Do Mobile Developers Ask on Q&A Sites About Error Codes Thrown by a Cross-Platform App Development Framework? An Empirical Study

Matias Martinez
University of Valenciennes, France

Sylvain Lecomte
University of Valenciennes, France

ABSTRACT
During last years development frameworks have emerged to make easier the development and maintenance of cross-platform mobile applications. Xamarin framework is one of them: it takes as input an app written in C# and produces native code for Android, iOS and Windows Mobile platforms. When using Xamarin, developers can meet errors, identified with codes, thrown by the framework. Unfortunately, the Xamarin official documentation does not provide a complete description, solution or workaround for all those codes. In this paper, we analyze two sites of questions and answers (Q&A) related to Xamarin for finding questions that mention those error codes. We found that, in both sites, there are questions written by developers asking about Xamarin errors, and the majority of them have at least one answer. Our intuition is this discovered information could be useful for giving support to Xamarin developers.

ACM Reference format:
Matias Martinez and Sylvain Lecomte. 2016. Do Mobile Developers Ask on Q&A Sites About Error Codes Thrown by a Cross-Platform App Development Framework? An Empirical Study. In Proceedings of ACM Conference, Washington, DC, USA, July 2017 (Conference’17), 5 pages. DOI: 10.1145/nnnnnn.nnnnnn

1 INTRODUCTION

1.1 Context
Nowadays, there are billions of smartphone devices around the world which run either Android or iOS mobile platforms [14]. A cross-platform mobile application is an application that targets more than one mobile platform. For example, Facebook mobile app is cross-platform: it exists one app for Android, another for iOS.

A traditional approach for developing this kind of apps is to build, for each platform, a native application (i.e., an app built to run in a particular mobile platform) using a particular programming language, SDK (Software Development Kit) and toolkits. Unfortunately, the development of two or more native apps for a cross-platform app increases the costs of development and maintenance [26]. Other approaches such as hybrid-mobile have emerged to provide non-native cross-platforms mobile apps [7, 20, 22]. However, beyond a good performance for simple apps [12, 16], those apps do not have the same quality that natives for more complex apps, such the Facebook app [26].

Xamarin is a development framework by Microsoft which goal is to make easier the development and maintenance of native cross-platforms mobile apps by sharing code across all targeted platforms. Xamarin is cross-compiler framework which receives as input an application written in a non-native language (C#) and transforms it to native code for Android, iOS or Windows Phone platform.

The advantage of using Xamarin framework is that applications for different platforms can be written to share up to 90% of their code [1]. The framework offers unified API to access common resources across all three platforms, and contains bindings for nearly the entire underlying platform SDKs in both iOS and Android.

Xamarin offers two main tools: Xamarin.iOS (formerly named MonoTouch) and Xamarin.Android for building iOS and Android native apps, respectively. Both tools can be used inside the IDE Visual Studio by Microsoft or by command line.

1.2 Architecture of Xamarin apps
When developing cross-platform apps with Xamarin, the overall solution structure (which includes all code of the cross-platform app) is organized in a layered architecture that encourages code sharing. For that, Xamarin proposes three alternative methods for sharing code between cross-platform applications [2]: 1) Shared Projects, 2) Portable Class Libraries, and 3) .NET Standard Libraries. Let us briefly describe the first one. The Shared Projects method groups code into two project types: a) Shared project: contains re-usable code to be shared across different platforms, b) Platform-specific application projects: reference and consume the re-usable code and contains platform-specific features, built on components exposed in the Shared project. Each of them uses either Xamarin.Android or Xamarin.iOS to generate the native code.

1.3 Problematic
When generating the native code using either Xamarin.iOS or Xamarin.Android, developers can face errors thrown by those tools. For example, a mobile developer reported in the Xamarin Forum that, after updating the Google Maps package, the app compilation threw the error: "Error MT5212: Native linking failed, duplicate symbol [.]". Xamarin identifies that error with the code MT5212.

