted as "$x - y$," where y is the fraction of students with non-zero credit value and x is the median of these non-zero credit values.

Transfer credit loss is probably the most widely studied factor affecting extra credit accumulation. Fig. 4(a) and Fig. 4(b) show the extra credit breakdown for Transfer vs. Non-Transfer engineering students. It can be observed from Fig. 4 that UE continues to be the preeminent extra credit category, followed by Ex, and then UU. *Non-transfer* credits dominate each of the constituent extra credit categories for both Transfer and Non-Transfer students. It can be further discerned from Fig. 4(a) and Fig. 4(b) that Transfer students have lower NZStats for Ex and UE categories (for each credit *type*, i.e., *transfer* and *non-transfer* credits) as compared to Non-Transfer students, and comparable UU credits. This suggests that Transfer students accumulate fewer extra credits than Non-Transfer students. The results indicate that transfer

credit loss is not a contributor to extra credit accumulation. This is also consistent with our finding for campus-wide students in an earlier work [19].

4.4 Program Change Analysis

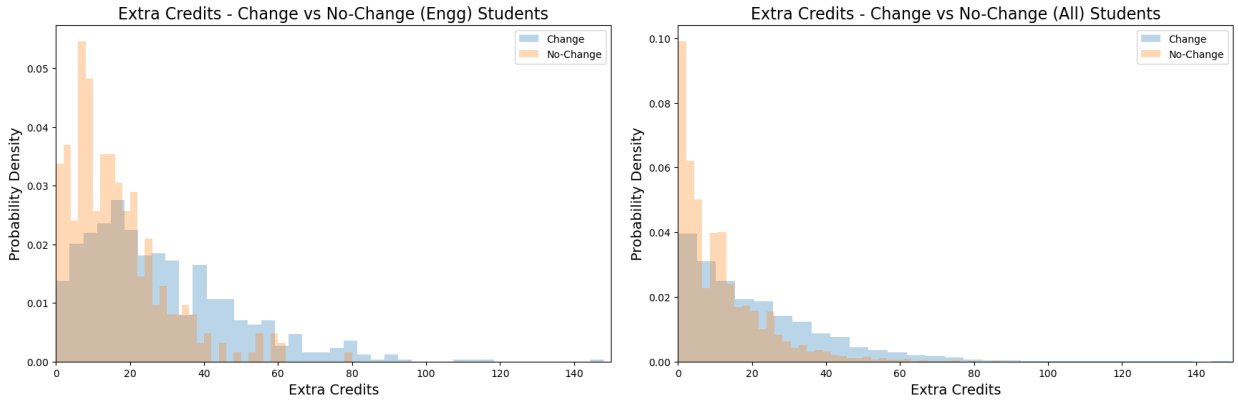


Figure 5: Comparison of *extra* credit distribution between (a) engineering students (left), and (b) campus-wide (all) students (right). Additionally, each chart contrasts the *extra* credit distribution between the Change and No-Change students.

Program (major) change is considered to be a major source of extra credits in the higher-education literature. Students accrue many credits specific to the program-specific degree requirements, which may not be *applicable* towards the degree requirements of the program post switch. Even if some of them are *applicable*, they may still be more than the credit requirement of the new program, thereby producing *excess*. More formally, imagine programs A and B, requiring x and y (respectively) credits of the same type. If a student changes to program B from program A, and $x > y$, excess will be produced. Defining what constitutes a program change may not always be as trivial. For instance, at the university under study, students mostly start as pre-majors (intended majors). We define a program change as [19]:

All program (major) changes, except the one from a pre-major to its corresponding major under the same degree (i.e., BA, BS, etc.), constitute a program (major) change.

Thus, transitions such as pre-major to a different major, pre-major to another pre-major, major to another major, major to a different pre-major, pre-major to a corresponding major but involving a change of degree (e.g., the pre-major was BA and the major is BS), etc., result in a program change. Having established the definition of program change, we evaluate the influence of program change on extra credit accumulation using the following two metrics: "extra credits at graduation," and "extra credits gained after their final program switch." Additionally, we break the students into the following two cohorts: "Change" students with at least one program change, and "No-Change" students with no program change.

More than two thirds (about 69%) of engineering graduates undergo at least one program change, similar to campus-wide students at about 65%. The probability density histograms in Fig. 5(a) and Fig. 5(b) show that Change students are likely to accumulate higher extra credits than

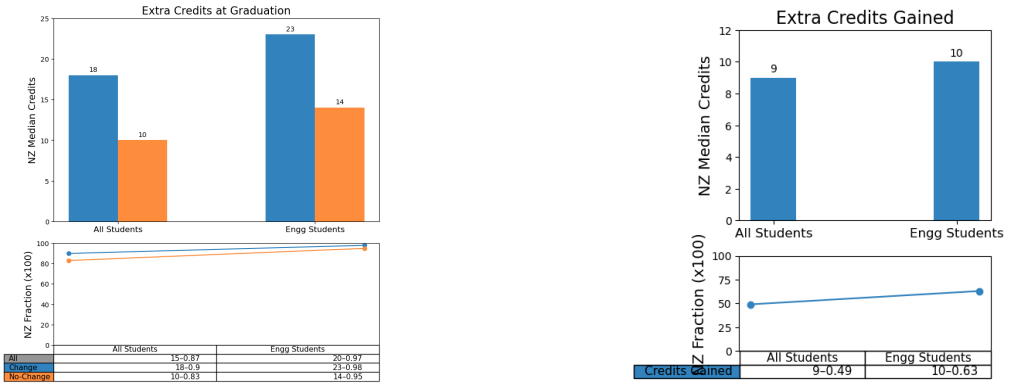
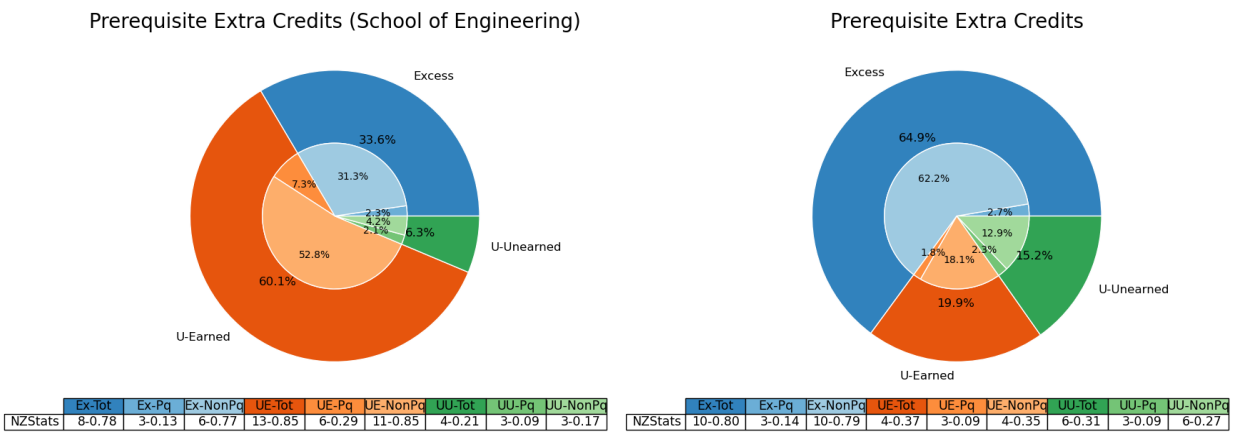


Figure 6: (a) Extra credits accumulated at the time of graduation by all students and engineering students, further broken down into Change and No-Change students (left), and (b) the extra credits gained by Change students and after their final program change (right). The data table displays NZStats with each cell formatted as "$x-y$," where y is the fraction of students with non-zero credit value and x is the median of these non-zero credit values.

No-Change students, for both engineering and campus-wide students. In terms of extra credits accumulated at graduation, the NZStats in Fig. 6(a) shows that Change students graduate with higher extra credits than No-Change students, and that this credit difference is similar for engineering and campus-wide graduates, with 9 and 8 additional credits, respectively. Although similar in terms of the difference between Change and No-Change, the NZStats further reveal that engineering students graduate with noticeably higher extra credits than campus-wide graduates (the non-zero median is higher by 5 credits). As for the Change students, they gain about 3 courses worth of extra credits after transitioning into their final program. Both engineering and campus-wide graduates have similar credit gains of 10 and 9, respectively. We would like to mention here that the time (number of terms) spent in the final program has not been accounted for in this analysis, which may help explain the relatively high extra credit gain after the last change. Over all, the results in this section reinforce the belief that program (major) change is an important contributor to extra credits accumulated by engineering students but is not the sole contributor. Also, the results weakly disagree with the *accumulation hypothesis* with engineering students' accumulation; although program change affects engineering and campus-wide students alike in terms of extra credit accumulation pattern, the engineering students clearly graduate with higher extra credits and gain slightly more after final program change.