Xamarin documents two catalogs of error codes: one with those from Xamarin.iOS, the other with errors from Xamarin.Android. However, those catalogs do not clearly describe neither the root...
of the error not the solution for all error codes. For this reason, developers need to find more information about the code error and its solution in other sources of information, including questions and answers (Q&A) sites such as Stack Overflow.

1.4 Research goals
Our long term goal is to support mobile developers by proposing them extra-information (e.g., solutions, workarounds, augmented error descriptions) when they meet Xamarin error codes. In this paper, our goal is to know whether two questions and answers (Q&A) sites, i.e., Stack Overflow and Xamarin Forum, contain additional information for each Xamarin error code. For that, we first search in both sites for all questions that mention any error code. We then study whether those questions have at least one answer and whether any of those answers was accepted as correct. Our intuition is that accepted answers could contain solutions or workarounds for those errors. The research questions that guide our work are:

- RQ 1: How many questions mention error codes?
- RQ 2: Which are the error codes more asked?
- RQ 3: Which are the error categories with more questions?
- RQ 4: How many error codes have at least one a) answer; b) accepted answer?

The paper is structured as follows. Section 2 presents the two catalogs of error codes extracted from the Xamarin documentation. Section 3 details the research methodology. Section 4 presents the results. Section 5 presents the related works. Section 6 concludes the paper.

2  ERROR CODES FROM XAMARIN
The official documentation of Xamarin includes two catalogs of errors: one with codes used by Xamarin.iOS [4], the other with codes used by Xamarin.Android [3]. The codes are grouped into categories, which are displayed in Table 1. We now describe each catalog.

2.1 Error Codes from Xamarin.iOS
Error codes from Xamarin.iOS [4] are grouped in 9 categories and identified with the prefix MT. For example, category MT2 groups all error codes related to "Linker error". Errors code identifiers start with their category identifier followed by a number. For example, error code MT2001 "Could not link assemblies" is the code 001 of category MT2 "Linker error". Table 1 shows the number of error codes per category (column #Codes). For example, the category MT2 has 21 codes. The identifiers of codes from a category are not consecutive, i.e., there is a error code MT2102, but none with code MT2100. In total, Xamarin documentation reports 360 error codes for Xamarin.iOS.

Error codes descriptions are in general self-explanatory, such as MT8 "Runtime error", even some use Xamarin or Microsoft-related terminology. For example, mtouch (aka MonoTouch, now called Xamarin.iOS) tool is the entry point for compiling code for use in iOS devices and to deploy and launch the code on the device. MSBuild (Microsoft Build Engine) is a platform for building applications with is used by Visual Studio. AOT (Ahead of Time compilation) compiles code to a native platform.

The information presented in each code error documentation is not uniform and varies across the codes. There are codes with an error description (e.g., MT2011), others propose a solution or workaround (e.g., MT2016), and others only include a simple error message (e.g, MT2002).

2.2 Error codes from Xamarin.Android
Xamarin documentation displays 10 categories for Xamarin.Android errors [3], which are identified with prefix XA. Two categories, XA7 and XA8, are described as "Reserved" and do not contain any code. In total, Xamarin documentation reports 105 codes for Xamarin.Android. Let us to clarify two concepts. mandroids refers to Mono Android, former name of Xamarin.Android, whereas symlink refers to symbolic link. The documentation of code errors from Xamarin.Android is different that one for Xamarin.iOS errors: it only includes the code error and one-sentence description. None presents neither a workaround nor a proposed solution.

3 METHODOLOGY
In this section we present the methodology used for responding the research questions.

Datasets of Q&A. We analyzed Xamarin-related questions provided by two datasets of Xamarin-related questions and answers [25]: a) Xamarin Forums, which has 85,908 questions from the Xamarin Forum site; b) Xamarin-related Q&A extracted from Stack Overflow, which has 44,434 questions mined using a technique from Rosen et Shihab [30]. In the remainder of this paper, when we mention questions from Stack Overflow, we refer to those from the latter dataset. We analyzed questions and answers written until September 1st, 2017.

Protocol. We first extracted all error codes available on the official Xamarin documentation [3, 4]: those iOS-related which have the prefix MT and those Android-related which have the prefix XA. We then filtered questions from both datasets which include one or more retrieved error code in: a) question title, or b) question description. Finally, we grouped questions according to two criteria: 1) same code errors; 2) same error category.

Table 1: Description of each category of code and number of codes per category (#Co).

| Xamarin.iOS | Xamarin.Android |
|-------------|------------------|
| Cat. | Description | #Co | Cat. | Description | #Co |
| MT0 | mtouch | 106 | XA0 | mandroids | 17 |
| MT1 | Project related | 36 | XA1 | File copy/symlinks | 20 |
| MT2 | Linker | 21 | XA2 | Linker | 6 |
| MT3 | AOT | 9 | XA3 | AOT | 3 |
| MT4 | Code generation | 68 | XA4 | Code generations | 23 |
| MT5 | GCC & toolchain | 25 | XA5 | GCC & toolchains | 17 |
| MT6 | Internal tools | 6 | XA6 | Internal tools | 3 |
| MT7 | MSBuild | 67 | XA7 | Reserved | - |
| MT8 | Runtime | 22 | XA8 | Reserved | - |
| XA9 | Licensungs | 16 |
| Total | 360 | | Total | 105 |

2
4 EVALUATION

4.1 RQ 1: How many questions mention error codes?

After filtering questions from Xamarin Forum and Stack Overflow, we found 719 and 226 questions, respectively, that mention one or more error code from Xamarin.iOS; and 402 and 104 questions, respectively, that mention one or more error from Xamarin.Android. These questions represent the 1.3% (1121 out of 85,908) of all questions written in the Xamarin Forum, and the 0.74% (330 out of 44,434) from all Xamarin-related questions from Stack Overflow.

Response RQ 1: In Xamarin Forum and Stack Overflow Q&A sites, there are 1121 and 330 questions, respectively, that mention, at least, one Xamarin error code.

The 25.3% (91 out of 360) of the error codes from Xamarin.iOS are present on questions from Xamarin Forum, whereas in Stack Overflow the 15.8% of the errors (57 out of 360) are mentioned. Regarding with Xamarin.Android, 40 (38.1%) and 24 (22.9%) error codes are in questions from Xamarin Forum and Stack Overflow, respectively.

4.2 RQ 2: Which are the error codes more asked?

Table 2 displays the 10 most mentioned error codes in questions from Xamarin Forum and Stack Overflow. The most mentioned code from Xamarin.iOS is MT2002 with 168 questions. The code description is "MT2002 Can not resolve reference: " and, unlike other error codes from the same category, it does not have neither an associate description (e.g., such that one from MT2011) nor proposed solution (e.g., such that one from MT2016). For this reason, it makes sense that developers ask about that error code on Stack Overflow and Xamarin Forum for facing the missing information in the Xamarin documentation.

Moreover, we found that for 4 out of the 10 most mentioned error from Xamarin.iOS, their documentation do not include neither an explanation nor a proposed solution. Between the other error codes, we observe that some have a proposed solution: e.g., code MT3001 "Could not AOT the assembly " has: "disabling incremental builds in the project’s iOS Build option".

For error coded related to Android, the most mentioned code isXA2006 "Reference to metadata item '0' […] could not be resolved", and it belongs to error category XA2 "Linker Errors". The second one, XA0000, does not provide much information: its description is Unexpected error - Please fill a bug report at https://bugzilla.xamarin.com.

Furthermore, the sum of the number of questions per error code (Table 2 row "Total"), is larger that the number of questions reported in section 4.1. This happens due to questions that mention two or more error codes, e.g., question 57081 from Xamarin Forum mentions error codes MT5212 and MT5213.

Response RQ 2: MT2002 and XA2006 are the most frequent error codes from Xamarin.iOS and Xamarin.Android, resp., on both Stack Overflow and Xamarin Forum.