4.5 Prerequisite (hidden) requirements

We define requirements that are prerequisites to required classes that do not directly apply to the degree requirement as hidden requirements [19]. We would like to note here that only prerequisites to requirements with *applied* courses were included in this analysis. Such prerequisite credits that end up in the extra category are accumulated by 39% of engineering students, with a non-zero median of 6, affirming the notion that prerequisites contribute to extra credits. In comparison, about a quarter (26%) of campus-wide students accumulate prerequisite extra credits, with a non-zero median of 3, indicating that prerequisites are more influential towards extra credit accumulation in engineering. Figs. 7(a) and (b) reveal the influence of



	Ex-Tot	Ex-Pq	Ex-NonPq	UE-Tot	UE-Pq	UE-NonPq	UU-Tot	UU-Pq	UU-NonPq
NZStats	8-0.78	3-0.13	6-0.77	13-0.85	6-0.29	11-0.85	4-0.21	3-0.09	3-0.17

	Ex-Tot	Ex-Pq	Ex-NonPq	UE-Tot	UE-Pq	UE-NonPq	UU-Tot	UU-Pq	UU-NonPq
NZStats	10-0.80	3-0.14	10-0.79	4-0.37	3-0.09	4-0.35	6-0.31	3-0.09	6-0.27

Figure 7: Composition of prerequisite *extra* credits in terms of constituent *extra* credit categories for (a) engineering students (left) and (b) all students (right). The outer ring in the charts represents the *total* credits, whereas the inner pie breaks down the *total* credits into *prerequisite* and *non-prerequisite* credits. The data table displays NZStats with each cell formatted as "$x - y$," where y is the fraction of students with non-zero credit value and x is the median of these non-zero credit values.

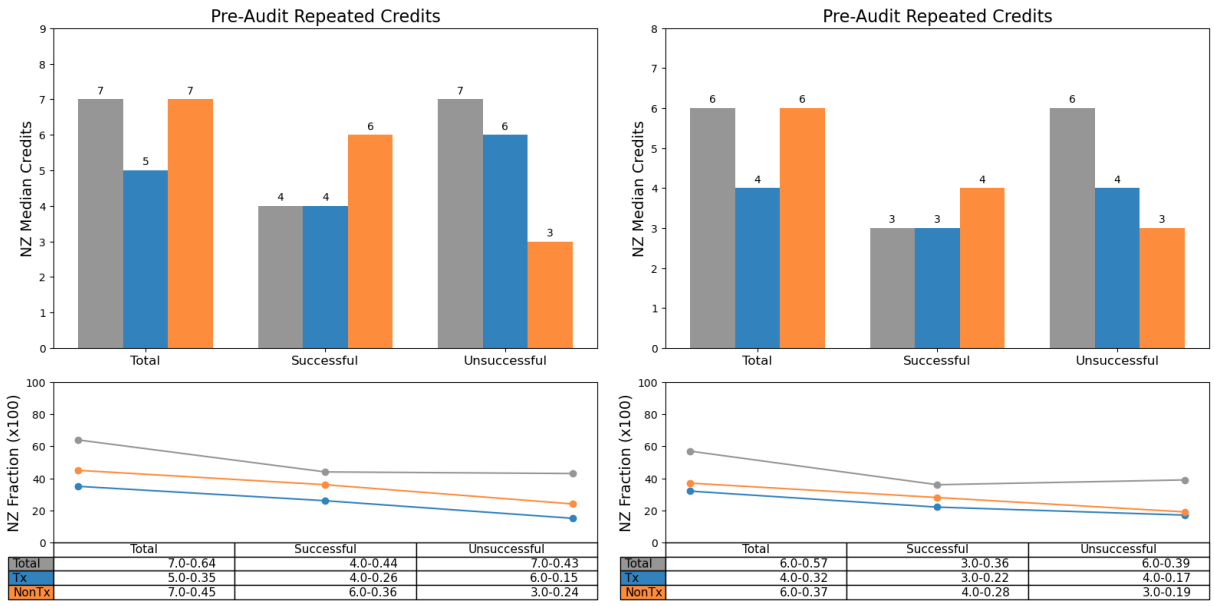
prerequisites within each constituent extra credit category. The NZStats in Fig. 7(a) clearly illustrate that UE is driving the prerequisite extra credits, distantly followed by Ex, and then UU. In contrast, at the campus-wide level, the prerequisite credits contribute quite similarly to the constituent extra credit categories. In terms of sum total credit hours, prerequisites contribute to about 11.6% of the total extra credits, which is almost twice the contribution of prerequisites to extra credits at the campus-wide level (6.7%). The results in this section again somewhat refute the *accumulation hypothesis*, as prerequisites, although a noticeable extra credit contributor for both engineering and campus-wide students, are more influential in engineering.