4.3 RQ 3: Which are the error categories with more questions?

Table 3 displays the number of questions that mention codes from a given category (columns #Q) and the total number of codes from a given category that are mentioned by 1+ questions (columns #Codes in Q). The code categories from Xamarin.iOS most mentioned are in both Q&A sites: MT5 (with 202 and 75 questions, resp., i.e., the
Table 4: Error codes grouped by % of answered/accepted answers. Each cell displays the number of codes where the questions that mention them have a given percentage (i.e., 0%, >0% or 100%) of answered/accepted answers.

|        | Xamarin Forum | Stack Overflow |
|--------|---------------|----------------|
| %      | XA            | MT            |
| 0%     | 5 (15.20%)    | 7 (50%)       |
| >0%    | 35 (67.5%)    | 84 (92.3%)    |
| 100%   | 15 (37%)      | 47 (52%)      |

|        | XA            | MT            |
|--------|---------------|----------------|
| %      | 0%            | >0%            |
| 0%     | 26 (56.5%)    | 11 (45.83%)    |
| >0%    | 35 (38.46%)   | 13 (54.17%)    |
| 100%   | 0 (0%)        | 4 (16.67%)     |

|        | #Questions    | #Answers       |
|--------|---------------|----------------|
| Xamarin Forum | 157 | 45 |
| Stack Overflow | 25 | 5 |

29.3% of asked questions, MT2, and MT1. Moreover, there are two categories MT7 ("MSBuild") and MT8 ("Runtime") whose codes are not mentioned any question. The most code mentioned categories are: XA2 with 157 and 45 questions, i.e., the 39.9% of asked questions), XA0, and XA5. Here, there are 4 categories whose error codes are never mentioned: XA1 ("Tile copy/symlinks"), XA6 ("Internal Tools"), XA7 and XA8 (both "Reserved").

Response RQ 3: The error categories with questions more asked are: MT5 (GCC and toolchain errors) with the 29.3% of asked questions and XA2 (Linker errors) with the 39.9%.

Moreover, Table 3 displays the percentage of error codes from a category that are present in 1+ questions (Column %). In Xamarin.Android, the category that has a higher percentage is MT5: the 72% (18 out of 25) of its codes are present in 1+ question in Xamarin Forum whereas the 60% (15 out of 25) in Stack Overflow. In Xamarin.iOS, the 81.3% of codes from category XA9 have 1+ questions on Stack Overflow, whereas in Xamarin Forum its percentage is lower: 37.6%.

4.4 RQ 4: How many error codes have at least one a) answer; b) accepted answer?

Table 4 presents the number of error codes mentioned by questions Q that have a) zero answers (0%), i.e., none question from Q was answered, b) one or more (>0%), i.e., 1+ question from Q with 1+ answer, or c) all questions from Q with 1+ answer (100%). The table also shows a similar analysis for questions with accepted answers.

4.4.1 Codes with answered questions. In Xamarin Forum, the 87.5% (35 out of 40) and 92.3% (84 out of 91) of error codes from Xamarin.iOS and Xamarin.Android, resp., are mentioned by, at least, one question which was answered. Moreover, those mentioned by all answered questions (i.e., 100%) represent the 37.5% and the 51.6%, resp. In Stack Overflow, we observe a similar trend for codes Xamarin.iOS. However, Xamarin.Android codes mentioned by not answered questions (i.e., 0%) is proportionally higher: 25%.

4.4.2 Codes with accepted answers. In Xamarin Forum, the 35% and 38.46% of codes from Xamarin.Android and Xamarin.iOS are mentioned by 1+ questions with 1 accepted answer. In Stack Overflow, those percentages are higher: 54.17% and 85.96%, resp., which means that, for the majority of the error codes, there is 1+ question with an accepted answers. Moreover, there are codes (4 from Xamarin.Android and 11 from Xamarin.iOS) which have an accepted answer for all the questions that mention them. We inspect those questions finding that they have, at most, 2 answers per question.

Response RQ 4: a) The 92.6% (127 codes) and 82.8% (53) of error codes from Xamarin.iOS and Xamarin.Android, respectively, have 1+ answered question. Moreover, b) the 56.7% (84 codes) and 42.1% (27) of error codes from Xamarin.iOS and Xamarin.Android, respectively, have one accepted answer.

5 RELATED WORK

There are several works that classify, compare and evaluate cross-platform mobile application development tools to build hybrid mobile and native apps [8, 9, 11, 12, 18, 23, 28, 29]. To the best of our knowledge, only one work [25] focuses on Xamarin, which studies Q&A sites for discovering the main topics of Xamarin related question. Other works [19, 21] focus on Progressive Web Apps (PWAs), a technology introduced by Google for improving Web mobile apps. Regarding with the testing of cross-platform applications, CHECKCAMP [15] is a tool for helping mobile developers to test their apps across multiple platforms. DIFFDROID [10], a technique that helps developers automatically find cross-platform inconsistencies.

Other works [13, 24, 27] have studied the quality of cross-platforms mobile applications by analyzing apps stores such Google Play. For example, comparison of user-perceived ratings of cross-platform app [6], and comparison between rankings of hybrid mobile apps and native apps [22]. To the best of our knowledge, no work has studied Xamarin apps from the apps stores.

Previous works have studied Q&A sites (e.g., Stack Overflow) to mine questions about mobile platforms. For example, studies about: questions and activities in Stack Overflow when changes on Android APIs occur [17], posts from Stack Overflow related to iOS and Android APIs to find API usage obstacles [34], questions about Android permission use on Stack Overflow [31], code reuse on Stack Overflow from Android apps [5], self-explanatory of code fragment present in a thread of Stack Overflow [33], impact of platform dependence on source code quality [32].

6 CONCLUSION

Xamarin is a cross-compiler framework for building mobile apps that target more than one platforms. In this paper we analyzed two sites of questions and answers (Q&A) for mining questions that mention code errors thrown by the Xamarin platform. We found that there are 1121 and 330 questions from Xamarin Forum and Stack Overflow Q&A sites, resp., that mention one or more Xamarin error code. This result shows that developers search for additional information to face those errors. Moreover, the 87.5% and 92.3%, resp., of error codes found on those questions have 1+ answer which could potentially be useful to clarify the error.

For future work, we plan to analyze answers corresponding to those questions to help developers when they meet such error codes.
by proposing an augmented explanations about the error, candidate solutions and workarounds.

REFERENCES

[1] Introduction to mobile development. https://developer.xamarin.com/guides/cross-platform/.
Accessed: 2018-1-20.

[2] Xamarin sharing code options. https://developer.xamarin.com/guides/cross-platform/application-development/sharingcode/
Accessed: 2018-1-20.

[3] Xamarin.android.errors. https://developer.xamarin.com/guides/android/troubleshooting/errors/
Accessed: 2018-1-20.

[4] Xamarin.ios.errors. https://developer.xamarin.com/guides/ios/troubleshooting/ios-touch-errors/
Accessed: 2018-1-20.

[5] Rabe Abdalkareem, Emad Shihab, and Juergen Rilling. On code reuse from stack-overflow: An exploratory study on android apps. Information and Software Technology, 88(Supplement C):145 – 158, 2017.

[6] Mohamed Ali, Mona Erfani Joorabchi, and Ali Mesbah. Same app, different app stores: A comparative study. In Proceedings of the 4th International Conference on Mobile Software Engineering and Systems, MOBILESoft ’17, pages 79–90, Piscataway, NJ, USA, 2017. IEEE Press.

[7] Mohamed Ali and Ali Mesbah. Mining and characterizing hybrid apps. In Proceedings of the International Workshop on App Market Analytics, WAMA 2016, pages 50–56, New York, NY, USA, 2016. ACM.

[8] Isabelle Dalmasso, Sonnuya Kanti Datta, Christian Bonnet, and Navid Nikaein. Survey, comparison and evaluation of cross platform mobile application development tools. In 2013 9th International Wireless Communications and Mobile Computing Conference (IWCMC), pages 323–328. IEEE, 2013.