4.6 Remedial courses

We look into the influence of remedial (or preparatory) courses on extra credit accumulation in this section. Preliminary inspection showed that students are not awarded *earned* credits for successfully completing remedial courses at the university under consideration. Additionally, these credits are also not required by degree programs at the university under study. As a result, these credits end up being constituents of the UU category. Further analysis of the UU catgory revealed that 2% of engineering students accumulated remedial credits, which is even lower than 7% at the campus-wide level, making it safe to deem its effect on extra credit accumulation negligible.

4.7 Pre-audit repeated courses

As mentioned in Section 3.3, we will now present an analysis of the pre-audit repeated courses that we studied separately. To reiterate, these are courses that the students completed multiple times but received credit for only once. It can be observed from the NZStats in Fig.8(a) that almost two thirds (64%) of engineering graduates accumulate non-zero pre-audit repeated credits, with a non-zero median of 7. In comparison, Fig.8(b) shows that 57% of campus-wide graduates



	Total	Successful	Unsuccessful
Total	7.0-0.64	4.0-0.44	7.0-0.43
Tx	5.0-0.35	4.0-0.26	6.0-0.15
NonTx	7.0-0.45	6.0-0.36	3.0-0.24

	Total	Successful	Unsuccessful
Total	6.0-0.57	3.0-0.36	6.0-0.39
Tx	4.0-0.32	3.0-0.22	4.0-0.17
NonTx	6.0-0.37	4.0-0.28	3.0-0.19

Figure 8: NZStats for total, successful, and unsuccessful pre-audit repeated courses, further broken down by *transfer* and *non-transfer* courses, for (a) engineering students (left), and (b) campus-wide (all) students (right). The data table displays NZStats with each cell formatted as "$x - y$," where y is the fraction of students with non-zero credit value and x is the median of these non-zero credit values.

do so with a non-zero median of 6. The NZStats further reveal that *unsuccessful* credits contribute to these pre-audit repeated courses more than successful credits. However, about 44% of engineering students, and more than a third of campus-wide students, graduate with at least one course worth of pre-audit repeated credits. Thus, the results in this section indicate that engineering students are more likely to have repeated credits than are campus-wide students.

5 Conclusion

In this paper, we studied the extra credit accumulation pattern of undergraduate engineering students using actual data from a large public university. We took into account the *usability* of credits towards the student's degree program requirements by leveraging a custom-built specialized audit tool [13] to automatically allocate student credits to one of three categories: unusable credits that do not match any degree requirement, excess credits that can be removed without changing the requirement satisfaction, and applied credits that contribute to requirement satisfaction without excess. This led to the three constituent extra credit categories: excess(Ex), unusable-earned(UE), and unusable-unearned(UU). We studied the composition of extra credits, and commonly held notions of extra credit accumulation for engineering students, such as transfer credit loss, program (major) change, prerequisite (hidden) requirements, remedial courses, etc. We contrasted these results with those of campus-wide students to investigate the *accumulation hypothesis* that engineering and campus-wide students exhibit similar extra credit accumulation behavior in terms of the quantity, composition, and factors influencing extra credit accumulation. The results showed that 97% of engineering students graduated with extra credits, and they did so with a non-zero median of 20, which was higher than that of the campus-wide population. The

composition study of extra credits revealed that engineering students were mostly earning extra credits for courses not usable for their degree program requirements (UE was the dominant category), whereas campus-wide students mostly earned extra credits that were usable but not applicable to their degree program requirements (Ex was the dominant category). Analysis into the common factors responsible for extra credits listed above highlighted that all of these (except remedial credits, which were negligible) were instrumental for both engineering and campus-wide students but varied in the level of impact. Thus, the results disagreed with the *accumulation hypothesis* in terms of quantity, composition, and factors responsible for extra credit accumulation.

Limitations and future work: This paper is currently limited to graduated students. We plan to study other populations, such as drop-outs, current students, etc., as part of the future work. This paper does not explore some other commonly held notions of extra credit accumulation, such as financial incentives (financial aid, tuition rebate, etc.), consciously delayed graduation, skill enhancement, etc., which will be included in the future. The program change analysis did not take into account the number of terms in the final program, which can shed light on the high extra credits after the final program switch. The results indicated that a combination of factors contribute to extra credit accumulation, outlining that a data-driven model explaining the relationships between these factors maybe a suitable next step.

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