[9] Heiko Desnuelle, John Lyle, Simon Herberg, and Frank Gielen. On the challenges of building a web-based ubiquitous application platform. In Proceedings of the 2012 ACM Conference on Ubiquitous Computing, pages 733–736. ACM, 2012.

[10] Mattia Fazzini and Alessandro Orso. Automated cross-platform inconsistency detection for mobile apps. In Proceedings of the 32nd IEEE/ACM International Conference on Automated Software Engineering, ASE 2017, pages 308–318, Piscataway, NJ, USA, 2017. IEEE Press.

[11] Ruta Francese, Michele Rui, Genoveffa Tortora, and Giuseppe Scanniello. Supporting the development of multi-platform mobile applications. In 2013 15th IEEE International Symposium on Web Systems Evolution (WSE), pages 87–90. IEEE, 2013.

[12] Henning Heitkötter, Sebastian Hanschke, and Tim A Majchrzak. Evaluating cross-platform development approaches for mobile applications. In International Conference on Web Information Systems and Technologies, pages 120–138. Springer, 2012.

[13] Hanyang Hu, Cor-Paul Bezemier, and Ahmed E Hassan. Studying the consistency of star ratings and the complaints in 1 & 2-star user reviews for top free cross-platform android and ios apps. PeerJ Preprints, 4:e2589v1, November 2016.

[14] IDC. Smartphone os market share, 2017 q1, 2017.

[15] M. E. Joorabchi, M. Ali, and A. Mesbah. Detecting inconsistencies in multi-platform mobile apps. In 2015 IEEE 26th International Symposium on Software Reliability Engineering (ISSRE), pages 450–460, Nov 2015.

[16] M. E. Joorabchi, A. Mesbah, and P. Kruchten. Real challenges in mobile app development. In 2013 ACM //IEEE International Symposium on Empirical Software Engineering and Measurement, pages 15–24, Oct 2013.

[17] Mario Linares-Vásquez, Gabrielle Ravota, Massimiliano Di Penta, Rocco Oliveto, and Denys Poshyvanyk. How do api changes trigger stack overflow discussions? a study on the android sdk. In Proceedings of the 22nd International Conference on Program Comprehension, ICPC 2014, pages 83–94, New York, NY, USA, 2014. ACM.

[18] Tim Majchrzak and Tor-Morten Grønli. Comprehensive analysis of innovative cross-platform app development frameworks. In Proceedings of the 50th Hawaii International Conference on System Sciences, 2017.

[19] Tim A Majchrzak, Andreas Buuren-Hansen, and Tor-Morten Grønli. Progressive web apps: the definite approach to cross-platform development? In Proceedings of the 51st Hawaii International Conference on System Sciences, 2018.

[20] I. Malavolta, S. Rumberto, T. Soru, and V. Terragni. End users’ perception of hybrid mobile app services in the mobile tourism context. In Proceedings of the Second ACM International Conference on Mobile Software Engineering and Systems, MOBILESoft ’18, pages 35–45, Piscataway, NJ, USA, 2017. IEEE Press.

[21] Ivano Malavolta, Giuseppe Scanniello, Paul Noorlander, and Petar Vukmirovic. Assessing the impact of service workers on the energy efficiency of progressive web apps. In Proceedings of the 4th International Conference on Mobile Software Engineering and Systems, MOBILESoft ’17, pages 56–59, Piscataway, NJ, USA, 2015. IEEE Press.

[22] Euler Horta Marinho and Rodolfo Ferreira Resende. Native and multiple targeted mobile applications. In Osvaldo Gervasi, Beniamino Margante, Sanjay Mistra, Marina L Gavrilova, Ana Maria Alves Coutinho Rocha, Carmelo Torre, David Taniar, and Bernady O. Apduhan, editors, Computational Science and Its Applications – ICCSA 2015, pages 544–558, Cham, 2015. Springer International Publishing.

[23] William Martin, Federica Sarro, and Mark Harman. Causal impact analysis for app releases in google play. In Proceedings of the 2016 24th ACM SIGSOFT International Symposium on Foundations of Software Engineering, FSE 2016, pages 435–446, New York, NY, USA, 2016. ACM.

[24] Matias Martinez and Sylvain Lecomte. Discovering discussion topics about development of cross-platform mobile applications using a cross-compiler development framework. 2017.

[25] Matias Martinez and Sylvain Lecomte. Towards the quality improvement of cross-platform mobile applications. In Proceedings of the 4th International Conference on Mobile Software Engineering and Systems, MOBILESoft 17, pages 184–188, Piscataway, NJ, USA, 2017. IEEE Press.

[26] Ehsan Noei, Mark D. Syer, Ying Zhou, Ahmed E. Hassan, and Iman Kravanoo. A study of the relation of mobile device attributes with the user-perceived quality of android apps. Empirical Software Engineering, 22(6):3988–3116, Dec 2017.

[27] Manuel Palmieri, Inderjeet Singh, and Antonio Cicchetti. Comparison of cross-platform mobile development tools. In Intelligence in Next Generation Networks (ICIN), 2012 16th International Conference on, pages 179–186. IEEE, 2012.

[28] A. Ribeiro and A. R. da Silva. Survey on cross-platforms and languages for mobile apps. In 2012 Eighth International Conference on the Quality of Information and Communications Technology, pages 255–260, Sept 2012.

[29] Christoffer Rosen and Emad Shihab. What are mobile developers asking about? a large scale study using stack overflow. Empirical Softw. Eng., 21(3):1192–1223, June 2016.

[30] Ryan Stevens, Jonathan Ganz, Vladimir Filkov, Premkumar Devanbu, and Hao Chen. Asking for (and about) permissions used by android apps. In Proceedings of the 10th Working Conference on Mining Software Repositories, MSR ’13, pages 31–40, Piscataway, NJ, USA, 2013. IEEE Press.

[31] David Taniar, Mark D. Syer, Ying Zhou, Ahmed E. Hassan, and Iman Kravanoo. A study of the relation of mobile device attributes with the user-perceived quality of android apps. Empirical Software Engineering, 22(6):3988–3116, Dec 2017.

[32] Manuel Palmieri, Inderjeet Singh, and Antonio Cicchetti. Comparison of cross-platform mobile development tools. In Intelligence in Next Generation Networks (ICIN), 2012 16th International Conference on, pages 179–186. IEEE, 2012.

[33] A. Ribeiro and A. R. da Silva. Survey on cross-platforms and languages for mobile apps. In 2012 Eighth International Conference on the Quality of Information and Communications Technology, pages 255–260, Sept 2012.

[34] Christoffer Rosen and Emad Shihab. What are mobile developers asking about? a large scale study using stack overflow. Empirical Softw. Eng., 21(3):1192–1223, June 2016.

[35] Ryan Stevens, Jonathan Ganz, Vladimir Filkov, Premkumar Devanbu, and Hao Chen. Asking for (and about) permissions used by android apps. In Proceedings of the 10th Working Conference on Mining Software Repositories, MSR ’13, pages 31–40, Piscataway, NJ, USA, 2013. IEEE Press.

[36] Mark D. Syer, Metyappan Nagappan, Brain Adams, and Ahmed E. Hassan. Studying the relationship between source code quality and mobile platform dependence. Software Quality Journal, 23(3):485–508, Sep 2015.

[37] C. Trenche and M. P. Rohillard. Understanding stack overflow code fragments. In 2017 IEEE International Conference on Software Maintenance and Evolution (ICSME), pages 509–513, Sept 2017.

[38] Wei Wang and Michael W. Godfrey. Detecting api usage obstacles: A study of ios and android developer questions. In Proceedings of the 10th Working Conference on Mining Software Repositories, MSR ’13, pages 61–64, Piscataway, NJ, USA, 2013. IEEE Press.